BACTERIOLOGICAL QUALITY OF HAND-DUGWELL WATER AND ITS' EFFECTS ON THE PREVALANCE OF DIARRHOEA AMONG USERS IN BWEYALE TOWN COUNCIL-KIRYANDONGO DISTRICT

A POSTGRADUATE RESEARCH DESERTATION PRESENTED TO THE INSTITUTE OF HEALTH POLICY AND MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER OF SCIENCE IN PUBLIC HEALTH

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ICA DANIEL

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DECLARATION

I **Ica Daniel** do hereby declare that all the work presented in this dissertation is my own original work. It has never been presented either in part or in full for publication in any other institution for similar purpose. I hence forth present it for the award of the degree of Master of Science in Public Health of International Health Sciences University, Kampala-Uganda.

Author

…… ……

Mr. Ica Daniel Date

Supervisor;

…… ……

Mr. Afayo Robert Date

BSN, Msc. Clinical Epidemiology & Biostatistics.

DEDICATION

This project is dedicated to my wife (Ms Atim Agnes Martha),Daughter (Ekua Desire-peace Gloria) and Parents(Draga Logi & Natalina Lalia Fuli) who have never failed to give me financial and moral support and fulfilling my needs in the face of so many competing priorities during the time of my study.

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ACRONYMS

NTU	:	Nephelometric Turbidity Unit
TDS	:	Total dissolved solids
Mg/l	:	Milligram per liter.
HDWs	:	Hand-dug wells.
NGO	:	Nongovernmental organization
W.H.O	:	World Health Organization.
DWD	:	Directorate of Water Development.
PH	:	Potential of Hydrogen ion
IDP	:	Internally Displaced Persons.
Tcfc	:	Total coli form count
HHs	:	Households.
KIs	:	Key informant s.
UNOCHA	:	United Nations office for coordination of Humanitarian Assistance.

OPERATIONAL DEFINITIONS

Safe water: Is water that is free from disease causing organisms, toxic chemicals, color, smell, and unpleasant taste.

Diarrhoea: Defined as the passage loose stool three or more times per day (World Health Organization).Types considered are;

1. Acute watery diarrhoea – lasts several hours or days, and includes cholera;
2. Acute bloody diarrhoea – also called dysentery; and
3. Persistent diarrhoea – lasts 14 days or longer.

Nephelometric Turbidity Unit: Is a measure of how much light is scattered by suspended particles in the water.

Total Coli forms count: Is the sum of Escherichia Coli form (E. coli) and faecal Coli forms flora measured as Coli forms per 100 ml.

Total dissolved solids: Is the total weight of all solids that are dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L).

Hand-dug wells: Constructed to the max depth of 15 meters at 1-2 meters diameter using Hand tools in high water table area and either installed with Hand pump or not. Shallow wells taps water from the first impermeable stratum.

Protected springs: Construction with water collection box with delivery spout.

Boreholes: Drilled more than 30 meters deep and abstraction is done by Hand pumps.

Tap stands: Are secondary water collection points delivered through pipe water.

Confluent growth: It's a notation when the bacterial colonies are too many to count in the culture dish.

Contamination: The introduction into water toxic materials, bacteria or deleterious agents that makes the water unfit for Human consumption.

Sanitary completion: refers to the protection works of the underground water abstraction point and the immediate surrounding areas.

ABSTRACT

Active surveillance of drinking water is a vigilant Public Health assessment to review safety and acceptability of human drinking water. In August and September 2011, a prevalence survey for diarrhea in 771 households was conducted and 106 water samples from Hand-dug wells in Bweyale Town Council were analyzed in the National Water and Sewerage Cooperation Central laboratory. The objective was to establish the bacteriological quality of water from Hand-dug wells and its effects on the prevalence of diarrhoea among user/ residents in Bweyale Town Council.

The Study design was cross-sectional and sample sizes of 771 households and 106 water samples were derived using Keish and Leisli (1965) and Yamane's (1967) formulae at 95% confidence interval respectively. Sample selection was two-stage cluster and simple random sampling of households and Hand-dug wells respectively. Membrane filtration method was used for bacteriological water quality analysis. Cross tabulation, frequencies and logistic regression was performed to make scientific meaning out of the data collected.

