Current Water Quality Monitoring Practices in Small Towns in Bushenyi

Work Package 2

July 2018

Author: Moses Nyakana
Reviewers: Sara J. Marks, Frank Kansiime, Christopher Kanyesigye, Giuliana Ferrero

Contents

List of Tables

List of Figures

Executive Summary

The expansion of the National Water and Sewerage Corporation (NWSC) services to cover more town centres, town boards and rural growth centres, hereafter referred to as small towns, has occurred at the same time as a major policy shift from a supply-driven to a demand-driven approach. This not only focuses on adequate water quantity provision but also on good quality water that ensures water consumers' public health is protected. For example, between 30 June 2015 and 30 June 2016, there was a rapid takeover of 170 towns nationally by NWSC. This baseline survey sought to understand the water quality practices of 10 small towns: Bushenyi-Ishaka, Buhweju, Bugongi, Kabwohe-Itendero, Kashenshero, Kabira-Mitara, Mitooma, Kitagata, Kyabugimbi, and Rubirizi. These towns are located throughout the districts of Bushenyi, Buhweju, Mitooma and Rubirizi in Uganda. Designated Ministry of Water and Environment (MWE) area officers, public standpipe attendants, NWSC branch managers and plant operators, official town leaders and water consumers were interviewed while relevant official reports on the Ugandan water sector, NWSC laboratory sampling and testing reports, and NWSC SOPs were analysed to provide secondary information relevant to the water quality of these small towns alongside general visual observations.

The takeover of the service by NWSC in small towns has not only improved operation and maintenance, coverage and functionality, but also introduced the disinfection aspect of drinking water treatment to guarantee safe water consumption, something not previously undertaken by private water operators or local governments. However, the major challenge of guaranteeing good quality drinking water provision is that NWSC coverage does not reach 100% of the population. Those who do not have access to this service depend on unimproved water supplies such as ponds, swamps, hand-dug shallow wells and unprotected springs, with water quality that is questionable, unregulated and not monitored. In addition it has been noted that in dry seasons, there is an irregular supply of drinking water by NWSC and therefore consumers use alternative unimproved water sources, further endangering public health. Consumer practices in water storage, usage and plumbing have also been observed to be a major source of contamination to the treated water supplied by NWSC. Newly taken over small towns such as Buhweju have also inherited major operation and maintenance problems, understaffing and the need for water disinfection treatment systems.

The report further clarifies the institutional framework of the Ugandan water sector, the legal framework and the drinking standards development, surveillance, regulation and monitoring. The growth of the piped water supply systems has increased the area of coverage for sampling and testing, requiring additional resources in personnel, laboratory services and transport across the region.

A further evaluation of the sanitation and hygiene practices and their effects on water quality and public health has been carried out. It has been observed that the absence of faecal sludge emptying, transportation, treatment and reuse services poses a great threat of drinking water contamination at the source. This requires urgent intervention in the sanitation service value chain by setting up FS treatment plants and building local capacity to absorb the services whilst also creating value for the treatment by-products.

It is envisioned that the report's observations, deliberations and recommendations will contribute to a greater understanding of the underlying challenges to quality drinking water provision in other small towns and pave the way for the development of water safety plans and water risk mitigation plans.

List of Abbreviations

CBMZs: Catchment-Based Management Zones
CBO: Community-Based Organization
CSO: Civil Society Organization
DEA: Directorate of Environment Affairs
DLG: District Local Government
DWD: Directorate of Water Development
DWRM: Directorate of Water Resource Management
EAC: East African Community
EC: Electrical Conductivity
FS: Faecal Sludge
GoU: Government of Uganda
IWRM: Integrated Water Resource Management
LC: Local Council
MoFPED: Ministry of Finance Planning and Economic Development
MoH: Ministry of Health
MoLHUD: Ministry of Land Housing and Urban Development
MWE: Ministry of Water and the Environment
NEMA: National Environment Management Authority
NFA: National Forestry Authority
NGO: Non-Government Organization
NWP: National Water Policy
NWQRL: National Water Quality Reference Laboratory
NWSC: National Water and Sewerage Corporation
PEAP: Poverty Eradication and Action Plan
PSP: Public Standpipe
SOP: Standard Operating Procedure
TDS: Total Dissolved Solids
TSS: Total Suspended Solids
TSU: Technical Support Unit
UBOS: Uganda Bureau of Statistics
UNBS: Uganda National Bureau of Standards
UNCED: United Nations Conference on Environment and Development
UWA: Uganda Wildlife Authority
UWASNET: Uganda Water and Sanitation Network
WAP: Water Action Plan
WMZs: Water Management Zones
WSDF-SW: Water and Sanitation Development Facility-South West
WSP: Water Safety Plan
WTO: World Trade Organization

CHAPTER ONE: The Uganda Water Sector

1. Introduction

Water lies at the heart of humanity's social and economic transformations (Agnew and Woodhouse, 2010). Lack of access to adequate quality and quantity of water is a form of expropriation that denies opportunity whilst also undermining human dignity (Watkins, 2006). Cognizant of the importance of water to life, Goal 6 (target 6.1) of the United Nations Agenda 2030 for Sustainable Development specifically challenges water sector professionals to 'achieve, by 2030, universal and equitable access to safe and affordable drinking water for all' (United Nations, 2016). The measurement indicator for safely managed drinking water under this target specifies that 'Drinking water is from an improved water source which is located on the premises, available when needed and free from faecal and priority chemical contamination' (WHO/UNICEF Joint Monitoring Programme, 2016).

The Ministry of Water and Environment (MoWE) through the Water Quality Management Department published the 'Strategy for Water Quality Management in Uganda' in 2006, and the Uganda National Bureau of Standards (UNBS) reviewed the Drinking (Potable) Water – Specification (US 201:2008) Standard, by adapting the East African Drinking Water Standards in 2015, cited as US EAS 12:2014. Currently, the MoWE is in the process of development of a 'National Framework for Management and Regulation of Drinking Water Quality in Uganda' that will include guidelines for water safety and security.

Despite such endeavours, access to safe water in Uganda is still a challenge. The Uganda Bureau of Statistics (UBOS) reported in 2016 that only 78% of the population in small towns was using an improved water source. The number of urban areas in Uganda is currently increasing as newly designated town areas and districts are created. New town centres often include large areas with a rural character but this comes with an increase in the expected standards of service delivery of which water is a priority. According to the Uganda Water and Environment Performance Sector Report (2016), the National Water and Sewerage Corporation (NWSC) started to cover 170 new small towns between 30 June 2015 and 30 June 2016 to bridge the gap in water quality and quantity service delivery. The takeover of small towns by NWSC, following their appointment as NWSC operational areas by the MoWE and also prompted by demand for improved quality of services, has been positively welcomed by various stakeholders. This has as such created a shift in the dynamics of water service delivery from a supply-driven to a demand-driven approach, with a complex network of players, with shared responsibilities, scope of action and interaction described further on in this report. In addition, Chapter One describes a compendium of policies and laws relevant to the Ugandan water sector.

Identifying the current water quality monitoring practices is essential for the identification of public health risks and recommending improvements that ultimately guarantee water safety. This report provides an insight into the physicochemical, bacteriological, and radioactive sampling, testing, monitoring, regulation and surveillance practices that are current at the water catchment, treatment plants, reservoirs and consumer points in accordance to the national drinking water standards and guidelines for protecting water sources for piped supply systems. Gaps and risks in the sampling, testing, reporting and data handling are also reported for operation and management improvement in a bid to improve water quality for consumer public health protection. Although the report mainly focuses on NWSC piped water supplies, other point water sources in the small towns that are described as unimproved are identified in these areas since populations relies on several different water sources. In addition, since sanitation and hygiene practices interface with water quality, these have also been identified in the small towns.

The NWSC cluster area in this baseline survey consists of Bushenyi-Ishaka, Bugongi, Buhweju, Kabwohe-itendero, Kashenshero, Kitagata, Kyabugimbi, Mitara-Kabira, Mitooma, Rutokye and Rubirizi; these are all subsequently referred to as small towns based on a population of 5,000-15,000 inhabitants (WSP, 2002). This report was generated out of personal interviews conducted with official town leaders, water consumers, public standpipe attendants, NWSC branch managers and plant operators, and designated Ministry of Water and Environment area officers. In addition, a review of secondary data relating to water sector policy, laboratory sampling and testing, NWSC standard operating procedures (SOPs), general visual observations and official water sector performance reports were used as the basis for this report.

2. Overview of the Ugandan Water Sector

The water sector in Uganda is highly prioritized as a strategic natural resource necessary for improving the population's quality of life and overall productivity. At the launch of the Poverty Eradication and Action Plan (PEAP) in 1997, water supply and sanitation were identified as amongst the major issues required for the Ugandan population to thrive economically and for a major transformation of society. Furthermore, the Uganda National Water Policy 1999 emphasizes that water for domestic use will be given first priority. Other key uses of water in Uganda are irrigation, hydropower generation, tourism, transport, fisheries, recreation and industrial supply.

The absolute control and management of the water resources is vested in the government according to the Water Act Cap.152. Strategically, the government of Uganda promotes the Integrated Water Resource Management (IWRM) principles to ensure the sustainable use, management and development of water resources to meet the population's needs.

2.1 Water sector goal and objectives

According to the Uganda National Water Policy 1999, the overall policy objective of the Ugandan government in the management of water resources is: '*To manage and develop the water resources of Uganda in an integrated and suitable manner, so as to secure and provide water of adequate quality and quantity for all social and economic needs for the present and future generations with the full participation of all stakeholders*.'

The report further specifies sub-objectives of the water sector in Uganda as:

1. To promote coordinated, integrated and sustainable water resources management to ensure conservation of water resources and provision of water for all social and economic activities.

2. To achieve sustainable safe water supply and sanitation facilities, based on management responsibility and ownership by the users, to 100% of both the rural and urban population in Uganda.

3. To promote the development of water supply for agricultural production in order to modernize agriculture and mitigate the effects of climatic variations on rain-fed agriculture.

3. Water Sector Policy and Legal Framework

In order to manage the water sector, the Ugandan government has in place a comprehensive policy and legal framework consisting of a set of policies and legislation; of particular note are: the Uganda National Water Policy (1999), the Water Statute (1995), the National Water and Sewerage Corporation Statute (1995) and the Local Government Act (1997).

3.1 National Water Policy

Adopted in 1999, the Uganda National Water Policy (NWP) provides an overarching policy framework for the Ugandan water sector. In principle, this establishes and promotes IWRM practices to enable the sustainable utilization and management of Ugandan water resources. Water is recognized as a social and economic good, with domestic use being the first priority. The policy is based on the principles of the 1990 'New Delhi Statement: some for all, rather than all for some.' This policy further emphasizes operation and maintenance as absolutely important to the sustainable provision of water and sanitation services whilst also recognizing the inclusivity of the private sector, women and local council levels as key players in the water sector.

The NWP ratifies the water resources management principles of the United Nations Conference on the Environment and Development (Dublin-Rio de Janeiro UNCED Agenda item 21) as shown below:

- Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Management of water resources at the lowest appropriate level.
- The role of government as an enabler in a participatory, demand-driven approach to development.
- Integration of water and land use management.
- Recognition of the central role played by women in the provision, management and safeguarding of water.
- The important role of the private sector in water management.

The NWP further reinforces the Uganda Water Action Plan (WAP) previously developed in 1993-94 which also emanates from UNCED Agenda item 21, Chapter 18.

3.2 The Water Statute 1995

This is the principle water sector law and its related regulations cover the use, protection and management of water resources and supply; the constitution of water and sewerage authorities, and the dissolution of water and sewerage undertakings. This law gives the government absolute rights as the custodian of water through which other users can inherit rights of use, construction or operation and pollution through the issuance of time-bound permits to abstract and discharge wastewater or to construct hydraulic works.

The objectives of this water statute are:

1. To promote the rational management and use of the waters of Uganda.

2. To promote the provision of a clean, safe and sufficient supply of water for domestic purposes to all persons.

3. To allow for the orderly development and use of water resources for animals, irrigation, industrial, commercial and mining uses, energy, navigation, fisheries, preservation of flora and fauna and recreation in ways which minimize harmful effects to the environment.

4. To control pollution and to promote the safe storage, treatment, discharge and disposal of waste which may pollute water or otherwise harm the environment and human health.

The Water Supply Regulations (1999), the Water Resources Regulations (1998), Waste Discharge Regulations (1998) and Sewage Regulations (1999) make the NWP operative through the issuance of Surface Water Abstraction, Groundwater Abstraction, Construction and Wastewater Discharge permits. Permit issuance is a permanent function of the central government executed

through the Directorate of Water Development (DWD), the Directorate of Water Resources Management (DWRM) and in consultation with the National Environment Management Authority (NEMA) and District Local Governments (DLGs).

3.3 National Water and Sewerage Corporation Statute 1995

Through this statute, the NWSC was established and mandated to operate and provide sound and commercially viable water supply, and sewerage services in areas entrusted to it. A performance contract exists between NWSC and the Government of Uganda (GOU) to provide these operations. One of the avenues for achieving improved operational efficiency and service delivery is by implementation of the documented research and development policy and objectives. Table 1 provides a summary of the main objectives of the NWSC Statute (1995).

Table 1: NWSC Act 1995 objectives

National Water and Sewerage Corporation Statute 1995
• To manage water resources in ways that are most beneficial to the people of Uganda. • To provide water supply services for domestic, stock, horticultural, industrial, environmental and other usage. • To provide sewerage services in areas in which it may be appointed to do so under this statute or the Water Statute 1995. • To do anything connected, or incidental, to the above. • To develop the water and sewerage systems in urban centres and big national institutions throughout the country.

Source: Uganda National Water Policy 1999.

3.4 Local Government Act 1997

Through the enactment of the Local Government Act (1997), roles of different governance levels were defined in relation to the provision of water-related services paving way for a continuous process of decentralization where functions, powers and services are devolved and transferred from central government to local administrative units. This builds capacity, local democratic control, decision-making and increases support of the water sector development relevant to local needs (Uganda National Water Policy, 1999).

3.5 National Environment Statute 1995

The National Environment Management Authority (NEMA) is established through the National Environment Statute (1995) as the overall coordinating and monitoring body of environmental management in Uganda. Particularly for water resource management in Uganda, the objective of this statute is 'to sustainably manage and develop the water resources in a coordinated and integrated manner so as to provide water of acceptable quality for social and economic needs'.

This statute empowers NEMA in consultation with other lead government agencies to provide guidelines, measures and standards for sustainable utilization, management and conservation of natural resources. Mandatory Environmental Impact Assessments (EIAs) are conducted by NEMA to rule out negative environmental impacts (Uganda National Water Policy, 1999).

