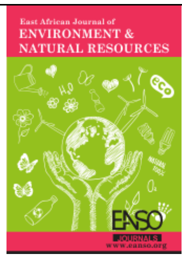

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Original Article

A Framework for Managing Water Quality from Hand-dug Well: A Case of Mutukula Town Council, Uganda

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ABSTRACT

This research proposed the adoption of a framework as a supporting tool to enhance the management of the quality of water from hand-dug wells in Mutukula Town Council, Uganda. Although water from hand-dug wells is often considered prone to contamination, no such study has been carried out for Mutukula Town Council. Adopting both qualitative and quantitative approaches including the use of surveys, experimentation and tools such as the sanitary inspection package developed by the World Health Organization, the research clearly indicated that not only was the quality of water from the 5 wells considered poor but that the wells also lacked pertinent components such as secure covers, drainage provisions, headwalls among others. Moreover, the absence of regulatory tools/guidelines, and cultural and socioeconomic practices amongst community members further contributed to risks associated with using water from these wells. This research proposes a framework that can be adopted by respective local authorities to enhance management and monitoring of water quality and it incorporates key components of training and capacity building, collective supervision and encouraging regular engagements with the various stakeholders.

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INTRODUCTION

Globally, about 2 billion people still do not have access to safely managed drinking water with at least 771 million of this population not having access to any basic water services Moreover, statistics showed that less than half the population in Sub-Saharan Africa could access safe water with most countries recording access between 6-48%. Furthermore, absent, inadequate or inappropriately managed water, sanitation systems and services expose individuals to some preventable diseases and health risks such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio. These diseases if not well managed could result in death which is pronounced for children under the age of 5 years with statistics from the World Health Organization indicating that at least 1.5 billion childhood cases of diarrheal disease every year (WHO, 2017; Merid, et al., 2023).

In Uganda, poor sanitation is estimated to account for the loss of at least 177 million USD annually. This is partly contributed to by contamination of potable due to exposure of the water sources to waste, faecal matter and use of unclean containers in storage and transportation of water to locations where it is needed. For the most part, common types of water supply technologies in the country include deep boreholes accounting for 45% coverage, shallow wells 22%, protected springs 20%, public standpipes 11%, rainwater harvesting, piped water as well as gravity systems. Although mainly used as technology in rural areas of the country, hand-dug wells often considered prone to contamination are also used in urban areas and are opted for due to ease of access and affordability of water to many households.

The quality of water from hand-dug wells in many of these systems is susceptible to biological, chemical and physical contaminants partly due to poor management associated with these facilities (Abanyie et al., 2016; Previsich et al., 2011). In Uganda, statistics show that about 16% of mushrooming urban centres often lack piped water which compels the majority of the population, especially domestic users to draw water from unimproved or unprotected sources such as hand-dug wells (Makoko et al., 2021; UBoS, 2015). Mutukula Town Council in Kyotera District, central Uganda is one of the areas where residents heavily depend on water from hand-dug wells. The Town Council has been reported as one of the areas in Uganda worst hit by water shortages resulting in high costs incurred to access water. Reports further indicate that during the dry season, a 20-litre jerrycan of water is sold by water vendors at about UGX 2,000 (USD 0.55) and yet for a household of an average of 4 persons, a minimum of 80 litres/day would be required. As a short-term solution to the water shortages experienced, at least nine (9) hand-dug wells have been constructed in the area and water from these wells is utilized by 92 % of the households. Despite this being the case, no investigations about the quality of water drawn from this hand-dug water sources have been carried out and yet statistics show that between 2015 and 2019, at least 315 diarrheal disease-related cases were diagnosed and 20 deaths reported at Mutukula Health Centre IV with Public Health professionals linking the statistics to poor sanitation possibly from use of unclean water among other aspects (Mutukula Town Council Health Centre IV Records, 2015-2019). Based on this background, the overall goal of this study was to determine the levels of contamination of water in hand-dug wells

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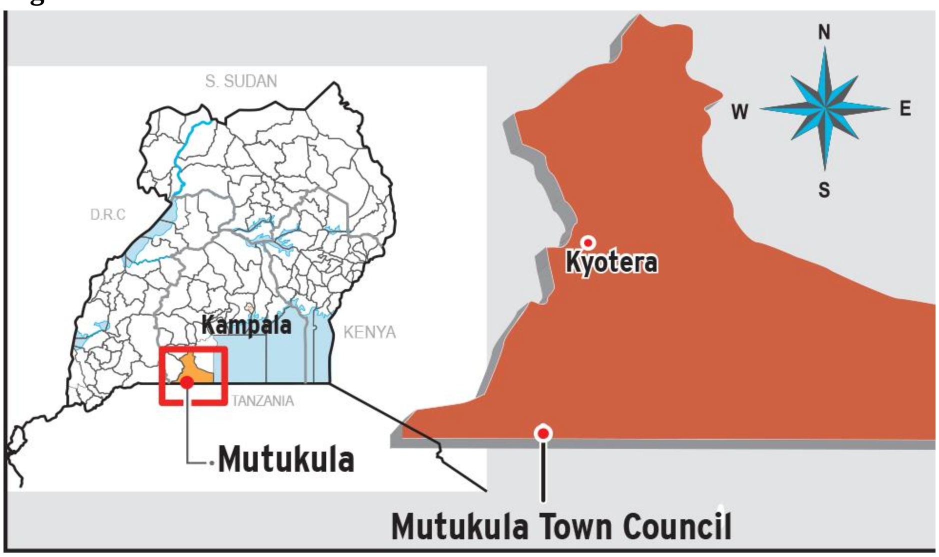
in Mutukula Town Council investigate contamination linkage to poor sanitation practices and propose a framework to support the management of the quality of water from hand-dug wells for improved livelihoods.