Of the Hand-dug well water samples tested, 15.1% were found contaminated with E. coli and a prevalence of diarrhoea of 24.5%. A chi-square test for the association between *E. coli* and the prevalence of diarrhoea among those who drink water from Hand-dug wells turned out to be insignificant ($\chi^2_{cal} = 1.0426$ compared to χ^2_{observ} at 0.05 level of significance = 3.841).

The distances of Hand-dug wells from contamination points such as latrines, household/ communal damping sites as well as construction technology including well lining, drainage well cover and quality assurance including disinfection frequencies, abstraction mechanisms and turbidity turned out to be significant in influencing the bacteriological quality of water from Hand-dug wells with except of the distance from communal damping sites (>30meters) inferred as less significant.

The study Recommended for an increased health education, awareness and sensitization on better sanitary completion of Hand-dug wells construction and extra-ordinary efforts on superior technical supervision towards sitting, well lining as well as super structure completion of Hand-dug wells in Bweyale in accordance to DWD's (2007) & sphere minimum standards (2005).

Provision of alternative water sources such as deep wells and tap water, better lining technology such as PVC, concrete. Proper disposal of waste and latrines away from hand-dug wells

Vigilant public health assessments & surveillance, government support towards provision of enabling environment (relevant policies, laws, adequate funding) and encouraging availability of appropriate facilities and safe water goods such as Bio-sand filters, water purification materials such as aqua-tab.

CHAPTER ONE - INTRODUCTION

1.1 Introduction

This study was about assessing the bacteriological quality of hand-dug wells in Bweyale Town Council and its effects on the prevalence of diarrhoea among the users. The study was conceptualized based on the observation of sprawling hand-dug wells in the Town council with limited adherences to minimum standards to ensure clean and safe water. The dimensions to assess included *E.coli* counts in water from hand –dug wells, the prevalence of diarrhoea among the users of these wells in Bweyale Town Council as well as exploring the parameters of distance from contamination points, construction technology and quality assurance practices.

The dissertation is organized into six chapters including introduction, literature reviews, methodology, data analysis, discussions, conclusion and recommendations. The first chapter covers background of the study, problem statement, objectives, research questions and conceptual framework. The chapter for literature reviews was categorized into objectives and research questions. Chapter three (Methodology) covers study design, sample size calculation and sampling techniques, area of study analysis plan and ethical issues. Chapter four which covered data analysis, interpretation and presentation was again organized by specific objective. The fifth and sixth chapters covered discussions, conclusions and recommendations respectively. These were organized to response to the research questions with optimum references to previous studies by other scholars. Practical recommendations were made as well as global ones like providing supportive environment.

1.2 Background

Water borne diseases outbreak given they are indicative of how safe the water cycle is managed by individuals or communities. The active surveillance of drinking water therefore serves as a continuous and vigilant Public health assessment which warrants knowledge of safety and acceptability (WHO, 1976). The principal hazards that may accrue in drinking water facilities are doorway of microbial contamination, proliferation and dispersal of bacteria growing on water contact surfaces (Lloyd & Bartram, 1991).

Quality of water supply and poor sanitation are the major causes of preventable morbidity and mortality. Unsafe water is a global public health problem predisposing persons to risks of contracting diarrheal diseases as well as chemical intoxications (Hughes and Koplan, 2005). About 88% of diarrhea is attributed to unsafe and inadequate sanitation and hygiene practices (WHO, 2002; Pruss-ustun, 2004).

Considerable efforts have been consolidated to comprehend underground water contamination and how urbanization can exacerbate the situation. In Nigeria for example, Omotoyinbo (2007) conducted a research to establish the contamination level of underground water and the proximity to urban waste damping sites. His findings were suggestive of water source siting (location) not predetermined only by hydro geological facts, but set of standards that put distance from toilets, dumpsites contamination points and physical conditions of the wells into consideration.

In Uganda, underground water remains the most important source of drinking water in rural - urban centers (DWD, 1994). The Over-all access to clean and safe water was estimated at 64% (WHO, 2006) against national set coverage targets (2005 to 2015) of 77% and 100% in rural and urban population respectively. However the challenges of high population growth of 3.2% (WHO, 2006), high rural to urban migration, chronic poverty, displacement due to civil strife and other factors including urbanization undermined the drive to achieve these goals.