4. Water Sector Institutional Framework

The NWP lays out a dynamic framework for the sustainable development and management of the Ugandan water sector through national initiatives (central government), decentralization, privatization, gender empowerment and community participation. The Government of Uganda considers requirements of balancing the need for management of water resources at the lowest appropriate level, against the need for central monitoring and regulation and has thus divested management functions. Thus, the government provides an enabling environment for the participation of other players, according to the NWP, through:

- Legislation to support policy.
- Regulatory control only in response to need at enforceable levels.
- Regulatory control combined with economic incentives.
- Water Action Plan process to provide a dynamic management framework.

The existing institutional and management structure as provided for by the NWP are based on:

- The need to adequately manage water resources given its transboundary nature.
- Demand for resources due to development activities and increase in pollution threats.
- Devolution of powers to local government.

The Uganda Water and Environment Performance Sector Report (2016) describes the sector's current institutional framework as consisting of:

- **National**: the Ministry of Water and the Environment consists of the Directorate of Water Development (DWD), Directorate of Water Resources Management (DWRM) and Directorate of Environment Affairs (DEA). Coordinating/other line ministries include the Ministry of Health (MoH), Ministry of Education and Sports, and Ministry of Agriculture, Animal Industry and Fisheries.
- **De-concentrated support structures:** related to the Ministry of Water and Environment such as Technical Support Units (TSUs), regional Water Supply Directorate Facilities (WSDFs) and catchment-based Water Management Zones (WMZs).
- **Local governments:** districts and town councils that are responsible for service delivery under the Local Government Act (1997).
- **Four semi-autonomous national agencies**: NWSC, NEMA, National Forestry Authority (NFA) for forestry management in Government central forestry reserves and the Uganda National Meteorological Authority for weather and climate-related services.
- **Non-Governmental Organizations (NGOs) and Community-Based Organizations (CBOs)**: merging together under the Uganda Water and Sanitation Network (UWASNET), Environment and Natural Resources Civil Service Organizations (ENR CSOs). Water user committees and associations are also recognized.

- **The private sector**: operators, contractors, consultants and suppliers of water and sanitation services.

Table 2 describes the main actors in the water sector and their roles.

Table 2: Institutional framework in the Ugandan water sector

Institution	Function
Ministry of Water and Environment (MWE)	Overall responsibility for initiating national policies, setting priorities for water resource management, provision of technical assistance and capacity building in addition to surveillance and enforcement of national standards.
Directorate of Water Development (DWD)	Arm of MWE in charge of policy guidance, coordination and regulation. They are responsible for the provision of oversight and support to the local governments and private water supply service providers.
Directorate of Water Resource Management (DWRM)	Arm of MWE responsible for developing and maintaining national water laws, issuance of water use, abstraction and wastewater discharge permits, water quality surveillance, transboundary water management, overseeing and support of water supply in areas not allocated to NWSC.
National Water and Sewerage Corporation (NWSC)	Autonomous public utility operating on a commercial basis in the delivery of water supply and sewerage services in the major towns, large urban centres, rural growth centres and small towns (a total of 170 service centres during 2015/16).
Ministry of Local Government (MoLG)	Developing and facilitating the management of decentralized government systems capable of delivering quality services to the people at district level.
Local governments (LGs)	In liaison with DWD, they provide water and sanitation services where NWSC is not appointed.
Ministry of Health (MoH)	Promotion of household hygiene and sanitation.
User communities	In rural areas, they operate and maintain water sources. They are responsible for the payment of water services provided by private operators and NWSC.
Ministry of Finance, Planning and Economic Development (MoFPED)	Mobilization and allocation of finances to the water sector.
Donors	Taking part in the Joint Water Sector Review Process, a consultative process involving stakeholders and development partners discussing the implementation of agreed annual undertakings, involving mainly the Ministry of Water and the Environment, Ministry of Finance, Planning and Economic Development, Ministry of Local Government, Ministry of Agriculture, Animal Industry and Fisheries and Ministry of Education; and donors participating in the water and sector.
Non-Governmental Organizations (NGOs) and Community-Based Organizations (CBOs)	Supplement government activities in the water sector especially in less privileged communities.
Private sector	Designing, constructing, operating and maintaining water and sanitation facilities under contract with central and local government. Also involved in capacity building in the water sector.

Source: Uganda National Water Development Report, 2005 and the Uganda Water and Environment Performance Sector Report, 2016.

CHAPTER TWO: Ugandan National Water Quality Standards Review

1. Ugandan Water Quality Standards

The Uganda National Bureau of Standards (UNBS), a body of the Ministry of Trade, Industry and Cooperatives (MTIC), was established under a part of Ugandan legislation named CAP 327, and its mandate is to coordinate the issuing and monitoring of national standards. UNBS is a member of the International Standards Organization (ISO), the African Regional Organization for Standardization (ARSO), the East African Standards Committee (EASC), a reference point for the WHO/FAO codex commission on food standards and the national enquiry for TBT/SPS agreements of the World Trade Organization (WTO).

The mandate of UNBS revolves around the formulation, promotion and enforcement of national standards in order to promote the competitiveness of Ugandan products, promote fair trade and protect consumers. Thus, this mandate is both promotional and regulatory. The promotional mandate is geared towards the standardization of local services and locally manufactured goods to enhance their quality and competitiveness. The regulatory mandate is aimed at protecting consumers and achieving fairness in trade.

The Uganda standard, *US EAS 12:2014, potable water - Specification* has been adopted as the current standard for potable water quality and is the basis for the minimum water quality to be produced for domestic consumption by all water producers. This standard replaces *US 201:2008, Drinking (potable) water - Specification*. Development of these standards is through a technical committee consisting of consumers, traders, academicians, manufacturers, government and stakeholders in the water sector. The current standard, *US EAS 12:2014, Potable Water - Specification* is identical to the East African Community drinking standard EAS 12:2014 and has been adopted due to the need to harmonize products and services in the East African community. This is expected to ease trade barriers within the community. The current standard is subject to review in order to keep in pace with technological advances and public health requirements of the East African Community.

The scope of *US EAS 12:2014, Potable Water - Specification* specifies requirements and methods of sampling and testing for both treated potable water and natural potable water. The general requirements for potable water is that 'It shall be free from organisms and chemical substances that are hazardous and injurious to public health' and comply with requirements in tables 3-9 (*US EAS 12:2014, Potable Water - Specification)*. Also, it is required that 'the location, construction, operation and supervision of a water supply source, its reservoirs, and its distribution shall be such that they exclude any possible pollution in compliance with the relevant national regulations.'

Table 3: Physical requirements for potable water

Characteristic	Treated potable water*	Natural potable water**	Testing method
Colour (TCU) max	15	50	ISO 7887
Turbidity (NTU) max	5	25	ISO 7027
pH	6.5-8.8	5.5-9.5	ISO 10523
Taste	Not objectionable	Not objectionable	-
Odour	Odourless	Odourless	-
Conductivity (µS/cm) max	1,500	2,500	ISO 7888
Suspended matter	Not detected	Not detected	ISO 11923

* Water that has undergone processes such as flocculation, coagulation, sedimentation, filtration and disinfection.
** Water that is from natural sources that is fit for human consumption without undergoing any form of treatment which will alter its original chemical composition and bacteriological purity.

Table 4: Chemical quality requirements for potable water

Substance or characteristic	Treated potable water (mg/L max)	Natural potable water (mg/L max)	Testing method
Total dissolved solids	700	1500	ASTM D 5907
Total hardness as $CaCO_3$	300	600	ISO 6059
Aluminium as Al^{3+}	0.2	0.2	ISO 12020
Chloride as Cl^-	250	250	ISO 9297
Total iron as Fe	0.3	0.3	ISO 6362
Sodium as Na^+	200	200	ISO 99641
Sulphate SO_4^{2-}	400	400	ISO 22743
Zinc as Zn^{2+}	5	5	ISO 8288
Magnesium as Mg^{2+}	100	100	ISO 7980
Calcium as Ca^{2+}	150	150	ISO 7980

Table 5: Inorganic contaminant limits for potable water

Substance	Treated potable water limit (mg/L max)	Natural potable water limit (mg/L max)	Testing method
Arsenic as As	0.01	0.01	ISO 11969
Cadmium as Cd	0.003	0.003	ISO 5961
Lead as Pb	0.01	0.01	ISO 8288
Copper as Cu	1.000	1.000	ISO 8288
Mercury (total as Hg)	0.001	0.001	ISO 12846
Manganese as Mn	0.1	0.1	ISO 6333
Selenium as Se	0.01	0.01	ISO 9965
Ammonia (NH_3)	0.5	0.5	ISO 11732
Chromium total as Cr	0.05	0.05	ISO 9174
Nickel as Ni	0.02	0.02	ISO 8288
Cyanide as CN	0.01	0.01	ISO 6703
Barium as Ba	0.7	0.7	ISO 14911
Nitrate as NO_3^-	45	45	ISO 7890
Boron as boric acid	2.4	2.4	ISO 9390
Fluoride as F	1.5	1.5	ISO 10359
Bromate as BrO_3^-	0.01	0.01	ISO 15061
Nitrite	0.003	0.003	ISO 6777
Molybdenum	0.07	0.07	ISO 11885
Phosphate as PO_4^{3-}	2.2	2.2	ISO 15681
Residual free chlorine	0.2-0.5*	absent	ISO 7393

* Under conditions of epidemic diseases, it may be necessary to increase the residual chlorine temporarily.

Table 6: Organic contaminant limits for potable water

No	Variable/parameter	Limit µg/L max.	Testing method
	Aromatics		
1	Benzene	10	ISO 11423
2	Toluene	700	-
3	Xylene	500	-
4	Polynuclear aromatic hydrocarbon	0.7	ISO 13877
	Chlorinated alkanes and alkenes		
1	Carbon tetrachloride	2	-
2	1,2-dichloroethane	30	-
3	1,1-dichloroethylene	0.3	-
4	1,1-dichloroethene	30	-
5	Tetrachloroethene	40	-
	Phenolic substances		
1	Phenols	2	ISO 8165
2	2,4,6-trichlorophenol	200	ISO 14402
	Trihalomethanes		
	Chloroform	30	-
	Pesticides		
1	Aldrin/dieldrin	0.03	ISO 15089
2	Chlordane (total)	0.3	
3	2,4-dichlorophenoxyacetic acid	30	
4	DDT (total)	1	
5	Heptachlor and heptachlor epoxide	0.03	
6	Hexachlorobenzene	1	
7	Lindane BHC	2	
8	Surfactants (reacting with methylene blue)	200	ISO 16265
9	Mineral oil	0.01	-
10	Organic matter	3	-

Table 7: Microbiological limits for potable water

No	Type of micro-organism	Potable water	Testing method
1	Total viable counts at 22 °C, in mL, max. [(a)]	100	ISO 6222
2	Total viable counts at 37 °C, in mL, max. [(a)]	50	
3	Total coliforms [(b)] in 100 mL	Absent	ISO 4832
4	*E. coli* in 100 mL	Absent	ISO 9308-1
5	*Staphylococcus aureus* in 100 mL	Absent	ISO 6888-1
6	Sulphite-reducing anaerobes in 100 mL	Absent	ISO 6461-2
7	*Pseudomonas aeruginosa* fluorescence in 100 mL	Absent	ISO 16266
8	*Streptococcus faecalis* in 100 mL	Absent	ISO 7899-2
9	*Shigella* in 100 mL	Absent	ISO 21567
10	*Salmonella* in 100 mL	Absent	ISO 6785

(a) This parameter is for monitoring the system at source. Total time before analysis should not be more than 6 h at 4 °C. Determination of total viable counts will start within 12 h after collection of the potable water sample.
(b) Refer to Annex A for bacteriological quality control for different types of water supply.

Table 8: Bacteriological quality requirements for different types of water supply

Type of supply	Number per 100 ml		Testing method
Treated water entering the distribution system	*E. coli*	Absent	ISO 4832
	Coliforms	Absent	
Untreated water entering the distribution system	*E. coli*	Absent	
		3 coliform organisms in any one sample	
		Absent in any two consecutive samples	
		Absent in 98 % of yearly samples	
Water in distribution system	*E. coli*	Absent	
		3 coliform organisms in any one sample	
		Absent in any two consecutive samples	
		Absent in 95 % of yearly samples	
Unpiped supplies	*E. coli*	Absent	
	Coliforms	10	
Emergency supplies of water	*E. coli*	Absent	
	Coliforms	Absent	

Table 9: Limits for radioactive materials in treated and natural potable water

No	Radioactive material	Limits in Bq/L	Testing method
1	Gross alpha activity	0.5	ISO 9696
2	Gross beta activity	1	ISO 9697

The national standard, *US EAS 12:2014, Potable Water - Specification,* also provides for the minimum frequency of water sampling for surveillance purposes by water producers, yet also admits that the costs of a full analysis of all the parameters can be prohibitive to water producers. Thus the standard indicates acceptable physico-chemical and microbiological parameters for minimum monitoring of operational efficiency in a water treatment plant. Tables 10 and 11 show the minimum frequency of sampling and the acceptable physico-chemical and microbiological monitoring of operational efficiency in a water treatment plant, respectively. Based on a review of the *US EAS 12:2014, Potable Water - Specification*, the water producer is expected to fulfil these standards and keep records of sampling, testing and monitoring. Furthermore, water production operators are required to develop, implement and maintain water safety plans customized to the potential safety risks of the raw water supply area, the treatment plant, and the distribution network to the consumer points. See *US EAS 12:2014, Potable Water - Specification* for a full description.

Table 10: Minimum frequency of sampling of water for surveillance

Population served (P)	Frequency (*minimum) of sampling
P>100,000	10 samples every month per 100,000 of population
25,001-100,000	10 samples every month
10,001-25,000	3 samples every month
2500-10,000	2 samples every month
P<2500	1 sample every month
*During the rainy season, sampling should be carried out more frequently	

Table 11: Physico-chemical and microbiological parameters required for minimum monitoring

Property	Testing method
Physico-chemical	
Conductivity or dissolved solids	ISO 7888
Colour	ISO 7887
Turbidity	ISO 7027
Taste	-
Odour	-
Microbiological	ISO 4832
Faecal coliform bacteria or *E. coli*	
Salmonella spp	
Shiegella spp	
Chemical	
Fluoride as F^-	ISO 10359
Nitrate	ISO 7890
Nitrite	ISO 6777
Aluminium	ISO 12020
Iron (total)	ISO 6362
Ammonia	ISO 9174
Residual chlorine	ISO 7393

2. Strengths, Weaknesses, Opportunities and Threats Identified

The strengths, weaknesses, opportunities and threats reviewed from *US EAS 12:2014, Potable Water - Specification* are summarized in Table 12.