MATERIALS AND METHODS

Area of Study

The study was conducted in Mutukula Town Council located in the southern part of Kyotera District. The district is located at the border of Uganda and Tanzania where there is a significant influx of population due to the transit of people between the borders resulting in an estimated population of 88,371 in 2020 (Kyotera District, 2019), competition for services such as water, sanitation, energy provision and lagging development of necessary infrastructure. Figure 1 shows the location of Kyotera District and Mutukula Town Council respectively.

Figure 1: Location of Mutukula Town Council



Study Design and Methods

The study adopted the Design Science Research (DSR) methodology which involves the use of analytical techniques and perspectives that enable researchers to produce artefacts/tools that can offer solutions to recurrent and long-standing problems affecting a given setting (Vaishnavi *et al.*, 2019). Further adopting a case study approach, the researchers attempted to address the 'bystander' problem avoiding merely reporting the results but also designed and proposed a framework for management of quality of water (Romme & Meijer, 2020). Moreover, reference was made to existing methods/tools to further enhance understanding, such as the use of the sanitary inspection package for dug wells and the guidelines for drinking water quality . With reference to a modified sanitary inspection package initially designed by the World Health Organization, key information regarding the risks, water quality surveillance and eventual well management was obtained. Furthermore, qualitative and quantitative approaches to obtain necessary data to inform quality management were adopted. Specifically, analysis of water samples from the wells gave key insight into the quality of water while a survey supported by questionnaires and key informant interviews gave insight to qualitative aspects of the research. All stakeholders consulted gave consent since this was included in the questionnaires and ethical considerations to protect the identity of the respondents were equally adhered to.

Data Collection

Both primary and secondary data were collected and referred to during this research. Primary data was

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obtained from the analysis of water samples from the wells to check the quality of the water in addition to information obtained from the survey and key informant interviews. Secondary data from the literature was referred to, informing analysis of water samples among other aspects. With reference to tools like the sanitary inspection package, key details such as location, age, use, functionality of the well and quality of the water from the wells were obtained. Further discussion of key aspects considered follows;

Water Supply – Wells and Water Samples Considered

In Mutukula Town Council, nine (9) hand-dug wells were identified although during the study, reference was made to five (5) hand-dug wells (coded S1 to S5) since these were still functioning, i.e. water was collected for potable use from these wells and they were easily accessible. Reference was made to the Sanitary Inspection package, which consists of three key components including;

Sanitary inspection form – a checklist that helps identify common risk factors and prompts corrective action that can be taken. It additionally highlights general water supply information including water quality testing data. This form can aid risk assessment and help to develop or maintain water supply inventories.

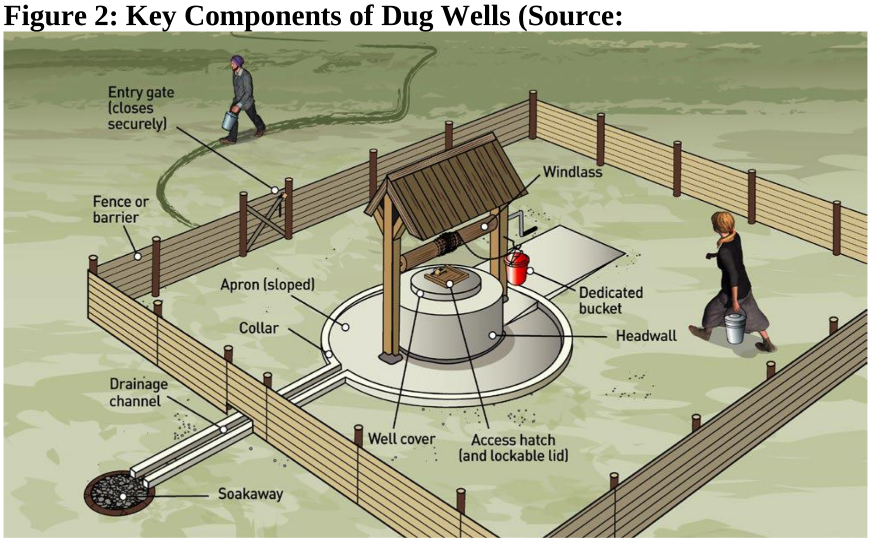
Technical fact sheet – generally provides an overview of the water supply technology/scenario and information to support sanitary inspection. The information obtained can be used to help identify risk factors when compared to the sanitary inspection form.

Management advice sheet – provides general guidance to support the safe management of the water supply through basic operations, maintenance and monitoring and may include simple problem-solving corrective actions that can be considered for each identified risk factor (WHO, 2024).

Cognizant that water supply systems, such as hand-dug wells could be variable in structure adjustment of the package requirements to consider the variations in relation to the wells considered was taken into account.

With reference to the sanitary inspection tool kit, all five of the hand-dug wells S1-S5 had a provision for a bucket and rope to draw water but did not have in place other components such as a collar, apron, drainage channel, soak away, fence or barrier. Refer to Figure 2 to appreciate the key components expected within such wells;

Figure 2: Key Components of Dug Wells (Source:



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All 5 wells had in place inner walls built from the ground as lining and well support structures. It was also identified that for all the wells considered, the depth ranged between 9-12m while the well age ranged between 4 to 8 years. Only one of the wells coded S4 had a properly constructed headwall and metallic well cover while all the other 4 wells did not have headwalls neither did they have proper well covers. Other key characteristics of the wells including assessment of water quality were considered and parameters analyzed as discussed. Table 1 gives a summary description of the five (5) wells considered.

Table 1: Description of Hand-dug Wells.

Hand dung well	GPS coordinates	Picture	Key details
S1	-0.9981809, 31.4149604		-Inside well diameter-1.2m - Built with a masonry wall from the ground -Surrounded by commercial activity, shops and makeshift motorbike repair - Well considered functional since water was collected for use. -Well had bucket and rope installed by the owner
S2	-1.0001238, 31.4156919		-Inside well diameter 1.1m - Built with a masonry wall from the bottom -Makeshift cover -Surrounded by residential establishments, including pit latrines located less than 15m away - Well considered functional since water was collected for use

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S3	-0.9995834, 31.4184650		-Inside well diameter-1.1m - Built with a masonry wall from the bottom -Makeshift cover -Surrounded by residential establishments within 5m -Waste heaps collected nearby - Well considered functional since water was collected for use
S4	-0.9983428, 31.4200354		-Inside diameter-1.2m - Built with a masonry wall from the bottom -Had a metallic cover -Well considered functional since water was collected for use
S5	-0.9983106, 31.4204009		-Inside diameter-1.1m -Built with a masonry wall from the bottom - Had a makeshift cover -Located in the gently sloping area easily affected by water run-off -Well considered functional since water was collected for use

Quantitative Water Quality Assessment

At least two water samples each were collected from the 5 hand-dug wells in accordance with the drinking water sample collection guide (USEPA, 2016; WHO, 2022) and analysis for the microbial safety, potential chemical and physical contamination of the water was carried out. One grab sample was drawn from the surface while the second sample was drawn from approximately one (1) meter below the surface of the well.

Sterilized 200ml high-density polyethene bottles obtained from the NWSC laboratory were used to collect water samples drawn and stored in a cooler box to enable transportation without conditions of samples changing.

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All samples collected were then delivered to the National Water and Sewerage Corporation (NWSC) certified laboratory in Masaka City, Uganda. Key to note is that tested protocols were referred to during analysis to determine the quality of the water samples for all parameters considered refer to Table 2

Qualitative and Secondary Data Collection

A purposive sampling approach was used to select interviewed participants including 133 household owners and ten (10) officials from Mutukula Town Council. Participants engaged were considered to have knowledge and understanding of the use of water from the hand-dug wells while others as well as experience in relevant thematic areas such as water quality assessment, public health and water management at the Town Council (Kumar, 2018).

Data Analysis

The results obtained from water sample analysis were interpreted making reference to the national standards for portable water. Reference was made also to the guidelines for drinking water quality (WHO, Guidelines for Drinking Water Quality, 2022). These helped to portray the magnitude of the contamination of water in the hand-dug wells. Reference to additional qualitative data helped identify relationships and boosted further analysis.

RESULTS AND DISCUSSION

The following section gives a summary of the results obtained and discussions thereof.

Characteristics of Water in the Hand-dug Wells

Twelve (12) water quality parameters were measured while referring to the national standards and international water quality guidelines mentioned although the focus of the discussion was zeroed in on parameters for which the minimum requirement was superseded. Table 3 gives a summary of the water quality results obtained.

Table 3: Results from Physicochemical and Biological Parameter Analysis of Water from Hand-dug Wells

Parameters	Sampled Sites (hand-dug wells)					National standards/H_2O guidelines
	S_1	S_2	S_3	S_4	S_5	
pH	6.9	7.2	7.1	7.0	6.9	6.0-9.2
Turbidity(NTU)	13.3	13.2	12.9	13.3	14.1	5-10
TDS(mg/L)	233	214	228	235	244	500
TSS(mg/L)	6.5	5.9	4.1	2.2	7.7	5.0
Hardness(mg/L)	117	120	123	119	124	200-300
Calcium	32	40	23	28	24	75-100
Magnesium	18	14	15	21	17	30-50
BOD(mg/L)	3.0	3.3	2.1	2.7	2.9	5.0
DO (mg/L)	9.9	9.5	9.3	8.7	8.4	4.0-6.0
EC(μmho/cm)	392	324	330	371	318	300
Chloride(mg/L)	266	271	244	239	276	200-250
Sulphate(mg/L)	52	49	47	61	41	150-250
Total Alkalinity (mg/L)	153	144	164	147	150	120
COD (mg/L)	11.1	12	14	8.9	10	4.0
Ferrous Iron mg/L	1.3	1.3	1.3	1.3	1.3	0.1-0.3
NO_3-N (mg/L)	10.0	12.0	14.0	13.0	12.0	10-45
E. coli (CFU/100m/L)	120	440	500	100	370	100