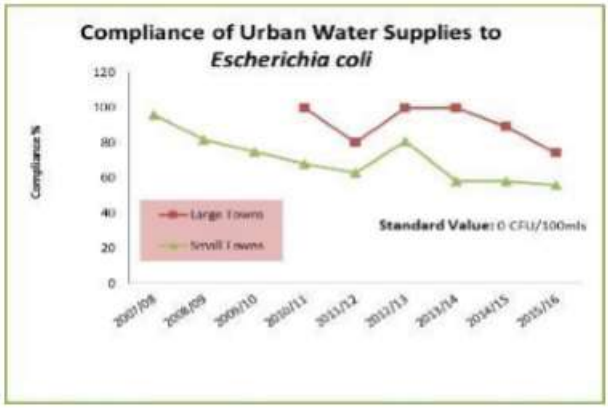
Table 12: Strength, weaknesses, opportunities and threats of the drinking water standard

Strengths	Weaknesses
The standard prioritizes consumer safety and public health. The standard is developed by a technical committee of government, private sector and consumer representatives. The standard applies across the EAC and harmonizes drinking water quality requirements. The standard requires development of WSPs by water operators.	The regulatory role of UNBS in water quality surveillance is not observed. The standard does not show how information should flow between water producers, surveillance agents and consumers. Enforcement of the standard is not well articulated. The standard does not specify certification of plumbing and storage systems at consumption points. Recent MWE and NWSC publications still refer to US 201:2008, Drinking Water-Specification instead of the updated US EAS 12:2014, Potable Water - Specification.
Opportunities	**Threats**
Standard subject to review based on EAC regional water quality demands and growth of water treatment technologies.	In an ever-changing environment with increased human activity across water sources, treatment plants and distribution network, the promotion of minimum physico-chemical and microbiological monitoring for operational efficiency may not guarantee consumer safety.

3. Surveillance and Enforcement of National Standards

The MWE through Catchment-Based Water Management Zones (CBMZs) currently surveys and enforces adherence of water producers to the *US EAS 12:2014, Potable Water - Specification*. DWRM performs this function through routine quarterly sampling, testing and spot checks both at water sources and consumer points. There are 4 CBMZs, namely Kyoga, Victoria, Albert and Upper Nile water management zones, which are under the Directorate of Water Resource Management. Lake Victoria Water Management Zone is in charge of the small towns in this baseline survey and surveillance feedback is through letters sent to water producers that do not comply asking them to state their commitment to standards or face withdrawal of abstraction permits. According to the Uganda Water and Environment Performance Sector Report (2016), the National Water Quality Management Strategy (NWQMS), 2006, recommended a 3-tier water and environment laboratory testing system for Uganda, which comprises of the: National Water Quality Reference Laboratory (NWQRL) at the centre (DWRM); 4 regional water quality laboratories; and basic laboratories at district local governments and at all drinking water treatment/production facilities. This proposed 3-tier water laboratory testing system is in place except that only 3 of the 4 regional laboratories have already been established for the water management zones of the Upper Nile, Albert and Kyoga. Water quality surveillance testing for LVWRM small towns is done at NWQRL in Entebbe.

The golden indicator for monitoring drinking water quality is defined by DWRM as '*the percentage of water samples taken at the point of water collection, or waste discharge point that comply with National Standards of Drinking (potable) water (2008) and Water (waste) Effluent Discharge Standards (1999*)'. For drinking water, the presence of *E. coli* from protected/improved sources in rural areas or in water from treated drinking water supplies in urban towns is considered as a major indicator of performance of drinking water sources. Figure 1 below, as taken from the Uganda Water and Environment Performance Sector Report (2016), indicates the compliance of urban water supplies to the *E. coli* specification.



Source: Uganda Water and Environment Performance Sector Report, 2016

Figure 1: Compliance of water supply sources nationally to microbial standards.

The main distinguishing factor between large and small towns is the population whereby towns with less than 5,000 people are categorized as small, and above 5,000 people are larger towns. It so happens that most town councils and all boards have a small population, because when the population increases beyond a certain number, the Government gazettes them as Municipal Councils. The trend observed for the large towns is indicative of water supply quality from NWSC sources while that of small towns is a combination of both NWSC and other water sources. A comparable low compliance level of 58 % and 56 % was obtained for small towns nationally for the years 2014/15 and 2015/16. This low surveillance test outcome is attributed to a number of factors according to the Uganda Water and Environment Performance Sector Report (2016), including:

- The supply of untreated water from production wells.
- Poor operation and maintenance.
- Lack of skilled labour for water treatment.
- Seasonal variations in water quality.
- Swamp water abstraction, which is problematic to treat.
- Inadequate and sometimes the absence of local laboratory facilities to monitor the operational efficiency of water treatment facilities.
- Lack of risk management, WSPs.
- Inadequate supervision by regulators.

Interviews with the Lake Victoria Catchment Management Zone (LVWRM) revealed that the golden indicators were based on the old standards of drinking water (National Standards for Drinking (Potable) Water (2008)) before the current *US EAS 12:2014, Potable Water-Specification* was effected and that particularly temperature, electrical conductivity, pH, turbidity, total alkalinity, faecal coliforms, *E. coli*, cations and anions are determined during the quarterly water quality surveillance. The reason for the delay in applying the new potable water standard (US EAS 12: 2014) that was published in 2015, to replace the 2008 Standard (US 201:2008), was that it took time for the water authorities to internalize and apply it. Currently the NWSC is applying the new standard. Table 13 shows the planned and achieved sampling targets of the WMZs while Table 14 shows the testing outcome of NWSC water supplies as of June 2016 across Uganda.

Table 13: Surveillance samples planned and actually received based on WMZs in 2015/2016

Sample source by WMZ	Target number of samples	Samples received and tested at labs	Performance %
Kyoga WMZ	400	328	**82**
Victoria WMZ	400	330	**83**
Albert WMZ	400	369	**92**
Upper Nile WMZ	400	364	**91**
NWQRL	2400	2593	**108**
Grand Total	**4000**	**3984**	**99.6**

Table 14: NWSC towns/areas drinking water quality performance as at June 2016

Water quality	Calculated as	Indicator	Actual performance (%)
Compliance with US 201:2008, Drinking (Potable) Water – Specification	(No. of samples passing national standards/total samples tested)*100	Bacteriological quantity	99.4*
		Colour	93.2
		Turbidity	98.0
		Chlorine residual	95.2
		pH	100
		Electrical conductivity	100
		Alkalinity: total	100
		Hardness: total	100
		Average	98.2

Source*: Uganda Water and Environment Performance Sector Report, 2016.*

* As provided by the WQ Management Department of NWSC as performance during the financial year 2015/2016. N.B.: Figure 1 reports a lower percentage (74%), reflecting sampling by the MoWE, WQM Department. These samples were likely taken from a subset of NWSC towns' distribution networks.

4. Challenges of Water Quality Surveillance

Personal interviews with R. Musota (20/06/2017) and C. Tusiime (20/06/2017), respondents of the Lake Victoria Water Management Zone, and a review of the *Uganda Water and Environment Performance Sector Report (2016)* showed that MWE operations of water quality monitoring are limited mainly due to problems in laboratory operations which include:

- Inadequate laboratory space with the NWQRL being too old and small.
- Insufficient funding for laboratory operation and maintenance.
- Lack of in-house technical skills to carry out minor equipment repairs.
- The need to import competent firms for specialized laboratory equipment servicing and repair.
- Unreliable local supply of laboratory chemicals and reagents.

Besides the laboratory testing challenges, personal interviews with R. Musota of the Lake Victoria Water Management Zone (20/06/2017) also revealed that monitoring of all the point sources of drinking water is a challenge because of violation of abstraction laws: '*Several consumers are involved in drilling of deep boreholes and abstracting water without the acquisition of abstraction permits from the Ministry. This does not only violate the law but also the quality of water abstracted is not monitored and risks of over-abstraction occur. The consumer's public health is at risk*.'

In 2015, there was a reported typhoid outbreak in Kampala and other towns of Uganda and it was alleged that piped drinking water supplies of NWSC were contaminated. NWSC refuted these allegations through testing of taps from the distribution network in Kampala by the UNBS SANAS accredited laboratory (TO 200) and all the samples tested negative. These results are provided in Appendix 3. A press statement at the National Media Centre in Kampala by MWE, MoH and NWSC was released to refute these allegations and restore consumer confidence. The

Managing Director of NWSC, Dr. Silver Mugisha, was quoted as saying the following about NWSC piped water quality: *'As of March 7, we extracted several samples of water from our system for testing and we found out that they were all complying with the national standards. We also tested for chlorine residue in the water samples and established that it was there. Where there is chlorine residue, there is no disease causing organisms that can survive.'* He further clarified: '*Our water is safe up to the moment it enters your premises depending on the equipment you use to dispense it for your consumption. Some people use already contaminated containers to fetch clean water. So you can't blame NWSC when you fail to make good use of the safe water we supply to you.*' Further quotes from this press brief were: *'Whether the water is supplied by NWSC or from any other source, always ensure that it is boiled to make it safe for drinking. In Mpererwe, a dead cat was found in the water tank which contaminated the water. Obviously, NWSC could not have supplied a dead cat through its water.*' The MoH representative, Dr. Ruth Aceng, blamed the typhoid outbreak on alternative contaminated water sources and unhygienic food. (source: http://www.newvision.co.ug/new_vision/news/1322844/kampala-water-safe-govt accessed 17/07/2017).

This incident of typhoid outbreak in Kampala which is due to several alternative water supplies that are not regulated or monitored by the Ministry and the mandated town water utility NWSC is applicable to other towns and small towns. These water supplies are often concealed from the DWRM surveillance teams and shared storage of water with NWSC supplies occurs at consumer storage tanks. However, personal interviews with Rep 004 (19/06/2017), a user of groundwater with no abstraction permits living in the Bushenyi area, revealed the following driving factors:

- Accessibility of NWSC services is not absolute and extension of these services requires prior assessment by the utility corporation to see if it makes economic sense.
- The water supply by NWSC is unreliable in the dry season, yet water is a necessity that people cannot do without.
- Abstraction permit charges are not affordable and regulations are stringent.
- The application process for abstraction permits is not properly understood.

Other users of unimproved water sources such as hand dug shallow wells justified these alternatives due to the absence of NWSC standpipes within easily reachable distance.

5. Guidelines for Water Source Protection

In addition to the drinking water standards, the Ministry of Water and Environment has developed guidelines for water source protection. The importance of the Guidelines for Protecting Water Sources for Piped Water Supply Systems (2013) is to provide a step-by-step guide to water producers such as NWSC to make water source protection plans. The overall

intention of making water source protection plans is to maintain and improve the quality of the local water environment. This is beneficial in ensuring good water quality at source, reduction of treatment costs and avoiding seasonal variations in water quantity and quality. The guidelines are a useful tool in monitoring and supporting the water source protection process, an activity undertaken by water producers and a number of catchment stakeholders. However, the Directorate of Water Resource Management takes the lead in the regulation of this process. Figure 2, taken from the Guidelines for Protecting Water Sources for Piped Water Supply Systems (2013), shows the roles of different stakeholders in the water source protection process.

Water Source Type	Implementer (New Scheme)	Implementer (Existing Scheme)	Contributor/ Facilitator		Monitoring & Regulation
Piped Water Supply	▪ NWSC ▪ WSDF ▪ NGOs/Civil Society Organizations (CSOs)	▪ Water Authority (NWSC/ Town Water Authority) ▪ NGO/CSOs	▪ Local Government (LC5-LC1) ▪ NWSC ▪ Water Provider (in non-NWSC gazetted areas) ▪ NFA ▪ MoFPED ▪ MWE ▪ MoLHUD ▪ Catchment Committees ▪ Businesses	▪ Development Partners ▪ NGOs/CSOs ▪ DEA ▪ Wetlands Department ▪ Water User Committees/ Community Based Organisation ▪ Landowners & Farming organisations	▪ District Technical Officers[1] ▪ NEMA ▪ DWRM/WMZ permitting ▪ DWD/TSUs ▪ UWA ▪ MWE Regulation Unit

Figure 2: Actors in the water source protection guidelines

5.1 Observations made relative to NWSC water sources in small towns

These guidelines are intended to be a first-line intervention in the protection of water sources in these small towns. However, it was observed that no water protection committees are in existence and no close working collaborations between NWSC and catchment stakeholders are in existence in the towns visited. There is a growing threat to water sources including:

1. Domestic animals grazing within 30 meters of the source, presenting problems of microbial contamination.
2. Swamp encroachment to established animal grazing lands and cultivation fields.
3. Deforestation which is contributing to reduced groundwater recharge.
4. Faecal sludge dumping in swamps, leading to microbial and chemical contamination.
5. Brick making and sand mining leading to siltation with increased treatment costs and reduced yield of water sources.

CHAPTER THREE: Water Sources and Infrastructure

1. Water Sources and Infrastructure Description in Small Towns

There are several drinking water sources in the small towns of Bushenyi which include piped water systems run by NWSC, dug-out wells, shallow wells, dams, valley tanks, swamp water, protected springs, ponds, lakes, hand-pumped boreholes, bottled water, mechanized pumps, streams and rainwater. Amongst the aforementioned water sources, dug out wells, streams, ponds, lakes and swamp water are considered as unimproved water sources according to the Uganda Water and Environment Performance Sector Report (2016). The use of unimproved water sources depends on access to improved water sources and their functionality. For instance, in Bushenyi and Ishaka towns, NWSC is fully established in the area with functional domestic, institutional, commercial and public standpipes. However, during the dry season (May-September), the raw water source at Nyaruzinga Swamp is observed to dry up and there is reduced water supply to the towns with approximately 6 hours a day availability, resulting in the use of unimproved water sources such as dug-out ponds and swamps. The water quality in these improvised water sources is not monitored and the surrounding environment is not sanitary and thus a threat to the public health of the consumers.

Figure 3: Water sources in Ishaka town

Photos: (A) untreated wastewater upstream of a drinking water well, (B) shallow dug well shared by people and cattle, (C) Kampala International University students carrying water from a shallow dug well in Ishaka town during the dry season.

The intermittent availability of the domestic water supply in the town of Bushenyi has led to the use of multiple water supplies to supplement the piped water supplies. Such additional sources include swamp water, groundwater pumping in consumer residences and dug-out shallow wells (Rep002, 17/05/2017). The untreated groundwater is often stored in household reservoir tanks that also receive treated piped water and are thus a point of contamination (C. Kebirungi, 19/06/2017). Besides the presence of NWSC piped water services, coverage does not reach the entire population and thus there is a need to resort to accessible alternative and un-improved water sources.

Figure 4: School pupils from Kamazumba Primary School in Buhweju using stream water for drinking

Table 15 shows the NWSC water coverage of some small towns in the greater Bushenyi network according to the Uganda Water and Environment Performance Sector Report (2016).