Key: pH = Hydrogen potential; TDS = Total Dissolved Solids, TSS=Total Suspended Solids, BOD=Biochemical Oxygen Demand, DO = Dissolved Oxygen, EC = Electrical Conductivity, COD = Chemical Oxygen Demand; NO_3-N = Nitrate-Nitrogen, MPN = Most Probable Number

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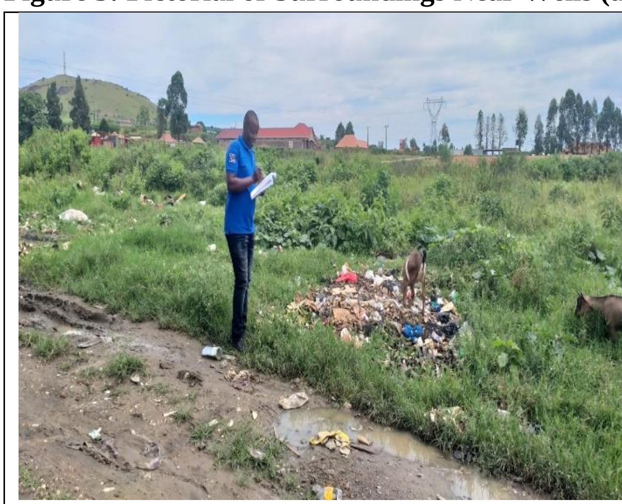
For the microbial tests carried out, the E-coli results for water samples taken from wells S1, S2, S3 and S5 were between 120-500 (CFU/100m/L), which was above 100 (CFU/100m/L). Assessment of the well conditions indicated exposure to contaminants that would result in the presence of Ecoli. Firstly, all of the 4 hand-dug wells had makeshift covers exposing the water in the wells to seepage of rain runoff that could have contained faecal matter and or waste given that waste was temporarily collected in some locations near the wells. In addition, for at least 3 of the hand-dug wells, proximity to pit latrines was estimated at less than 20 meters (refer to Table 1 on the location of wells), posing a risk of possible contamination from faecal matter.

From the survey carried out, respondents who included residents living within the areas where the wells were located, local and public health officials mentioned that open defecation was practised. Moreover, during field walks, instances of indiscriminate disposal of faecal matter were identified. It was also highlighted from the participants engagement that;

> "*At least 20 households practised open defecation due to cultural beliefs. These people believed that pregnant women and girls should not use pit latrines but rather the bush since using such facilities could make them lose the pregnancy*".

The promotion of such notions was identified as an enabling aspect of open defecation. From the results, correlation with other findings from studies can be traced with authors indicating increased coliform counts and nitrate concentration in water samples from sources located close to toilets and septic systems Arwenyo et al. (2017). As such, the researchers considered poor management of solid waste, practicing open defecation and storm water run-off could result in pollutants ending up in wells especially given that at least 4 of the wells did not have proper covers. Figure 3 shows some of the existing conditions during the assessment.

Figure 3: Pictorial of Surroundings Near Wells (author shown in images for scale)



Some of the open waste dumpsites near residential establishments where faecal matter was also disposed of in polyethene bags.

Rainwater run-off path, disposal of waste close to hand-dug well S 3 with poor cover

Worthy of mention is that although a small number of households in the area had established compost pits to manage mainly the organic waste streams generated, other households generally dumped solid waste at a central collection point while others also had waste collected within residential compounds near the wells, posing a risk in case of stormwater run-off carrying the waste to poorly covered wells.

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The absence of a designated dumpsite for the Town Council and the dispersed location of skips at least 500m away were cited as some of the factors enabling indiscriminate disposal of waste by residents in open spaces.

> *Some residents asserted "... the Town Council planners influence indiscriminate disposal of waste since they place skips almost 500 m apart. Residents do not want to carry waste for long distances as such indiscriminate disposal has resulted. ... Also the private sector waste collectors charged exorbitant fees for collection of waste from dispersed locations, resulting in indiscriminate disposal of waste".*

For parameters such as Turbidity and Electrical conductivity (EC), the results obtained for the samples were higher than the acceptable values for drinking water for all 5 wells. The turbidity values ranged from 12.9-14.1NTU while the EC values ranged from 318-392 μS/cm in comparison to the standards for portable water i.e. 10 NTU and 300 μS/cm for turbidity and EC respectively. Meanwhile, the TSS values for wells S1, S2 and S5 were above the standard limits of 5mg/L and ranged from 5.9-7.7 mg/L. Noteworthy is that all 3 wells had, poor covers, implying that they could be easily exposed to runoff consisting of dirt or waste resulting in high TSS and turbidity. Meanwhile, the presence of organic and inorganic material in water possibly carried by run-off contributed to the high EC values.

With the proximity of the wells to waste disposal areas, stormwater and having poor well covers, wash off of organic and inorganic contaminants influencing the quality of water with regards to these parameters.

Moreover, other activities that could have resulted in the presence of chemicals were linked to urban farming practised in some parts of the Town Council. Within the area, some of the residents practiced urban farming with most growing vegetables such as tomatoes, cabbages, and carrots. Some of the farmers used inorganic fertilizers to boost the fertility of the lateritic soils in the area and also used pesticides. As such, the use of these fungicides like Emthane/Uthane M 45/ and inorganic fertilizers which contain mainly nitrogen, phosphorous and small amounts of potassium were linked to the presence of nutrients (NO_3-N, and SO_4). Meanwhile, chlorides in the range of 266-276 mg/L above the 250 mg/L limit for wells S1, S2 and S5 and the total alkalinity ranging between 144-153 mg/L above the 120 mg/L threshold could have resulted from the use of fungicides. These are often quite soluble and may result in contamination of groundwater, especially from leaching and run-off. Such occurrences could be enhanced by the insufficient well covers and are in line with results from similar studies by Li et al. (2019) and Lapworth et al. (2017).

The results also indicated a high concentration of Iron up to 1.3 mg/L above the threshold of 0.3 mg/L for all five hand-dug wells. Generally, the presence of iron in the groundwater is expected and is associated with rainwater infiltrating through the soil and underlying geologic formations dissolving iron and causing it to seep into aquifers that serve as sources of groundwater for wells. However, in this case, since the same result was registered for all five wells, the presence of iron in the water was associated with underlying geologic formations dissolving iron in the water samples from the hand-dug wells. Although the presence of iron may not be considered hazardous to health, it is considered a secondary or aesthetic contaminant that could also result in staining of clothing and may result in a disagreeable metallic taste when water is drunk.

Other Potential Contaminants

It was also identified that other activities were carried out in the surroundings of the wells for instance repairs and or engineering works for motorcycles were carried out next to well S4. The makeshift mechanic/garage establishments where repairs on motorcycles were carried out were seen as potential sources of pollutants such as oil spills and suspended material from packaging for various components. A risk of these waste streams ending up in the well was identified and this was in line with other studies carried out by authors like Dietler et al. (2019) and

Qiao et al. (2020) who assert that the presence of contaminants from such works was associated with poor management of waste streams. Figure 3 shows some of the activities taking place near well S4 that could lead to contamination of the wells.

Figure 3: Other Activities Carried Out Around Wells

Sections of cracked apron with stagnant water prone to seepage

Water with oil traces near the well

Summary of Qualitative Data

During the survey carried out amongst the 133 respondents, key results indicated that;

- All the hand-dug wells were owned by individuals/private owners rather than Mutukula Town Council.
- 98% of the respondents preferred water from the hand-dug wells because it was affordable, costing users between UGX 1000-2000UGX (USD 0.41) per month in comparison to using water from standpipes supplied by NWSC which was at UGX 3,750 UGX (USD1.03) per month .
- All respondents stated that the water from hand-dug wells was considered reliable since one would get it all year round while water from the standpipes was intermittent in certain cases since its provision was dependent on pumping the water to storage tanks. The pumping of water was limited by intermittent power outages occurring within the Town Council.

Having appreciated both qualitative and quality results obtained, corrective actions were proposed for the management of the wells. From the results and discussion, it was clear that the minimum requirements for portable water were not met by all the wells although for well S4 some parameters such as *E. coli* and TSS tests were within the national standard limits for portable water. Key to note is that well S4 had a metallic cover and headwall, limiting the entry of some contaminants that could have ended up in other wells as run-off. Bearing in mind that for all the hand-dug wells, key components expected for such wells were absent and that aspects contributing to the poor quality of water samples were identified, the authors proposed critical corrective actions summarized in Table 4.

While the application of a sanitary inspection package for small water supply systems aims at enabling management of risk identified, the package is silent on how management actions and monitoring of proposed corrective actions can be carried out. Thus, the authors propose a framework as an additional supporting tool to enhance the management and monitoring of such small water systems. Specifically, consultation with Mutukula Town Council technical officials, residents and other relevant stakeholders was carried out to further understand the risks and appreciate how monitoring of management actions could be achieved as discussed.

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Table 4: Summary of Corrective Actions to Improve Water Quality

	Problem identified	Corrective actions to consider
1a	Conditions of the wells; Absence of well collar, apron, drainage and fence or barrier, head wall for wells S1, S2, S3, S5	Support well owners to install the basic components to reduce contamination of water from the wells. For all wells, at least an apron, collar and drainage should be installed. Additionally, for wells S1, S2, S3 and S5, headwalls and proper well covers be installed.
1b	Absence of proper well covers especially for wells S1, S2, S3 and S5	Provide better well covers made from an affordable but durable material (impermeable plastic sheeting, metallic shutter) to minimize the entry of contaminants. Where covers are existing but prone to damage for instance for well S4, repair or install a new cover and/or lid as soon as possible
1c	Absence of adequate buckets and clean ropes for drawing water from wells.	Although buckets and ropes were provided for by the well owners, regular inspection should be carried out to ensure that these are used and regularly cleaned or replaced to avoid scenarios where individuals attempt to use their own buckets.
1d	Condition of the walls for wells, cracks exposed to seepage of contaminants	Periodic maintenance of the wells by the owners with the support of Town Council officials to ensure regular repairs are made of the inner wall and top sections of the headwall, avoiding seepage of contaminants into the wells.
2a	Location of wells; Surrounding near wells having pit latrines, toilets, waste collected, puddles of water/storm-water run-off,	The location of the wells be considered in line with guidelines on aspects including minimum distances from latrines and waste disposal areas among others. In cases where wells are already installed as is the case for the research area, the following measures can be considered; - Waste collected should be disposed of away from the hand-dug wells. - Proper cleaning and maintenance of the pit latrines should be carried out by owners, to avoid wastewater from flowing near the well. - Clear any puddles of water near wells by creating drainage channels to lead away stormwater.
2b	Carrying out other activities within the vicinity of wells	Ensure management of waste streams from activities carried out near the wells, i.e. waste oil from the motorcycle repair area, the following measures can be considered - A concrete platform constructed where motorcycle repairs are carried out while enabling easy removal of oil spills led to a drainage system consisting of an oil sump, which can allow for skimming off of oil waste prior to discharge of the stormwater/wastewater to the environment, -A simple drainage be included to channel run-off appropriately without resulting in seepage of contaminants into the wells.
3	Quality of the water –no treatment practised	Consider treatment of water from the wells to ensure improved quality for potable use (refer to water quality results for all wells, i.e. presence of *E. coli*, COD and other parameters)