Table 15: Improved water source usage and NWSC coverage in small towns of Greater-Bushenyi

Town	Population (2016)	% NWSC coverage	% using an improved water source
Bushenyi-Ishaka	54,700	79	79
Kabwohe-Itendero	20,800	71	71
Kashenshero	6,000	81	81
Buhweju-Nsiika	3,000	42	42
Rubirizi	8,400	95	95
Bugongi	12,100	37	37
Mitooma	5,800	79	79

1.1 NWSC Water Infrastructure in Small Towns

According to the Uganda Water and Environment Performance Sector Report (2016), NWSC services expanded from 110 town areas as of June 2015 to 170 town areas in June 2016. Thus, approximately 80% of Uganda's total urban population's water supply service is managed by

NWSC. This increase in coverage is as a result of policy shift where even smaller towns and rural growth centres are also covered by NWSC, which has inherited water production infrastructures from private operators. Also, some areas have grown and therefore been designated urban areas as town councils and town boards which has led to this takeover by NWSC. Previously, DWD developed water supply sources and infrastructure and handed them to private operators who managed them under the support of DWD and local government. This transfer of management to NWSC is intended to improve the effective planning, management, control and coverage of water services.

The small towns of greater Bushenyi under the control and management of NWSC are Bushenyi-Ishaka, Buhweju, Bugongi, Kabwohe-Itendero, Kabira-Mitara, Kitagata, Kyabugimbi, Kashenshero, Mitooma, Rubirizi and Rutokye. With the exception of Bushenyi-Ishaka, all these small towns have recently been acquired by NWSC and the water abstraction and distribution systems were put in place by DWD. These are predominantly groundwater and spring potable water sources which previously supplied water to consumers without disinfection. Their transfer to NWSC has led to the introduction of chlorination as a means of disinfection and increase in the population coverage of a piped water service.

1.1.1 Bushenyi-Ishaka

Bushenyi town is located approximately 56 km on the Mbarara-Ishaka highway West of Mbarara and it lies 6 km East of Ishaka town. Its coordinates are 00° 32’30.0”S 30°11’16.0”E, latitude -0.541667; longitude 30.18778 (https://en.wikipedia.org/wiki/Bushenyi accessed 17/07/2017). The Bushenyi-Ishaka population was approximately 54,700 in 2016 according to the Uganda Water and Environment Performance Sector Report (2016) and 79% of the population’s water supply is under NWSC management.

The raw water source of these towns is Nyaruzinga Swamp, but during the dry season the Nyaruzinga WTP receives raw water (up to 1,000 m^3/d) from the Katenga water plant (property of PIBID) through a 5 km transport pipe. The treatment process consists of: coarse screening (two screens), aeration, pre-chlorination (HTH), pH adjustment (soda ash), coagulation (alum) and flocculation (poli), sedimentation (lamellar plate), slow sand filtration (3 layers) and post-chlorination (HTH). Afterwards the treated water is pumped to a clear-water well and then pumped to two reservoirs located at Katungu Hill (270 m^3) and Tank Hill (90 m^3) for distribution by gravity supply to consumers in homes, hotels, local business units and public standpipes. The average water production capacity of the Nyaruzinga water treatment plant is 2,000 m^3/d with a 24-hour supply in the rainy season and intermittent supply (~ 6 h per day) in the dry season between May and September. The plant cannot meet the demand that currently stands at 5,000 m^3/d. There are ongoing projects for supplementing production. The consumer network has 73 public standpipes (PSPs), 2,585 domestic connections, 161 institutional connections and 907 commercial accounts.

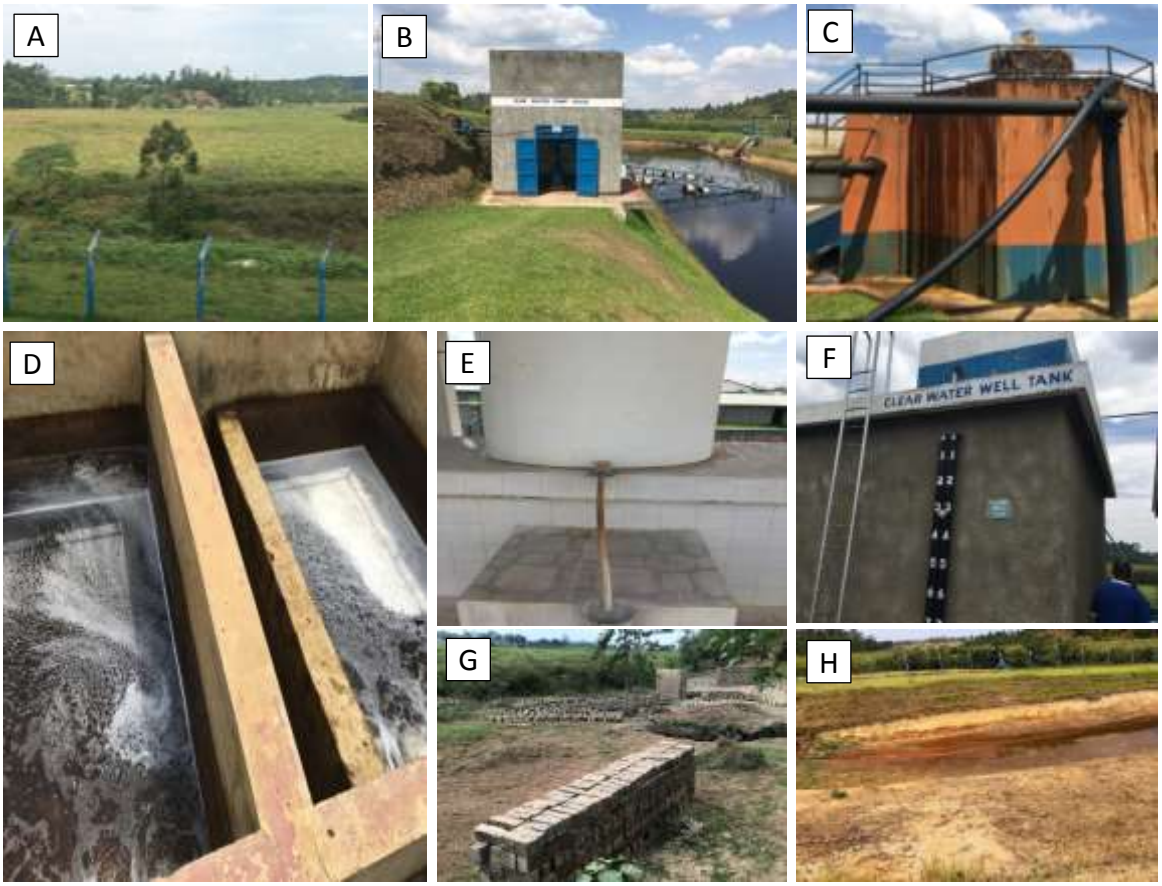


Figure 5: The Nyaruzinga water treatment plant supplying Bushenyi-Ishaka towns

Photos: (A) Nyaruzinga swamp, (B) raw water intake at Nyaruzinga swamp, (C) aeration tower, (D) rapid sand filtration, (E) HTH gravity dosing, (F) clear-water well tank, (G) swamp encroachment upstream of raw water intake, (H) dried up dam in the May-September dry season.

1.1.2 Kabwhohe-Itendero

Kabwohe town is located 33 km from Mbarara town on the Mbarara-Ishaka highway and is 29 km East of Ishaka. Its coordinates are 00° 34'49"S 30°22'42"E, latitude -0.580267°; longitude 30.378333° (https://en.wikipedia.org/wiki/Kabwohe accessed 17/07/2017). Together with Itendero town, approximately 1 km away, this forms the Kabwohe-Itendero metropolitan area, the largest town in Sheema district. The Kabwohe-Itendero population was approximately 20,800 in 2016 according to the Uganda Water and Environment Performance Sector Report (2016) and 71% of the population's water supply is under NWSC management.

These towns abstract raw water from the Katagata mountainous springs. The raw water treatment entails filtration through a stone, sand and clay bed followed by a four-chambered serial sedimentation. The clear water post-sedimentation is metered and then transported by gravitational flow to the Mushanga reservoir where it is chlorinated using HTH gravity dozers. Flow to consumer points is still by gravitational flow through a network of 92 km and an average supply of 20 hours/day is maintained. The daily average production of the springs is 393 m^3/day

and there is a utilization rate of approximately 88%. The water supply network currently consists of 69 PSP, 68 institutional and 1,408 domestic accounts.

Figure 6: Water infrastructure at Kabwohe-Katagata
Photos: (A) raw water source, (B) chambered sedimentation tank.

1.1.3 Kitagata

Kitagata, a small town in Sheema district lies on the Ishaka-Kagamba road and is approximately 17 km South of Ishaka town. Its coordinates are 00° 40'21"S 30°09'18"E (latitude -0.672499°; longitude 30.154991°). The Kitagata water supply service is under NWSC management. The raw water source of this town is from Mwijo-Kyomujungu and Rukondo boreholes where it is collected in a collection tank and disinfected by chlorination with subsequent gravitational flow to reservoirs and consumers. The daily average production of these boreholes is 135 m^3/d and a capacity utilization of 92%. There are 679 active water accounts consisting of 35 public standpipes, 28 institutional, 538 domestic and 78 commercial accounts with water flow for 24 hours/day with the exception of the May-September dry season when 12 hour/day water availability is guaranteed. The population served is 5,328, according to NWSC area management.

1.1.4 Bugongi

Bugongi is a small town in Sheema district and Its coordinates are 00° 39'03.2"S 30°15'41.0"E, latitude -0.6508900°; longitude 30.2614000°. The Bugongi population was approximately 12,100 in 2016 according to the Uganda Water and Environment Performance Sector Report (2016) and 31% of the population's water supply is under NWSC management.

At an average production capacity of 70 m^3/day, the raw water is abstracted from Kurungu-Kasana subcounty mountainous springs and there is 100% utilization capacity in the consumer network consisting of 30 PSP, 37 institutional, 38 commercial and 568 domestic accounts. This water is treated by chlorination using HTH gravitational dozers. Gravity flow is used for distribution to the reservoirs and supply network. The water supply reliability is 24 hours/day in the rainy season while in the dry season it is only 20 hours/day due to the reduced water source yield.

1.1.5 Rubirizi

Rubirizi is a small town located in Rubirizi district and lies just South of the Equator. It is 90 km by road North-East of Mbarara, the regional large town. Its coordinates are 00° 15'54"S 30° 06'00"E, latitude -0.2650°; longitude 30.1000° (https://en.wikipedia.org/wiki/Rubirizi accessed 17/07/2017). Its close proximity to Queen Elizabeth National Park makes it a major tourism hub. According to the Uganda Water and Environment Performance Sector Report (2016), the population of Rubirizi town was 8,400 in 2016 and 95% of this population is serviced by NWSC. However, the water supply network services an average of 12,778 people according to C. Mushabe (17/05/2017) due to the elaborate network covering water supply beyond the town to the neighbouring tourist hotels, park resorts and sub counties.

The raw water is extracted from Lake Rutoto with subsequent rapid sand filtration and chlorination as the treatment. Chlorination is through HTH gravity dozers. After the treatment, the water is supplied through the consumer network by gravity flow. The average daily production is 380 m^3/day at a water capacity utilization of 115% with water supply reliability of 20 h/day to 123 PSP, 43 institutional, 82 commercial and 674 domestic accounts.

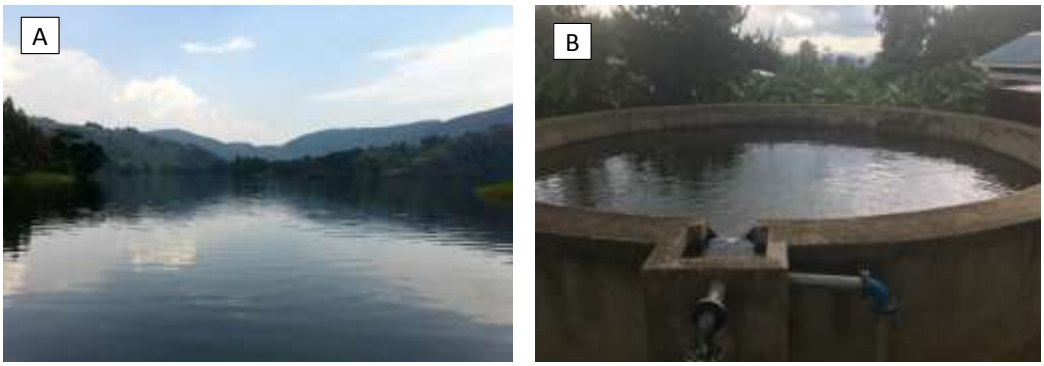


Figure 7: Water infrastructure at Rubirizi

Photos: (A) raw water intake at Lake Rutoto, (B) rapid sand filtration treatment at Buruma.

1.1.6 Mitooma

Mitooma town is the administrative headquarter of Mitooma district. It is approximately 24 km South-West of Bushenyi town and 85 km West of Mbarara town. Mitooma's coordinates are 0° 36'54.0"S 30° 02'42.0"E, latitude -0.6150°; longitude 30.0450° according to https://en.wikipedia.org/wiki/Mitooma.

The population of Mitooma town was approximately 5,800 in 2016 according to the Uganda Water and Environment Performance Sector Report (2016) and 79% of the population's water supply is under NWSC management. NWSC's water infrastructure in this town consists of a protected valley spring at Nsenga that flows to a sedimentation tank and finally to a clear water and disinfection tank where chlorine dozing by HTH gravity dozers is carried out and the water finally pumped to a reservoir uphill. The water supply is through gravity flow through the consumer network that consists of 248 domestic, 31 commercial, 17 institutional and 12 PSP accounts. The average daily production of water is 168 m^3/day.

Figure 8: Water infrastructure in Mitooma town

Photos: (A) sedimentation tank and clear water, (B) non-secure fencing at the Mitooma springs water source, (C) cattle feeding grounds within 30 meters of the water source, (D) a securely fenced reservoir in Mitooma.

1.1.7 Kabira-Mitara

Kabira-Mitara is a small town in Mitooma district located approximately 78 km from Mbarara town and its coordinates are 0° 41'28.2"S 30°01'44.8"E latitude -0.691170°; and 30.029099° longitude. The NWSC water supply source is at Isharaza and is a deep borehole with an average yield of 150 m^3/day. The abstracted groundwater is pumped to an onsite clear well where chlorine disinfection by gravity HTH dozers is carried out and then pumped to a 120 m^3 reservoir at Kabira Health Centre which supplies 3 other low-lying reservoirs by gravity flow along the distribution network. With a population of approximately 1,680, the consumer network consists of 201 domestic, 41 institutions, 24 commercial and 25 PSP accounts.