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	Problem identified	Corrective actions to consider
		-Treatment of water from wells with chlorine to ensure disinfection of the water and enable reduction of the iron in the water. -After treatment with chlorine, the water can be filtered to enable reduction of turbidity and EC. -The concentration of free chlorine in the water increased to greater than 0.5 mg/l to cater for recontamination that could occur during storage of the water. -Engagement of public health officials to guide use of the chlorine is crucial to avoid misuse

While the application of a sanitary inspection package for small water supply systems aims at enabling management of risk identified, the package is silent on how management actions and monitoring of proposed corrective actions can be carried out. Thus, the authors propose a framework as an additional supporting tool to enhance the management and monitoring of such small water systems. Specifically, consultation with Mutukula Town Council technical officials, residents and other relevant stakeholders was carried out to further understand the risks and appreciate how monitoring of management actions could be achieved as discussed.

Proposed Components for Framework

The framework proposed takes into consideration how the management of the quality of water from the hand-dug well can be achieved taking into consideration both short-term and long-range aspects related to eliminating contamination of the water. Following the corrective actions proposed, the framework included various remedies that are expected to improve water quality management. These remedies were proposed through a consultative process with various stakeholders supplemented by the best practices in water resources management as shown in Table.

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Table 5: Critical Components for the Framework

Code	Requirements derived from Qualitative data and Sanitary Inspection data	Code	Decision made	Linkage between requirement and decision	Source of Design Decision
DR1	The involvement of all stakeholders will engender collective supervision and ease the planning and management of the hand-dug wells.	DM1	Effective stakeholder involvement is highly needed since this will provide a seamless way of auditing the management of hand-dug wells through collective supervision.	This will minimize the gap of uncoordinated and conflicting information caused by a lack of cooperation between the stakeholders.	Field data
DR2	The involvement of water users will minimize the "***I don't care attitude***" among the users of hand-dug wells.	DM2	Once water users are involved at every stage of the hand-dug well management process, cases of contaminating the water in hand-dug wells through careless actions such as poor waste and wastewater management are minimized. Regular (monthly) engagement meetings are suggested as one of the important strategies.	Mandatory involvement of water users by hand-dug well owners will minimize the misuse of the hand-dug wells. This will be duly achieved through regular sensitization.	Field data
DR3	Involvement of subject matter experts and opinion framers	DM3	These experts, i.e. public health officers, environment officers and engineers are necessary in the management of hand-dug wells as well as in designing the strategies for improving the quality of water in hand-dug wells based on their influence and experiential knowledge.	This will help to among others eliminate the possibility of misinformation and apathy among the water users.	Field data

Key: DR = Design Requirement; DM = Decision Made

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As highlighted in Table 5, the key components of the framework were informed by the design requirements and design decisions that were proposed after careful consideration of the findings from quality assessment of water samples, engagement of various stakeholders and reference to best practices in water resources management to mention but a few. Although reference was made to Mutukula Town Council, the authors propose that adjustments be considered to cater for the uniqueness of other urban entities with similar contexts i.e. depending on the nature of the water supply systems and varying monitoring requirements stipulated by mandated authorities. For instance, not all ecological environments have cultural leaders while also, while the localities have different layers of leadership implying the composition of the implementation team may vary. Thus, the authors proposed the framework shown in Figure 9.

Key

The primary or core responsibility

Hand-dug management

Collaborative relations between parties

Feedback on the suitability of the framework

Outcome

Training

Supervisory role

Engagement meetings

Successful management of the quality of water

Failed management of the quality of water

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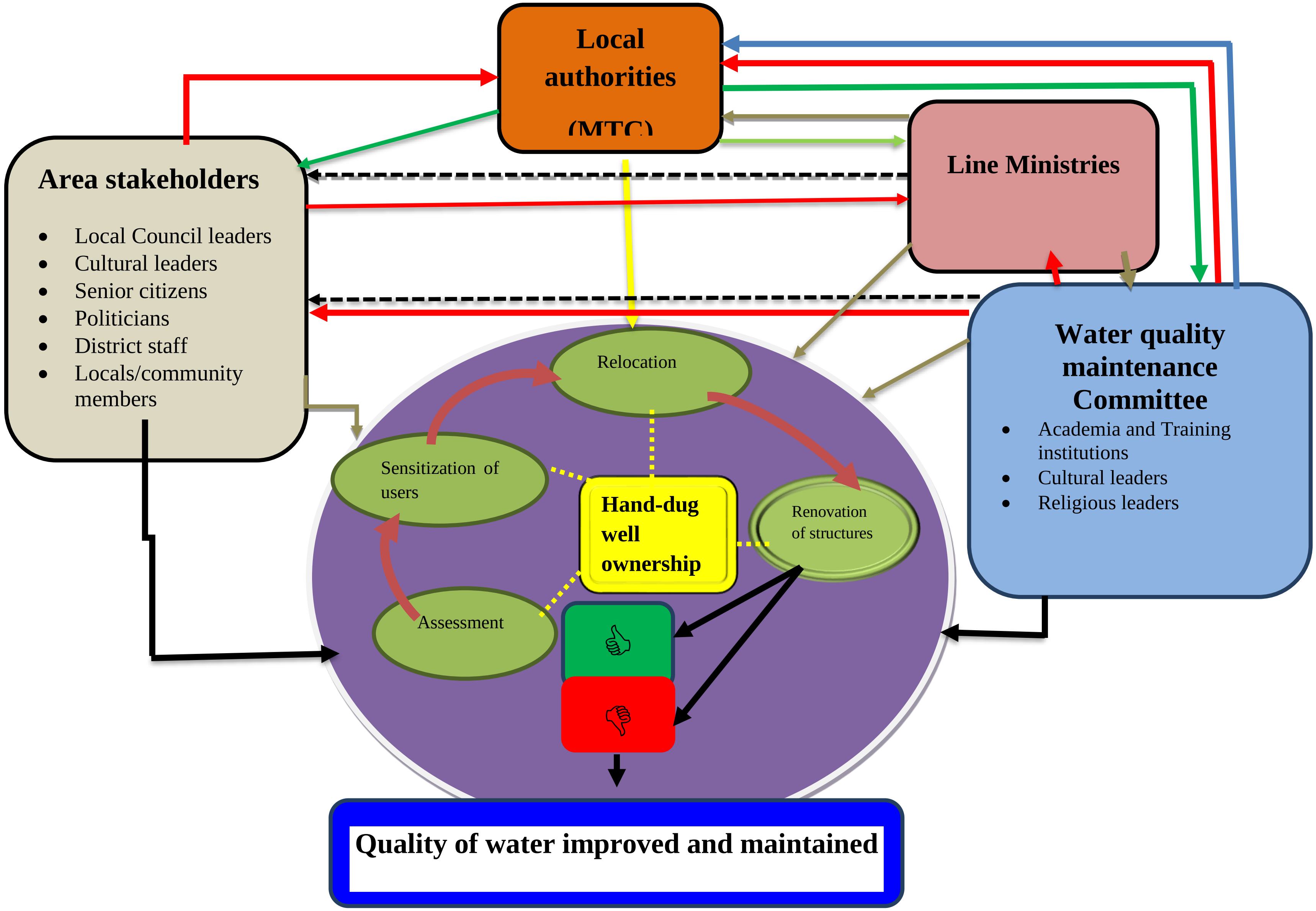
Figure 9: Framework for Maintenance of the Quality of Water in Hand-dug Wells



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Roles of Key Players in the Framework

A brief description of the roles of the various stakeholders deemed crucial to the framework follows;

Mutukula Town Council (MTC)

MTC is the premier institution charged with the responsibility of ensuring that water sources among other essential resources in the Town Council are well maintained. MTC takes the lead in any efforts to maintain the quality of water in hand-dug wells and is expected to create an enabling environment. In this context, MTC is expected to develop and support the implementation of guidelines for the establishment of such water supply systems (hand-dug wells). In addition, MTC should be involved in all the phases of a well establishment, i.e. provide oversight during construction, continually assess the operation and maintenance of the systems and monitor the quality of water over the lifetime of the systems. MTC should also continually engage beneficiaries to support attitude change, sensitize and raise awareness.

Line Ministries

Water resources management in Uganda involves three ministries: the Ministry of Water and Environment (MWE), the Ministry of Health (MoH) and the Ministry of Local Government (MoLG). MWE is charged with monitoring water resources while MoLG is charged with making follow-ups, supervising utilities and MoH supports in the implementation of international health standards among other roles. The designed framework recommends functional collaborations between local authorities and line ministries to ensure that water systems are maintained appropriately, and relevant quality assurance is provided in line with national standards. In addition to providing the enabling environment in the form of relevant policies and standards to be adhered to regarding the provision of portable water, line ministries also avail the necessary technical capacity to support the management and monitoring of the water supply systems.

Locals/Area Stakeholders

These stakeholders who may be beneficiaries and or providers of resources such as land where the wells are dug and neighbours to the facilities are very crucial to the daily operation, management and monitoring of the wells. This is because their culture and attitude could influence their interest and habits concerning the proper management of the wells.

By including the various community members/stakeholders an all-inclusive stance is promoted allowing for the formulation of holistic strategies that are expected to enhance better maintenance of hand-dug wells.