Figure 9: Water infrastructure in Kabira-Mitara town

Photos: (A) borehole at Isharaza, (B) gravity HTH dosing in a clear water well, (C) cattle rearing within 30 meters of the source, (D) herbicide storage in a pump house.

1.1.8 Nsika-Buhweju

Nsika-Buhweju town is the administrative centre of Buhweju town. The town's coordinates are 0° 23'59"S 30°28'54"E latitude -0.38306°; longitude 30.465° with the highest elevation at 1,546 m. The population of Nsika-Buhweju town was approximately 3,000 in 2016 according to the Uganda Water and Environment Performance Sector Report (2016) and 42% of the population's

water supply is under NWSC management. However, personal interviews with the area NWSC manager (J. Mbaine 18/07/2017) revealed that the network is approximately 73.2 km and that 5 sub-counties with a total population of 33,800 benefit from this piped water supply. Three mountainous water springs are used for the town supply and are located at Rubara 1, Kyenjogera and Nyakishana. However, Kyenjogera is the major water source and consists of a protected spring with a stone, sand and clay filter after which the water flows to a collection box and flows by gravity to two reservoir tanks at Mirama (55 m^3) and Kakamba (35 m^3).

Currently no disinfection is done to the water in Buhweju. Kyenjogera's average daily water production is 60 m^3/day. Being a newly acquired area of service (2016), Buhweju alongside other new towns has a lot of issues regarding public health protection, water source protection and security, water quality, and renovation or upgrading the existing infrastructure. Appendix 4 describes the current issues at hand in Buhweju, while the images in Figure 10 give a visual outlook of the drinking water risks in terms of quality, quantity and infrastructure.

Figure 10: Water infrastructure in Nsika-Buhweju town

Photos: (A) an old and leaking storage tank at Mirama hill with no security fence, (B) communities neighbouring the Kyenjogera source consume water from surface water next to the source outflow, (C) leaking old pipes in the distribution network, (D) Kyenjogera water source, (E) pig rearing within 30 meters of the source, (F) unlined pit latrines upstream of water source, (G) a final water collection box, (H) a pipe outlet from a stone-clay filter.

1.1.9 Kashenshero

Kashenshero town is located in Mitooma district and is located at latitude 0° 38’ 49.3” (0.647°) South and longitude 29° 59’ 3.9” (29.9844°) East at an elevation of 1,565 masl. According to the Uganda Water and Environment Performance Sector Report (2016), a population of 6,000 people inhabits this town with 81% of this population being serviced by NWSC. The water supply to this town is from the Kyemengo mountain springs with chlorination at reservoirs being the only treatment. An average 92 m^3/day of water is produced with 100% utilization across a consumer network consisting of 17 PSP, 216 domestic, 24 institutional and 15 commercial accounts. NWSC provides 24-hour water supply reliability in this town.

1.1.10 Kyabugimbi

Kyabugimbi, a town in Sheema district, is located at coordinates latitude 0° 28’ 22.8” (0.473°) South and longitude 30° 16’ 8.4” (30.269°) East at an elevation of 1,649 masl. The town’s NWSC water supply is from the mountainous springs of Kalyango, Mabanga and Nyakitooma with subsequent chlorination at the reservoir as the only form of treatment. The average daily water production is 150 m^3/day across a consumer network consisting of 39 PSP, 22 institutional, 342 domestic and 21 commercial accounts with 24-hour supply reliability irrespective of the season.

Further information about these small towns is contained in the NWSC small town fact sheet in Appendix 4.

CHAPTER FOUR: NWSC Water Quality Operational and Compliance Monitoring

1. NWSC Water Quality Testing in Small Towns

The Water Quality Management Department under the Business and Scientific Services Directorate of NWSC is mandated to ensure that the supply of water meets the national standards of drinking water to consumers. To ensure this mandate is fulfilled, operational and compliance monitoring is carried out.

1.1 Operational Monitoring

This is intended to monitor ongoing levels of operational efficiency at plant level. The Bushenyi-Nyaruzinga water treatment plant has an onsite water quality laboratory and a resident quality control technician responsible for evaluating the treatment performance. The parameters tested and the frequency of testing is indicated in Table 16 and Table 17, respectively, for the treatment process, distribution network and consumer points (public places) in Bushenyi town. Public places are public standpipes located in schools, market places and hospitals. The only operational monitoring carried out for the other small towns is daily testing for the residual chlorine concentration using Lovibond comparators and discs while monthly testing for pH, TSS, EC, colour, turbidity, residual chlorine faecal coliforms, *E. coli,* Iron and residual chlorine is carried out by the resident quality control technician of Bushenyi at the raw water source, reservoir and consumer PSPs.

Table 16: Operational monitoring organized by sample points

Sampling point	Daily parameters	Weekly parameters
Raw water	pH, TSS, EC, colour and turbidity	*E. coli*, faecal coliforms
Clarified water	pH, TSS, EC, colour and turbidity	
Rapid sand filter	pH, TSS, EC, colour and turbidity	
Clear water well	pH, TSS, EC, colour and turbidity, residual chlorine and residual aluminium	*E. coli*, faecal coliforms, total hardness, iron and alkalinity
New connection	Not done	pH, TSS, EC, colour, turbidity, residual chlorine
Vulnerable places	Not done	*E. coli*, faecal coliforms, pH, TSS, EC, colour, turbidity and residual chlorine
Public places	Not done	*E. coli*, faecal coliforms, pH, TSS, EC, colour, turbidity and residual
Reservoir	Not done	*E. coli*, faecal coliforms, pH, TSS, EC, colour, turbidity and residual
Control points	Not done	Not done
Dead ends	Not done	Not done

Table 17: Operational monitoring organized by sampling frequency

Sampling frequency	Sampling point	Parameters scheduled for analysis	Performed analysis
Daily	1. Raw water 2. Clarified water 3. Final water/ disinfected water	pH Electrical conductivity Colour Residual chlorine	pH Electrical conductivity Colour Residual chlorine
Weekly	1. Clear water well 2. New connection 3. Vulnerable places** 4. Public places 5. Reservoir	*E. coli**, faecal coliforms, total hardness, iron, alkalinity, pH, TSS, electrical conductivity, colour, turbidity, residual chlorine	Faecal coliforms, total hardness, iron, alkalinity, pH, TSS, electrical conductivity, colour, turbidity, residual chlorine
Monthly	1. Raw water 2. Clarified water 3. Final water 4. Reservoir water 5. Distribution system 6. Public place (PSPs)	*E. coli*, faecal coliforms, total hardness, iron, alkalinity, pH, TSS, electrical conductivity, colour, turbidity, residual chlorine, residual aluminium and total iron	*E. coli*, faecal coliforms, total hardness, iron, alkalinity, pH, TSS, electrical conductivity, colour, turbidity, residual chlorine, residual aluminium and total iron

*Although scheduled for weekly testing, the E. coli media is only stocked at the Mbarara laboratory and this test is performed monthly alongside other scheduled tests.

**Vulnerable place refers to a point in the water distribution network where water pipes are exposed to possible recontamination, e.g. a drainable channel crossing, a solid waste damping site, a flood prone site/valley.

Source: *Resident quality technician Bushenyi*.

1.2 Compliance Monitoring

An internal NWSC quality assurance team headed by the principal quality control officer based at the Mbarara regional laboratory ensures the conformance of the small towns to the testing schedules and water quality standards. Bushenyi town is audited monthly using the same parameters listed in Table 16 above and from the same sampling points. Other cluster towns are audited on a quarterly basis for pH, TSS, EC, colour, turbidity, residual chlorine, faecal coliforms, *E. coli,* iron and residual chlorine at the production plants, reservoirs and public consumer places. However, since Buhweju town has no chlorine disinfection in place, there is an exemption for this parameter auditing. Appendix 5 shows the outcome of this testing in 2016.

Compliance monitoring also focuses on record keeping for the quantities of HTH used for disinfection and testing for residual chlorine at reservoirs and consumer points for the cluster towns; flushing of dead ends; reservoir cleaning; customer complaint log and sanitation at public standpipes.

1.3 Challenges of Monitoring Cluster Towns

It was observed that the monitoring of cluster towns by the Bushenyi resident quality control technician is irregular yet the schedule in place requires monthly testing. Personal interviews with the resident quality technician revealed that as the NWSC coverage increases, the cluster town monitoring has become overwhelming due to the wide network to cover on a motorbike and still take care of the Bushenyi plant operations with no personnel backup. Efficient monitoring of the extended network requires a car and backup human resources. It was also revealed that some areas lack Lovibond comparators and discs for residual chlorine analysis while HTH weight is merely estimated due to the absence of weighing scales at water production sites which sometimes results in under/over estimation of required online chlorine concentrations. This presents a risk of contamination due to low residual chlorine concentration or excessive residual chlorine concentrations that make water undesirable for consumption. An operator in Rep001 (04/07/17) in Mitooma also revealed that transport expenses for monitoring network residual chlorine are not paid for by NWSC and testing has not been done for half a year.

2. Sampling Points Selection and Distribution

The distribution of sampling points depends on the treatment processes in place, for example Bushenyi-Nyaruzinga plant being a 3-stage treatment plant has more sampling points than other treatment plants for raw water intake, clarification and rapid sand filtration in addition to a clear water well, reservoir and consumer public standpipes. Sampling within the treatment process is aimed at evaluating ongoing treatment efficiency of processes (operational monitoring) while sampling of reservoirs and consumer standpipes is for evaluating the final water quality delivered to consumers and tracking possible recontamination points. According to the Regional Principal Quality Control Officer of NWSC, the rationale/criteria for selecting sampling points are as follows.

Raw water source: Since the raw water quality determines the extent of treatment, sampling is done for both bacteriological and physico-chemical testing. It is considered a major operational monitoring point in determining the scale of improvement of the water quality after final treatment.

Treatment works: Water production centres in small towns with treatment works such as the Bushenyi-Ishaka Nyaruzinga water treatment plant have sampling points to assess the extent to which water has been treated and chemical treatment residues, and these are considered critical control points of plant operation in terms of bacteriological and physico-chemical water quality before the water enters the network.

Reservoirs: These are considered high-risk points of contamination due to the potential for bio-terrorism and dirty reservoir tanks. Sampling is also done at these points to assess if the chlorine

concentration is still sufficient for microbiological protection or if there is a need for re-chlorination. Thus sampling at reservoirs gives information of the final water quality before entering the consumption network and is an indicator of the security and maintenance cleaning of reservoirs. Sampling at reservoirs is done for *E. coli*, faecal coliforms and physico-chemical parameters when they are at full capacity.

Consumer points: These are considered key for the determination of the final water quality being supplied to the consumer. Consumer sampling points are always chosen on direct lines and public stand points are preferred because they serve a high population and in particular locations such as schools, hospitals, and markets. Samples are taken for *E. coli,* faecal coliforms and physico-chemical parameters. Private homes are not usually chosen as sampling points because of difficulty in access, illegal connections, dual connections such as rainwater or groundwater, and dirty reception tanks.

Control points: These control points have valves in place to stop water flow to different areas. They are sampled and tested to enable swift action in stopping the flow of water in the case of poor quality water being observed in the network.

Dead ends: The need for sampling dead ends is to enable monitoring and assessment of preventive maintenance such as flushing of end caps in the network.

Appendix 6 shows the sampling points of the small towns; however, the Buhweju town sampling points are yet to be developed.

3. Laboratory Equipment at the Bushenyi-Nyaruzinga Water Treatment Plant

The Bushenyi NWSC laboratory is adequately equipped to handle minimum operational water quality testing for the Bushenyi-Nyaruzinga water treatment plant and the associated 10 cluster towns. Table 17 lists the available equipment, their functionality and maintenance dates.

Table 18: Laboratory equipment and functionality at Bushenyi-Nyaruzinga

Equipment	Manufacturer/model	Functionality	Maintenance service
pH /TDS/ conductivity meter	Palintest®800 waterproof	Functional	Serviced 25/03/17 due 25/03/18
Chlorine meter	Palin	Functional	No service record
Incubator	Portlab	Functional	Serviced 25/03/17 due 25/03/18
Autoclave	Dixon	Functional	Serviced 25/03/17 due 25/03/18
Electronic weighing balance	Adam	Functional	Serviced 26/04/17 due 26/04/18
Jar test mixer	Flocculator SW6	Not functional	No service record
Spectrophotometer	Hach DR 5000	Functional	Serviced 25/03/17 due 25/03/18
Magnetic stirrer (hot plate)	Genemate Bioexpress	Functional	Serviced 26/04/17 due 26/04/18
Turbidity meter	Hach 2100p	Functional	Serviced 25/03/17 due 25/03/18

Equipment	Manufacturer/model	Functionality	Maintenance service
Vacuum pump	Rocker 400	Functional	Serviced 26/04/17 due 26/04/18
Refrigerator	Lec medical	Functional	Serviced 26/04/17 due 26/04/18
Cool box		Functional	N/A
Aluminium meter	Octa-slide Lamatte®	Functional	Service documents not seen
Distilling machine	Waterstill GFL 2004	Not functional	Service documents not seen
15 flocculation jars			
9 items of glassware (flasks)		Functional	
Hot water bath			
Membrane filtration device			

Source: *Personal observations and interview with resident quality control technician-Bushenyi*.

4. Analytical Methods and Standard Operating Procedures

The Bushenyi laboratory testing is aligned to a set of standard operating procedures (SOP) developed at the NWSC central laboratory in Kampala. According to the regional principal quality control officer, SOPs are developed based on good laboratory practice and standard methods for the examination of water and wastewater. Technicians are trained in the test performance by the SOPs developed prior to rolling them out to regional and water treatment laboratories. Table 18 shows the Bushenyi laboratory SOP list currently in use while Table 19 shows the analytical methods for the different parameters tested. Appendix 2 shows the NWSC laboratory SOP master file list.

Table 19: Current SOPs in use at the Bushenyi laboratory

SOP title	Effective date	SOP ID and version no.
Work instructions for sample analysis using the spectrophotometer	Sept 2015	NWSC-BSH/ENG/WI/17 Rev.02
Work instruction for chlorination: chlorine demand test	Oct 2011	NWSC-BSH/ENG/WI/02 Rev.01
Work instruction for tap sampling	Oct 2011	NWSC-BSH/ENG/WI/07 Rev.01
Work instruction for carrying out a jar test	Oct 2011	NWSC-BSH/ENG/WI/15 Rev.02
Work instruction for electrical conductivity measurement	Sept 2015	NWSC-BSH/ENG/WI/15 Rev.02
Work instruction for pH measurement	Sept 2015	NWSC-BSH/ENG/WI/06 Rev.02
Work instruction for using the autoclave	Oct 2011	NWSC-BSH/ENG/WI/19 Rev.01
Work instruction for analysis of bacteriological samples	Sept 2015	NWSC-BSH/ENG/WI/18 Rev.02
Work instruction for distilling water	Oct 2011	NWSC-BSH/ENG/WI/20 Rev.01

Source: *Personal observations and interview with the resident quality control technician in Bushenyi*.