NWSC plays a vital role by providing technical support including analysis of water samples carried out at their laboratories. They are also the custodian of the national portable water standards thus also guiding in quality assurance aspects.

Cultural and religious leaders are also key stakeholders given that these normally act as champions in the community. In the case of Mutukula Town Council, cultural leaders from the Buganda Kingdom are considered critical in society and shape decisions made by community members on a broad range of issues. The religious ladies also act as necessary champions in the community and could support dissemination to community members.

Water Quality Committee

A water quality committee management committee is also deemed necessary and should consist of a mix of technical representatives from entities such as training institutions, NWSC as well as representatives from cultural groups and the religious leaders. Such a blended committee would offer both technical insight into the quality of water and expected operation/maintenance requirements while also enhancing the dissemination of

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information from the community representatives to the community. Representatives from the community will act as needed champions who are equally influential in communities, boosting sensitization.

Academia and Training institutions are indispensable in the proposed framework since they support capacity building first amongst professionals ranging from engineers, scientists and other experts relevant to the discussion of water supply system development and management. Moreover, academia further offers opportunities for research and innovation that can enable improved management of existing systems and support improved design which supports the establishment of better systems.

Main Features of the Framework and their Potential to Close the Gaps

Training of Stakeholders

Training of the area stakeholders will be crucial in improving water quality in hand-dug wells since all stakeholders will need to be informed of quality requirements, have an understanding of the existing policies and standards and be able to appreciate the benefits associated. The line ministries and leaders from local authorities such as MTC. Through training and capacity-building engagements, issues associated with ignorance, indifferent attitudes and superstitious behaviours can be resolved.

Collective Supervision

Collective supervision of the hand-dug wells enhanced by the involvement of different stakeholders will be crucial. Moreover, clear structures are necessary given that multi-stakeholder committees could encounter challenges in focusing priorities among other aspects. However, the structures formed should not deter flexibility that the collective approach contributes to such committees. Through continuous engagement of the stakeholders, impromptu supervision exercises could be organized since these could expose non-compliance if practised by well owners, locals and other stakeholders. It is expected that such an approach would discourage working in silos while boosting appropriate utilization of the limited resources since different stakeholders among the supervisory team contribute unique expertise that would otherwise be expensive to obtain if a silo approach was considered.

Regular Engagement Meetings

Engagement meetings between the various stakeholders/parties are proposed since these will enhance transparency and boost continuous improvement. Moreover, continuous meetings could also demystify the domineering and patronizing attitude that could result from working with various experts and representatives.

Evaluation of the Framework

Having designed a framework that can be used to guide the implementation and monitoring of the corrective actions, it was crucial to check if key stakeholders such as MTC and other opinion leaders deemed it useful and representative.

Following the DSR methodology, which also highlights the need to evaluate artefact/tool, the authors engaged MTC. Key findings from the second consultative meeting held 6 months after this study was carried out highlighted that;

- All 10 technical officials and opinion leaders understood the framework.
- They also asserted that the proposed components of the framework highlighted the need for training, collective supervision and periodic meetings which they deemed crucial in ensuring continuous monitoring of the wells and documentation of findings.
- That the proposed entities for the framework were relevant for the management actions that would be necessary for the hand-dug wells.

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- They also cited the need to pool funds from various entities so that the various tasks could be achieved through a collective effort.

CONCLUSION

For the most part, the use of water from hand-dug wells especially in urban areas within Uganda has deterred dues to such facilities being prone to contamination. Despite this, in certain areas, the use of water from such sources is inevitable given the challenges associated with accessing water from alternative sources including underground and surface water sources. Mutukula Town Council in Uganda is one such area where water from hand-dug wells is used by a significant number of residents within the town council. Given that most of these wells were established by individuals, no management committee(s) existed to support their management and the quality of water was not known, leading to quick assessment using the sanitary inspection package proposed by the World Health Organization. Key results from the study indicated that key components for such wells were not considered during construction such as well covers, drainage provisions, boundaries, etc. Moreover, the absence of guidelines and or restrictions on the location of such wells contributed to the contamination of water from all the five wells assessed, i.e. *E. coli* counts for samples from wells ranging from 120-500 CFU/100m/L, which was above 100 CFU/1m/L. In addition, turbidity values range between 12.9-14.1 NTU, which was above 10 NTU while, the EC values ranged from 318-392 µmho/cm in comparison to 300 µmho/cm. As such, the authors propose a supporting framework to enable the implementation of corrective actions for wells while also enhancing monitoring of the wells. Specifically, the framework proposes a cocktail of components deemed necessary such as training and continually building capacity, ensuring collective supervision and encouraging regular engagement amongst entities such as academia, line ministries and NGOs, local community members, well owners and the Town Council among others.

Conflict of Interest

The authors have no conflicts of interest to declare. The article has never been submitted to another journal for publication.

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Data

Any additional data from the survey is attached as addenda for this paper.

Author Contributions

Yosam. Tumwebaze. Data collection, fieldwork and writing of the initial draft

Dr. Miria Frances Agunyo: Review of methodology and concept, analysis of results and revision of the paper

Assoc. Prof. Eleanor Wozei: Review and further interpretation of results

Assoc. Prof Sarah Kizza Nkambwe: Review, organization of discussion flow and input in the analysis of the results

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