Table 20: Analytical methods applied to water quality testing in Bushenyi and cluster towns

Test parameter	Analytical method
Colour	Colorimetric by DR 5000
Total alkalinity	Neutralization reaction
Total hardness	EDTA complexometric titration
Residual chlorine	N-N-Diphenyl-P-Phenyleneamines (DPD): colorimetric and Lovibond comparators
Total iron	Colorimetric by Hach method
Aluminium	Colorimetric by Hach method
Turbidity	Nephloremetric method
E. coli	Chromocult media: pour culture method
Faecal coliforms	Cellulose acetate membrane: nutrient broth culture
TSS	Photometric method
pH	pH meter

Source: *Personal observations and interview with the resident quality control technician in Bushenyi*.

The following observations are critical for SOPs development:

- The master SOP file shows it is a draft copy yet has been in use since December 2014.
- SOPs in the master SOP file have not been signed off by the writer, reviewer or approver.
- No signed-off records of laboratory technician training.
- The SOP scope is mainly limited to operation with little attention given to safety or instrument maintenance.

4.1 Challenges of Laboratory Testing

It was observed that despite the Bushenyi NWSC laboratory having adequate equipment for handling the operational monitoring of treatment processes and the water quality supplied to consumers, there are a number of issues in the testing process:

- The location of the laboratory adjacent to the pump house creates an unpleasant noisy environment for the resident quality technician to comfortably perform tests.
- The laboratory is congested with some testing equipment put on the floor due to lack of space on lab benches. The laboratory refrigerator is in the hallway due to the congestion in the laboratory. Congestion limits the housekeeping required for the laboratory.
- The laboratory lacks the minimum safety conditions such as eye wash stations, a First Aid box, fire extinguisher, and fire blanket. The congestion within the lab further exacerbates the risks to operational safety.
- There are no backup personnel to ensure reliability of testing in the case of absence of the resident quality control technician. Furthermore, the area of sampling and testing is too extensive and overwhelming for one laboratory technician.
- There are inadequate resources in terms of transport for the laboratory technician to perform sampling and testing across the extensive cluster town network.

5. Laboratory Data Handling

The handling of data from testing at the Bushenyi laboratory is by recording into laboratory customized paper work sheets and filing daily. There is no computerized laboratory data information system on site. Laboratory results are signed off by the resident quality technician but no signatures of review were observed. The flow of testing information between the resident quality technician and Principal quality control officer is through phone conversations and WhatsApp due to the absence of a computer and Email system at the Bushenyi laboratory. Furthermore, no real time flow of information pertaining to water quality testing is received by plant operators in cluster towns due to the absence of laboratory data information systems that could be shared within the cluster towns, the Bushenyi laboratory and the regional laboratory in Mbarara. It was also observed that despite the regional laboratory in Mbarara having computers, there is no internet connection on site. To transfer laboratory data to the centralized database of NWSC through Email, the Principal quality control officer has to travel to the Mbarara NWSC commercial office to access internet services.

The handling of testing information within the small towns needs to be further developed by provision of computer and internet services, setting up an online information system, and developing SOPs in the handling of laboratory data, review and submission to the centralized database.

CHAPTER FIVE: Sanitation and Hygiene Practices in Small Towns

1. Sanitation and Hygiene in Small Towns

Goal 6 of the Sustainable Development Agenda seeks to achieve clean water and sanitation for all. The case of sanitation in all 11 towns in this baseline assessment is that there is no sewer in place and thus only on-site sanitation systems consisting of pit latrines and septic tanks. These ultimately require emptying, discharge and proper treatment of faecal sludge. However, in all these towns, there are no faecal sludge treatment facilities, according to H. Mutabazi (13/06/2017).

Personal interviews were organized with K. Fernard (17/05/2017), J. Mahesi (17/05/2017), TC Rep001 (17/05/2017) and H. Mutabazi (13/06/2017). These separate interviews all revealed that despite increasing coverage of safe water provision in these small towns, it is not in tandem with the handling of wastewater and faecal sludge. H. Mutabazi (13/06/2017) revealed that with increasing piped water supply, most home developers prefer construction of flush toilets with septic tanks as on-site 'treatment' and storage facilities. However, there is no standard for designs of septic tanks and these are merely storage facilities that fill up and require emptying and treating of the faecal sludge.

The small towns in reference are located in Bushenyi, Sheema, Mitooma, Rubirizi and Buhweju districts; the nearest wastewater handling facilities are wastewater stabilization ponds in Mbarara. According to K. Fernard (17/05/2017), J. Mahesi (17/05/2017), TC Rep001 (17/05/2017) and H. Mutabazi (13/06/2017), whereas there is an increasing demand for faecal sludge emptying services, there are no available cesspool trucks and it is a long way for the trucks from Mbarara town. This makes the cost prohibitive for most town dwellers especially the urban poor when house owners (landlords) are not ready to involve themselves in meeting these costs. Since the faecal sludge emptying is managed by private operators with no government regulation, the interview respondents above revealed that there is a lot of illegal dumping of faecal sludge in surrounding swamp areas which are also water catchments and sources. Manual emptying of pit latrines into drainage channels in the night and rainy season was also described by K. Fernard (17/05/2017). The faecal sludge (FS) is conveyed by storm water and this partly describes the increase in the faecal coliform count at the Bushenyi-Nyaruzinga raw water intake in rainy seasons.

H. Mutabazi (13/06/2017) also revealed that the Urban Water and Sewerage Department in the Ministry of Water and Environment has recently established a Sewerage and Sanitation Services division which will meet the provision of viable sanitation and sewerage systems for the commercial, institutional and public sector in these small towns. It was revealed that with the ongoing plans for the design and construction of 50 FS treatment facilities in Uganda serving 50

clusters across the country, the increasing FS challenge will be dealt with. NWSC is expected to operate and maintain these facilities in their areas of operation.

Figure 11: Sanitation situation

Photos: (A) untreated wastewater flowing into a swamp in Kabwohe, (B) untreated wastewater flowing from the back of a public ablution block in Ishaka town.

Regarding handwashing behaviour, the Uganda Water and Environment Performance Sector Report (2016) reported that an estimated 39.1% of the urban population has access to handwashing facilities at latrines. However, this is not indicative of actual usage and the National Service Delivery Survey (UBS, 2016) reported that nationwide, 78% of the population had no functional handwashing facilities at toilets while only 8% handwashing facilities had water and soap.

CHAPTER SIX: Conclusions and Recommendations

1. Conclusions and Recommendations

This baseline water quality and surveillance survey provided an opportunity for understanding the current practices in water quality monitoring in the 11 small towns. The current water sector organizational framework has been explored and the complimentary roles pertaining to water quality monitoring and surveillance have been reviewed between the different stakeholders. The water sector policy and legal framework has been studied to identify the provisions of the Ugandan law in safe water provision. The different players in development, monitoring and surveillance of national drinking standards have also been described and the challenges in these operations have been identified. The report further describes the water sources and infrastructure in small towns studied but with particular emphasis on NWSC managed facilities and the water quality testing facilities. Finally, the challenges of sanitation and hygiene in these small towns have also been briefly described through reports of personal interviews with local administrative leaders and WSDF-SW.

The following recommendations are made for the improvement in water quality monitoring practices in the small towns:

1. There is an urgent need for water safety plans development by NWSC for small towns.
2. There is need to plan for increased water quality testing in the small towns as the network expands. This planning includes resources in laboratory personnel, lab setup and transportation.
3. Improvements in laboratory data managements need to be made. There is need for development of laboratory data management information systems for these towns and improved sharing of information between the national, regional and plant-based laboratories.
4. Accessibility to NWSC services, their coverage and unreliability in the dry season is a major driver for use of unprotected water sources. There is need to increase coverage beyond peri-urban areas while as well as to secure a reliable water supply in the dry season.
5. The acquisition of new towns by NWSC should be complemented by water source protection. There is need to limit human activity especially farming around water sources which is linked to water source contamination by pesticides and animal manure. Other human activities such as swamp encroachment for farming, brick making, car-washing bays etc should be controlled.

6. There is an urgent need to provide water disinfection in Buhweju town and provide secure fencing for water infrastructures such as water sources and reservoirs. Old leaking pipes and reservoirs need urgent maintenance.
7. Despite sampling and testing at public standpipes, there is need for continued support and encouragement of water testing at private households since contamination is possible in these homes in the storage tanks and plumbing systems.
8. Despite domestic plumbing being a homeowner's responsibility, there is need for standardization, monitoring and approval of drinking water and sewerage plumbing construction to avoid cross-contamination of drinking water.
9. There is an urgent need for construction of centralized faecal sludge treatment plants for these towns and building local private capacity in cesspool emptying activities which also needs government regulation to avoid illegal dumping of FS in swamps.
10. Handwashing coverage after toilet usage remains very low and there is need to increase campaigns aimed at increasing handwashing facilities. The collaborative role of other stakeholders such as NGOs, CSOs, the Ministry of Health and the Ministry of Education and Sports would make a big impact in complementing NWSC activities of providing quality drinking water.

References

Agnew, C. and Woodhouse, P. (2010). Water Resources and Development, Routledge.

Guidelines for Protecting Water Sources for Piped Water Supply Systems (2013). In Framework and Guidelines for Water Source Protection, Volume 2.

Government of Uganda (1999). A National Water Policy, Ministry of Water, Lands and Environment, Kampala.

Government of Uganda (2005). Uganda National Water Development Report, Kampala.

Government of Uganda (2016). Uganda Water and Environment Performance Sector Report.

Uganda Bureau of Statistics (2016). National Service Delivery Survey – 2015 Report, Kampala.

United Nations (2016). Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators. New York/Geneva.

Watkins, K. (2006). Human Development Report - Beyond scarcity: Power, poverty and the global water crisis.

WHO/UNICEF Joint Monitoring Programme (2016). WASH in the 2030 Agenda: New global indicators for drinking water, sanitation and hygiene. Geneva/New York.

WSP (2002). Water and Sanitation Sector Reform in Uganda: A Government-Led Transformation, Water and Sanitation Programme, Nairobi.

Appendices

Appendix 1: Reference List of Interviewees

Name/ code	Designation	Location and date
Eng. Mutabazi Henry	Manager WSDF-SW (MWE)	Mbarara 13/06/2017
Mr. Richard Musota Ms. Caroline Tusiime	Manager LVWRM (MWE) Laboratory Services LVWRM (MWE)	Mbarara 20/06/2017
Mr. Profilio Andrew	Regional Principal Quality Control Officer (NWSC)	Mbarara 12/06/2017
Mr. Deo Mugume	Resident Quality Technician-Bushenyi (NWSC)	Nyaruzinga-Bushenyi 29/05/2017
Mr. Karuhanga Obed Rep001	Branch Manager Mitooma (NWSC) Plant Operator Mitooma-(NWSC)	Mitooma 04/07/2017
Mr. Julius Mbaine	Branch Manager Buhweju (NWSC)	Nsika-Buhweju 18/07/2017
Mr. Mushabe Charles	Branch Manager Rubirizi (NWSC)	Rubirizi 17/05/2017
Ms. Sarah Kedini	Branch Manager (NWSC)-Mitooma	Mitooma 04/07/2017
Mr. Andrew Mutekanga	Plant Operator Kabira Mitara (NWSC)	Isharaza Kabira Mitara 04/07/2017
Ms. Christine Kebirungi	Branch Manager Kabwohe Itendero (NWSC)	Kabwohe 19/06/2017
Ms. Esther Navubya	Branch Manager Kyabugimbi (NWSC)	Kyabugimbi 15/06/2017
Mr. Mahesi John	Town Clerk Rubirizi Town	Rubirizi 17/05/2017
TC rep001	Town Clerk representative Kabwohe Town	Kabwohe 17/05/2017
Mr. Katunda Kakuru Fernard	Town Clerk Bushenyi Town	Bushenyi 17/05/2017
Rep002	PSP attendant Ishaka	Ishaka 17/05/2017
Rep003	Water user Kabwohe	Kabwohe 19/06/2017
Mr. Mwesigye Muhumuza Junior	Technical Supervisor - Kitagata (NWSC)	Kitagata 15/06/2017
Rep 004	Unauthorized groundwater abstracter	Kabwohe 19/06/2017

Appendix 2: NWSC SOP Master-file Catalogue

SOP title	Effective date	Revision number
Good laboratory practice	01.12.2014	3
Preparation and standardization of volumetric solutions and reagents	01.12.2014	3
Laboratory Asceptic techniques	01.12.2014	3
Cleaning of the laboratory and glassware	01.12.2014	3
Disposal of spent reagents in the laboratory	01.12.2014	3
Disposal of waste material in the microbiology lab	01.12.2014	3
Disposal of samples	01.12.2014	3
Retention of samples	01.12.2014	3
Colour determination by DR 3900 spectrophotometer	01.12.2014	3
Electro-conductivity determination by conductivity meter/sensor	01.12.2014	3
pH determination	01.12.2014	3
Turbidity determination	01.12.2014	3
TSS determination by photometric method	01.12.2014	3
TSS determination by gravimetric method	01.12.2014	3
Total alkalinity	01.12.2014	3
Phenopthalein alkalinity	01.12.2014	3
Gravimetric standardization of aluminium oxide	01.12.2014	3
Calcium as $CaCO_3$ and Ca^{2+}	01.12.2014	3
Chromium Hexavalent determination	01.12.2014	3
Available chlorine in bleaching powder	01.12.2014	3
Residual and total chlorine	01.12.2014	3
Fluoride determination	01.12.2014	3
Total hardness determination	01.12.2014	3
Iron determination	01.12.2014	3
Manganese determination	01.12.2014	3
Silica determination	01.12.2014	3
Sulphate determination	01.12.2014	3
Dissolved CO_2 determination	01.12.2014	3
Chloride determination	01.12.2014	3
Aluminium determination	01.12.2014	3
Jar test for alum	01.12.2014	3
Chlorine demand test	01.12.2014	3
Calcium carbonate stability test (marble test)	01.12.2014	3
Dissolved oxygen test	01.12.2014	3
COD by closed reflux method	01.12.2014	3
COD by open reflux method	01.12.2014	3
BOD	01.12.2014	3

SOP title	Effective date	Revision number
Oil and grease determination	01.12.2014	3
Organic matter determination	01.12.2014	3
Trihalomethanes determination	01.12.2014	3
Nitrite determination by cadium reduction method	01.12.2014	3
Nitrite determination by salicylate method	01.12.2014	3
Nitrogen-ammonia determination by HACH method	01.12.2014	3
Nitrogen - total determination by spectrophotometric method	01.12.2014	3
Nitrogen - organic determination by Kjeldahl nitrogen method	01.12.2014	3
Orthophosphate determination by ascorbic method	01.12.2014	3
Total phosphate determination by persulfate method	01.12.2014	3
Faecal coliform test by cellulose acetate membrane and nutrient broth culture	01.12.2014	3
Total viable bacteria by total plate count or heterotrophic count	01.12.2014	3
E. coli determination by chromocult media pour culture method	01.12.2014	3
Total coliforms, faecal coliforms and E. coli by Collilert quantitative method	01.12.2014	3
Salmonella Typhi determination by salmonella/shigella agar culture test	01.12.2014	3
Phytoplanton determination by Sedgwick cell and haemocytometer	01.12.2014	3
COD reactor	01.12.2014	3
EC meter	01.12.2014	3
Laboratory weighing balance	01.12.2014	3
Desiccator	01.12.2014	3
Fume hood	01.12.2014	3
BOD incubator	01.12.2014	3
Forced conventional laboratory oven	01.12.2014	3
pH meter	01.12.2014	3
Water bath	01.12.2014	3
Water distiller	01.12.2014	3

Appendix 3: UNBS Results

UGANDA NATIONAL BUREAU OF STANDARDS

CERTIFICATE OF ANALYSIS

sanas Testing Laboratory
TO 200

Certificate No: ML/2015/0554

Field No: N/A

Name of Client: National Water and Sewerage Corporation

Address: P.O Box 7053, Kampala

Description of Sample: Potable water (Taps from distribution network)

Sample No: 139-149/2015M **Lot Size:** NA **Quantity of Sample:** 250mL each sample

Manufacturer: N/A

State of Sample(s): Received sealed in glass bottles

Sampling Report No: N/A **Date of Testing:** 2015-03-19 **Receipt/Sampling date:** 2015-03-18

Test Method(s): ISO 9308-1 & AOAC 967.26

Test Parameters:	Results:	Specification:	Status of Results:
MICROBIOLOGICAL PARAMETERS			
SEE ATTACHMENT			

Remarks:

1. The above sample was analysed as per donor's request.
2. The analysis was carried out as per the Uganda Standard, US 201:2008, Specification for potable water
3. This certificate of analysis (ML/2015/0554) is valid for the above samples 0139-0149/2015M only.

Note:
NA means 'not applicable', N/A means 'not available'
cfu/mL means 'colony forming units per millilitre', cfu/100mL means 'colony forming units per 100 millilitres'
<1cfu/100mL is equivalent in meaning to 'not detected in 100 millilitres'

Attachment(s) to the Certificate: 1

Analysed By: D. Mutabazi and N. Walyendo

Technical Signatory: J. Kwefuga Zwetuga **Date:** 24/03/2015

Executive Director UNBS: ..... **Date:** 24/03/2015

Page 1 of 1

Serial No: 42591

1. Results marked * are not SANAS Accredited and are not included in the SANAS Schedule of Accreditation for this laboratory.
2. Opinions and interpretations expressed herein are outside the scope of SANAS Accreditation.
3. This certificate of analysis is only valid if it bears an authorised signature and official seal. This certificate has been issued without any alteration and may not be reproduced other that in full except with written approval from the Executive Director, Uganda National Bureau of Standards.

Postal Address: P.O. Box 6329, KAMPALA.
Office Address: Plot M217 Nakawa, Industrial Area.
Telephone: Executive Director: +256-414-286123; General Line: +256-414-222367/505995
E-mail Address: info@unbs.go.ug; Fax: +256-414-286123; Website: www.unbs.go.ug

UGANDA NATIONAL BUREAU OF STANDARDS

MICROBIOLOGY TESTING LABORATORY

ATTACHMENT TO CERTIFICATE OF ANALYSIS **ML/2015/0554**

Name of Client: National Water and Sewerage Corporation

Sample Description: Potable water (Taps from distribution network)

Sample Number: 0139, 0140, 0141, 0142, 0143, 0144, 0145, 0146, 0147, 0148 & 0149/2015M

CENTRAL SUPPLY ZONE-SAMPLING POINTS **Date of sampling:** 18th March 2015

Method of analysis: Potable water samples were obtained from NW&SC water tap points around Kampala and analysed parameters in the table below.

Sample No.	Sampling points	Test parameters		
		Faecal (cfu/100mL) Specification: Shall not be detected	**E. Coli (cfu/100mL)** Specification: Shall not be detected	**Salmonella** Specification: Shall b absent in 25mL
		Result	**Result**	**Result**
139/2015M	UMI	<1	<1	Absent
140/2015M	Nakasero Market	<1	<1	Absent
141/2015M	Usafi Market	<1	<1	Absent
142/2015M	Wandegeya Market	<1	<1	Absent

Attachment to Certificate of Analysis ML/2015/0554

143/2015M	Shell Grand Imperial	<1	<1	Absent
144/2015M	Old Taxi park (Near airtel)	<1	<1	Absent
145/2015M	Bat Valley	<1	<1	Absent
146/2015M	Fire Brigade	<1	<1	Absent
147/2015M	Arua Park	<1	<1	Absent
148/2015M	Kisenyi Ovino	<1	<1	Absent
149/2015M	All Saints Nakasero	<1	<1	Absent

Analysed by: D. Mutabazi & N. Walyendo

Technical Signatory: ..... **Date:** 24/03/2015

Executive Director UNBS : ..... **Date:** 24/03/2015

Appendix 4: NWSC-Bushenyi Small Towns Cluster Fact Sheet

Town	Total pop.	Pop. served	Treatment system	Test parameters	Supply reliability	Connections	Avg production m^3/day	Challenges/risks
Bushenyi-Ishaka	54,700	42,956	Coarse screening, pre-chlorination, pH adjustment, aeration, flocculation, clarification, rapid sand filtration and chlorine disinfection respectively	**Daily**: pH, TSS, EC, turbidity (raw and final water), residual chlorine (final water), colour (final water), residual aluminium (final water) - Nyaruzinga lab **Weekly**: E. coli, faecal coliforms, total hardness, iron and alkalinity - Nyaruzinga lab **Monthly**: sampling of raw water, final treated water and in distribution network for pH, TSS, EC, turbidity, residual chlorine, colour, residual aluminium, *E. coli*, faecal coliforms, total hardness, iron, and alkalinity testing done at Mbarara lab.	24h during rainy season; 6h during dry season	PSP:73 institutional: 161 domestic: 2585 commercial: 907 Total: 3726	2000	• Drying up of raw water intake reservoir in dry season • Goats being reared within 30 m of water production area • Uncontrolled human activity upstream of abstraction swamp • Lack of laboratory data, information and management databases • Congested and unsafe laboratory • Overload of work for cluster towns WQ testing for one technician without transport facilities • Seasonal variation in water quality, especially faecal coliforms at raw water intake
Bugongi	12,100	4,525	Chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, turbidity, hardness, iron, alkalinity and colour at Mbarara lab.	24 hours/day in rainy season 20 hours/day in dry season	PSPs: 30 institutional: 37 commercial: 38 domestic: 568	70	• Poor quality pipes inherited from DWD in distribution network, not laid deep enough and prone to bursts • Seasonal variation in water quantity due to low yield of source
Buhweju	3,000	1,272	None	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, turbidity, hardness, iron, alkalinity, colour	24	PSPs: 39 domestic: 110 commercial: 4 institutional:24 Total: 177	100	• Poor quality pipes inherited prone to bursts and leaks • Long network of 73.2 km in a hilly terrain, under staffed and hard to maintain without reliable transport and maintenance plumbers • Distribution network designed with no flush points and not

Town	Total pop.	Pop. served	Treatment system	Test parameters	Supply reliability	Connections	Avg production m^3/day	Challenges/risks
								cleanable leading to high turbidity after no flow in pipes for some time • Cracked, old and leaking reservoir at Kankara-Mirama • Water source at Kyenjogera Rwamugoye not secured: animal feeding, crop cultivation, open defecation, no fencing • No disinfection • No bulk metering at source
Kabira-Mitara	No data	No data	Chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, turbidity, residual chlorine, hardness, iron, alkalinity, colour	24	PSP: 25 institutional: 41 domestic: 201 commercial: 24 Total: 291	150	• Unreliable power causing intermittent water supply. • Residual chlorine monitoring across WDN not being done due to lack of transport • WQ monitoring and audits not being done on schedule • Cattle rearing within 30 m of water production area
Kabwohe-Itendero	20,800	9,000	Sedimentation and chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, residual chlorine, turbidity, hardness, iron, alkalinity, colour	20	PSP: 69 institutional: 68 domestic: 1408 commercial: 218 Total: 1,763	393	• Pipe cuts during road maintenance • Leakages after customer meters
Kashenshero	6,000	4,832	Chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, residual chlorine, turbidity, hardness, iron, alkalinity, colour	24	PSP: 17 institutional: 23 domestic: 216 commercial: 15 Total: 271	95	• Undersized pipes in distribution network • Poor quality pipes prone to bursts
Kitagata	No data	No data	Chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, residual chlorine, turbidity, hardness, iron, alkalinity, colour	Wet season: 24 Dry season: 8	PSP: 35 Institutional: 28 domestic: 538 commercial:78 Total: 679	135	
Kyabugimbi	No data	No data	Chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, residual chlorine, turbidity,	24 h/day irrespective of season	PSP: 39 institutional: 22 domestic: 342	150	• Frequent bursts on transmission line due to old piping systems

Town	Total pop.	Pop. served	Treatment system	Test parameters	Supply reliability	Connections	Avg production m^3/day	Challenges/risks
				hardness, iron, alkalinity, colour		commercial: 21 Total: 424		
Mitooma	5,800	4,570	Chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, residual chlorine, turbidity, hardness, iron, alkalinity, colour	24	PSP: 12 institutional: 17 domestic: 248 commercial: 31 Total: 308	168	• Cattle rearing within 30 m of water production area
Rubirizi	8,400	7,951	Rapid sand filtration and chlorination	Quarterly testing for pH, TSS, EC, faecal coliforms, *E. coli*, residual chlorine, turbidity, hardness, iron, alkalinity, colour	20	PSP: 123 institutional: 43 domestic: 674 commercial: 82 Total: 922	380	• Frequent scrapping of algae in the rapid sand filter due to no backwash systems • Low lake levels at raw water source requiring adjustment of intake pipe in dry season • Overflow at reservoirs due to no ball valves requiring stoppage of production and affecting supply to high altitude areas. • No ongoing daily, weekly testing of residual chlorine due to no testing equipment • Low pressure in hilly areas
Rutokye	No data	No data	No data	Data unavailable	No data	No data	No data	No data

Appendix 5: Small Town Audit of Water Quality Data in 2016

Final WQ Bushenyi

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	Average	SD
Ph	5.9	5.8	5.7	5.8	5.7	5.9	5.8	5.8	5.8	N/D	N/D	N/D	6.5-8.5	5.800	0.071
EC	364	333	345	321	121	176	85	85	151	N/D	N/D	N/D	≤1500	220.111	118.469
Turbidity	1.55	1.84	2.18	1.45	1.96	2.25	1.78	1.78	2.57	N/D	N/D	N/D	≤5	1.929	0.354
Colour	4	4	9	3	4	3	3	3	8	N/D	N/D	N/D	≤15	4.556	2.297
Hardness	26	28	28	24	22	23	19	19	29	N/D	N/D	N/D	≤300	24.222	3.801
Iron	0.15	0.15	0.12	0.12	0.15	0.09	0.156	0.15	0.14	N/D	N/D	N/D	≤0.3	0.136	0.022
Res. Al	0.12	0.12	0.18	0.15	0.16	0.16	0.15	0.15	0.17	N/D	N/D	N/D	≤0.2	0.151	0.020
$F.Cl_2$	0.82	0.78	0.76	0.82	0.76	0.84	0.88	0.88	0.84	N/D	N/D	N/D	0.2-0.5	0.820	0.046
F. coliforms	0	0	0	0	0	0	0	0	0	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	18	17	15	17	17	17	19	N/D	N/D	N/D		17.143	1.215
TSS	N/D	N/D	0	0	0	0	0	0	0	N/D	N/D	N/D	Not detectable	0.000	0.000

Final WQ Kabwohe

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	Average	SD
Ph	5.3	5.3	N/D	6.4	N/D	5.6	N/D	N/D	N/D	N/D	N/D	N/D	5.5-9.5	5.650	0.520
EC	104	105	N/D	95	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤2500	101.333	5.508
Turbidity	3.89	3.98	N/D	0.61	N/D	1.24	N/D	N/D	N/D	N/D	N/D	N/D	≤25	2.430	1.757
Colour	23	22	N/D	0	N/D	5	N/D	N/D	N/D	N/D	N/D	N/D	≤50	12.500	11.733
Hardness	24	24	N/D	45	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤600	31.000	12.124
Iron			N/D	0.05	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤0.3	0.050	
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	0.42	0.4	N/D	0.7	N/D	0.53	N/D	N/D	N/D	N/D	N/D	N/D	0.2-0.5	0.513	0.137
F. coliforms	0	0	N/D	0	N/D	0	N/D	N/D	N/D	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity			N/D	4	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D		4.000	
TSS			N/D	0	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	Not detectable	0.000	

Final WQ Rubirizi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	7.4	N/D	N/D	8	7.7	N/D	7.3	7.1	7.6				5.5-9.5	7.517	0.319
EC	230	N/D	N/D			N/D	130		130				≤2500	163.333	57.735
Turbidity	1.8	N/D	N/D	1.79	2.76	N/D	0.64	0.48	1.71				≤25	1.530	0.846
Colour	4	N/D	N/D	13	13	N/D	16	0	14				≤50	10.000	6.419
Hardness	78	N/D	N/D	54	54	N/D	94	84	68				≤600	72.000	16.297
Iron	0.12	N/D	N/D	0.1	0.1	N/D	N/D	N/D	0.1				≤0.3	0.105	0.010
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A				≤0.2		
$F.Cl_2$	0.56	N/D	N/D	0.32	0.2	N/D	0.2	N/D	0.66				0.2-0.5	0.388	0.211
F. coliforms		N/D	N/D			N/D		N/D	N/D				Absent in 95% of yearly samples		
Alkalinity		N/D	N/D	64	64	N/D	66	86	84					72.800	11.189
TSS		N/D	N/D	2	2	N/D	0	0	0				Not detectable	0.800	1.095

Final WQ Kitagata

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	5.7	6.2	N/D	N/D	5.9	5.8	N/D	N/D	5.6	N/D	N/D	N/D	5.5-9.5	5.840	0.230
EC	138	87	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤2500	112.500	36.062
Turbidity	0.9	1.05	N/D	N/D	0.3	0.1	N/D	N/D	1.4	N/D	N/D	N/D	≤25	0.750	0.539
Colour	0	4	N/D	N/D	0	0	N/D	N/D	7	N/D	N/D	N/D	≤50	2.200	3.194
Hardness	40	40	N/D	N/D	48	44	N/D	N/D	34	N/D	N/D	N/D	≤600	41.200	5.215
Iron	N/D	0.05	N/D	N/D	0.03	0.03	N/D	N/D	N/D	N/D	N/D	N/D	≤0.3	0.037	0.012
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	0.4	0.1	N/D	N/D	0.63	0.52	N/D	N/D	0.59	N/D	N/D	N/D	0.2-0.5	0.448	0.213
F. coliforms	0	0	N/D	N/D	0	0	N/D	N/D	0	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	N/D	N/D	38	34	N/D	N/D	38	N/D	N/D	N/D		36.667	2.309
TSS	N/D	N/D	N/D	N/D	0	0	N/D	N/D	0	N/D	N/D	N/D	Not detectable	0.000	0.000

Final WQ Bugongi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	N/D	N/D	5.9	N/D	N/D	5.7	N/D	N/D	5.6	N/D	N/D	N/D	5.5-9.5	5.733	0.153

EC	N/D	N/D	152	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤2500	152.000	
Turbidity	N/D	N/D	0.39	N/D	N/D	0.18	N/D	N/D	0.41	N/D	N/D	N/D	≤25	0.327	0.127
Colour	N/D	N/D	0	N/D	N/D	0	N/D	N/D	0	N/D	N/D	N/D	≤50	0.000	0.000
Hardness	N/D	N/D	N/D	N/D	N/D	54	N/D	N/D	38	N/D	N/D	N/D	≤600	46.000	11.314
Iron	N/D	N/D	0.06	N/D	N/D	0	N/D	N/D	0.08	N/D	N/D	N/D	≤0.3	0.047	0.042
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	N/D	N/D	0.5	N/D	N/D	0.49	N/D	N/D	0.51	N/D	N/D	N/D	0.2-0.5	0.500	0.010
F. coliforms	N/D	N/D	0	N/D	N/D	0	N/D	N/D	0	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	44	N/D	N/D	N/D		44.000	
TSS	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D	Not detectable	0.000	

Final WQ Kyabugimbi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National Standard	AVERAGE	SD
Ph	N/D	N/D	N/D	5.7	4.4	N/D	N/D	N/D	5.6	N/D	N/D	N/D	5.5-9.5	5.233	0.723
EC	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	30	N/D	N/D	N/D	≤2500	30.000	
Turbidity	N/D	N/D	N/D	0.34	0.6	N/D	N/D	N/D	0.5	N/D	N/D	N/D	≤25	0.480	0.131
Colour	N/D	N/D	N/D	0	0	N/D	N/D	N/D	1	N/D	N/D	N/D	≤50	0.333	0.577
Hardness	N/D	N/D	N/D	24	24	N/D	N/D	N/D	8	N/D	N/D	N/D	≤600	18.667	9.238
Iron	N/D	N/D	N/D	0.08	0.08	N/D	N/D	N/D	0.01	N/D	N/D	N/D	≤0.3	0.057	0.040
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	N/D	N/D	N/D	0.49	0.4	N/D	N/D	N/D	0.5	N/D	N/D	N/D	0.2-0.5	0.463	0.055
F. coliforms	N/D	N/D	N/D	0	0	N/D	N/D	N/D	0	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	N/D	14	14	N/D	N/D	N/D	4	N/D	N/D	N/D		10.667	5.774
TSS	N/D	N/D	N/D	0	0	N/D	N/D	N/D	0	N/D	N/D	N/D	Not detectable	0.000	0.000

Final WQ Mitooma

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	N/D	N/D	6.3	N/D	4.4	N/D	N/D	N/D	5.6	N/D	N/D	N/D	5.5-9.5	5.433	0.961
EC	N/D	N/D	219	N/D	N/D	N/D	N/D	N/D	30	N/D	N/D	N/D	≤2500	124.500	133.643
Turbidity	N/D	N/D	2.34	N/D	0.6	N/D	N/D	N/D	0.5	N/D	N/D	N/D	≤25	1.147	1.035
Colour	N/D	N/D	12	N/D	0	N/D	N/D	N/D	1	N/D	N/D	N/D	≤50	4.333	6.658

Hardness	N/D	N/D	30	N/D	24	N/D	N/D	N/D	8	N/D	N/D	N/D	≤600	20.667	11.372
Iron	N/D	N/D	0.08	N/D	0.08	N/D	N/D	N/D	0.01	N/D	N/D	N/D	≤0.3	0.057	0.040
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	N/D	N/D	0.36	N/D	0.4	N/D	N/D	N/D	0.5	N/D	N/D	N/D	0.2-0.5	0.420	0.072
F. coliforms	N/D	N/D	0	N/D	0	N/D	N/D	N/D	0	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	34	N/D	14	N/D	N/D	N/D	4	N/D	N/D	N/D		17.333	15.275
TSS	N/D	N/D	0	N/D	0	N/D	N/D	N/D	0	N/D	N/D	N/D	Not detectable	0.000	0.000

Final WQ Kashenshero

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	N/D	N/D	6.7	N/D	6.7	N/D	N/D	6.8	N/D	N/D	N/D	N/D	5.5-9.5	6.733	0.058
EC	N/D	N/D	372	N/D	380	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤2500	376.000	5.657
Turbidity	N/D	N/D	1.6	N/D	1	N/D	N/D	0.81	N/D	N/D	N/D	N/D	≤25	1.137	0.412
Colour	N/D	N/D	0	N/D	0	N/D	N/D	0	N/D	N/D	N/D	N/D	≤50	0.000	0.000
Hardness	N/D	N/D	60	N/D	60	N/D	N/D	58	N/D	N/D	N/D	N/D	≤600	59.333	1.155
Iron	N/D	N/D	0.07	N/D	0.05	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤0.3	0.060	0.014
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	N/D	N/D	0.2	N/D	0.2	N/D	N/D	0.43	N/D	N/D	N/D	N/D	0.2-0.5	0.277	0.133
F. coliforms	N/D	N/D	0	N/D	0	N/D	N/D	0	N/D	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	68	N/D	62	N/D	N/D	64	N/D	N/D	N/D	N/D		64.667	3.055
TSS	N/D	N/D	0	N/D	0	N/D	N/D	0	N/D	N/D	N/D	N/D	Not detectable	0.000	0.000

Final WQ Rutokye

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	N/D	N/D	N/D	7.5	7.3	N/D	N/D	7.1	N/D	N/D	N/D	N/D	5.5-9.5	7.300	0.200
EC	N/D	N/D	N/D	351	355	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤2500	353.000	2.828
Turbidity	N/D	N/D	N/D	1.2	1	N/D	N/D	0.48	N/D	N/D	N/D	N/D	≤25	0.893	0.372
Colour	N/D	N/D	N/D	6	5	N/D	N/D	0	N/D	N/D	N/D	N/D	≤50	3.667	3.215
Hardness	N/D	N/D	N/D	82	80	N/D	N/D	84	N/D	N/D	N/D	N/D	≤600	82.000	2.000
Iron	N/D	N/D	N/D	0.06	0.07	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤0.3	0.065	0.007
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	N/D	≤0.2		

$F.Cl_2$	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.2-0.5		
F. coliforms	N/D	N/D	N/D	0	0	N/D	N/D	0	N/D	N/D	N/D	N/D	Absent in 95% of yearly samples	0.000	0.000
Alkalinity	N/D	N/D	N/D	84	81	N/D	N/D	86	N/D	N/D	N/D	N/D		83.667	2.517
TSS	N/D	N/D	N/D	N/D	0	N/D	N/D	0	N/D	N/D	N/D	N/D	Not detectable	0.000	0.000

Final WQ Kabira

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	National standard	AVERAGE	SD
Ph	N/D	7	N/D	N/D	6.4	N/D	N/D	N/D	N/D	N/D	N/D	N/D	5.5-9.5	6.7	
EC	N/D	132	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤2500	132	
Turbidity	N/D	1.9	N/D	N/D	4.96	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤25	3.43	
Colour	N/D	17	N/D	N/D	13	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤50	15	
Hardness	N/D	N/D	N/D	N/D	64	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤600	64	
Iron	N/D	0.04	N/D	N/D	0.09	N/D	N/D	N/D	N/D	N/D	N/D	N/D	≤0.3	0.065	
Res. Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/D	N/D	N/D	≤0.2		
$F.Cl_2$	N/D	0.2	N/D	N/D	0.54	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.2-0.5	0.37	
F. coliforms	N/D	0	N/D	N/D	0	N/D	N/D	N/D	N/D	N/D	N/D	N/D	Absent in 95% of yearly samples	0	
Alkalinity	N/D	N/D	N/D	N/D	64	N/D	N/D	N/D	N/D	N/D	N/D	N/D		64	
TSS	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D	N/D	N/D	N/D	N/D	Not detectable	0	

Appendix 6: Small Town Sampling Points

Bushenyi-Ishaka		**Kabwohe-Itendero**		**Kitagata-Rukondo**		**Rubirizi**		**Kabira-Mutara**		**Kashenshero**		**Mitooma**		**Rutookye**		**Bugongi**		**Kyabugimbi**
Intake points	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**	**A**	**Intake points**
Nyaruzinga Dam	1	Kashoko spring	1	Kyomujungu spring	1	Lake Rutoto	1	Kabira borehole	1	Kyemengo borehole	1	Mitooma spring	1	Rugarama Borehole	1	Kirugu spring	1	Spring 1 (Karyango)
	2	Katagata spring	2	Rukondo spring													2	Spring 2
	3	Nyaruzinga ww															3	Spring 3
Treatment	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**	**B**	**Treatment**
Raw (Dam)	1	Raw-Kashoko	1	Raw - Kyomujungu	1	Raw - L. Rutoto	1	Raw	1	Raw	1	Raw	1	Raw	1	Raw	1	Raw
Clarified	2	Raw-Katagata	2	Raw - Rukondo	2	Filtered												
Filtered	3	Final-Bushenyi	3	Final Rukondo	3	Final												
Final			4	Final - Kyomujungu														
Reservoirs	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**	**C**	**Reservoirs**
Katungu	1	Mushanga	1	Ibanga	1	Lugazi	1	Health Centre	1	Nyakagongo	1	Ryakahimbi	1	Rutookye 1	1	Kyarakunda	1	Bugarama
Tank Hill	2	Mushanga-Community	2	Kitagata-Hospital	2	Nyakashozi	2	Mutara							2	Nyabubaare	2	Nyamabaare
	3	Kibutamo			3	Nyakiyanja	3	Kyeibaare Girls									3	Kyeigombe
					4	Kyambura	4	Nyakishozwa										
PSPs	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**	**D**	**PSPs**

Kantunda PSP	1	Kibingo	1	Alice PSP	1	Ndekye C	1	Kabira Tech Rd	1	Town PSP	1	Kebirungi Kiosk	1	Sanga 1	1	Amina	1	Bujaga
Kabushaho PSP	2	Tree-Shed	2	Ibanga	2	Nyakasharu	2	Mutara Stage Kiosk	2	Opp. NWSC Office	2	Opp. Health C Kiosk	2	Rutookye Town	2	Kashushano	2	Stage Kiosk
Kizinda Centre	3	Kemikyera	3	Karugorora	3	POSTA	3	Kabira Kiosk 1	3	Omukatojo	3	Near Stage Kiosk	3	Kibaare Centre	3	Rwentuha Rd	3	Nyakiboreera
Kaymuhunga	4	Kabwohe-B-Kiosk 2	4	Jesca	4	Kyambura	4	Kabira Kiosk 2	4	Ignatius	4	NWSC Kiosk A	4	Mahunge Centre	4	Betty Karwani	4	Central Kiosk
Kashenyi	5	Kibutamo	5	Kyeibanga C	5	Kabete	5	Kabira Kiosk 3			5	NWSC Kiosk C	5	Nyerambire Centre	5	Rwamugangа	5	Kyeigonde C Kiosk 2
Igara H/Sch	6	Itendero Town Kiosk 2	6	Omukatoomа	6	Kirugu	6	Mile Kiosk	**E**	**Control points**	**E**	**Control points**	6	Nyakashiro Centre	6	Kihimba Alex	6	Kyeigonde C Kiosk 3
Ncucumo	7	Nyakashambyа	7	Kimondo	7	Kyenzaza - 1-A	7	Rubanga Kiosk			1	Ijumo	**E**	**Control points**	**E**	**Control points**	7	Kyeigonde C Kiosk 1
Numba	8	Nyamufumura	8	Rukondo	8	Rwandaro C	8	Nyakisozwa Kiosk	**F**	**Dead ends**	2	Buharambo	1	Ishaka-Road		Bugongi TC	8	Major Paddy
Katonya	9	Mbagwa	9	Kitagata Farm Sch	**E**	**Control points**	9	Nyakasharara Kiosk			**F**	**Dead ends**	**F**	**Dead ends**		Ahamuruka	**E**	**Control points**
Rwentuha	10	Highway Kiosk	10	Kasaana			10	Nyabubaare Kiosk			1	Kirambi-Ijumo	1	Nsanga	**F**	**Dead ends**		
Kiyaga			11	Topha			**E**	**Control points**			2	Katenga	2	Mahunje	1	Kashekuro	**F**	**Dead ends**
Kigoma			12	Mishenyi	**F**	**Dead ends**	1	Kabira-TC			3	Nshenga-B			2	Masya		
Kagonero			13	Kashekuro			2	Rwentuha							3	Kashushano		
Butaare 1			**E**	**Control points**			3	Kyobukyera-Kyeibaare										
Butaare 2			1	DOT - Services			**F**	**Dead ends**										
Butaare 3			2	Kitagata Trading Centre			1	Kyamuyanga										

Butaare 4			**F**	**Dead ends**			2	Bikungu										
Ryeishe-Ibaare			1	Bwooma Trading Centre			3	Rubanga										
Ishaka-Basajja			2	Rukondo CU														
Misiri			3	Kyeibanga-Kashenyi														
Control points	**E**	**Control points**																
Kizinda Chamber	1	Kabwohe-A																
Mother's Union Chamber	2	Kabwohe-B																
Dead ends	3	Itendero-A																
Kitookye East End cap	4	Itendero-B																
Kyamuhunga End-cap	**F**	**Dead ends**																
Rwakanyoni End-cap	1	Kyagaju																
Rwentuha End-cap	2	Kibingo-Nyakashambya																
	3	Muzirigyembe																