Bweyale Town Council is not reclusive of the urbanization syndrome given the urbanization and population growth. This subsequently led to safe water stress resulting to the residents adapting "self-supply" strategy to cope with the demand for clean and safe water by constructing Hand-dug wells (shallow wells). Over 118 Hand-dug wells were counted and confirmed operational at the time of this study (Local council records, 2011). Exploratory walk prior to conceptualizing this study witnessed most of the hand-dug wells seen were constructed with little or no consideration to guidelines provided by Uganda's Directorate of Water Development standards (DWD,2007) for underground water exploitation. This guideline provides for list of standards for siting construction and quality management to alleviate potential Public Health risks due to microbial and non microbial contaminations. This study was therefore conceptualized to re-awaken the local authorities and the users of hand-dug well water by demonstrating its nexus to prevalence of diarrhea among the users.

This research therefore serves the purpose of a vigilant Public health risk assessment which may provide an early warning for water related health risk posed by the Hand-dug wells among the user communities in the Town Council. The findings were envisaged to guide Public health

interventions to mitigate, prevent and protect good health of the communities. Policies and practices for peri-urban and rural water development activities are also expected to get nourished with facts from this study and eventually improve future underground water development whilst maintaining acceptability standards. The knowledge of the bacteriological quality of the water from the hand-dug wells and its relationship with the prevalence of diarrhoea among residents in Bweyale Town Council would broaden research opportunities in Public health safety associated to the rapidly growing water self supply strategy in the country.

1.3 Statement of the Problem

Water quality is generally defined by the collection of upper and lower limits on selected possible contaminants in water (Maier, 1999).The acceptable level of faecal coli forms (Bacteria colonies) in drinking water according to World Health Organization guideline (1993) and Uganda's Ministry of Water and Environment are Zero (0) and < 50(Less than 50) count per 100 ml of drinking water respectively. Any compromising practices may result in high morbidity and mortality experience related to water borne diseases including diarrhoea.

In Bweyale Town Council, hand-dug wells accounts for at least 76 % of all drinking water sources (Local Council I record, 2010). The qualities of water from these Hand-dug wells were not ascertained for human consumption besides adherence to construction, siting and safe water chain management practices by the users and constructors.

Data on prevalence of diarrhea in Bweyale Town Council was scanty. However, an average of 45% and 70% of adult and child patients who sought for health care services in four busy private

clinics within the Town Council were treated for symptoms of diarrhea during the January – March, 2011 period. These figures were far above the WHO Reference Values for Rapid Health Assessment threshold endemic prevalence of 25 % and 9.6 times the national prevalence & over 14.4 times the Central region prevalence (Uganda's National Health & Demographic survey, 2005). And besides it has direct consequences on children class attendance and household economic activities like time lost on farming, trade among others.

This dissertation was therefore a vigilant public health assessment aimed at determining the bacteriological quality of Hand-dug wells and its effects on the prevalence of diarrhea among the residents of Bweyale Town Council-Kiryandongo District.

1.4 General objective

To establish the bacteriological quality of water from hand-dug wells and its effects on the prevalence of diarrhoea among users/ residents of Bweyale Town Council.

1.5 Specific Objectives of the research

a) To measure *E. coli* form count in water from Hand-dug wells in Bweyale Town Council from August to September, 2011.
b) To estimate the prevalence of diarrhoea among the residents of Bweyale Town Council drinking water from hand-dug wells.
c) To establish the relationship of E. coli count and the prevalence of diarrhoea among residents drinking water from the Hand-dug wells Bweyale Town Council.

d) To determine the factors that influences the bacteriological quality of hand-dug well water in Bweyale Town Council-Kiryandongo District.

1.6 Research questions

a) What were the *E. coli* counts in water from Hand-dug wells in Bweyale Town Council?
b) What was the prevalence of diarrhoea among the residents of Bweyale Town Council drinking water from the Hand-dug wells?
c) What was the relationship between faecal coli form contamination of water from the Hand-dug wells and the prevalence of diarrhoea?
d) What were the factors that influence the bacteriological quality of Hand-dug well water?

1.7 Significance of the study

This study was premised on the concept that access to clean and safe water is a basic need and fundamental human right. Safe drinking water can be ensured by good management of safe water chain beginning with the source to the time of consumption (Bartram et al, 2009).

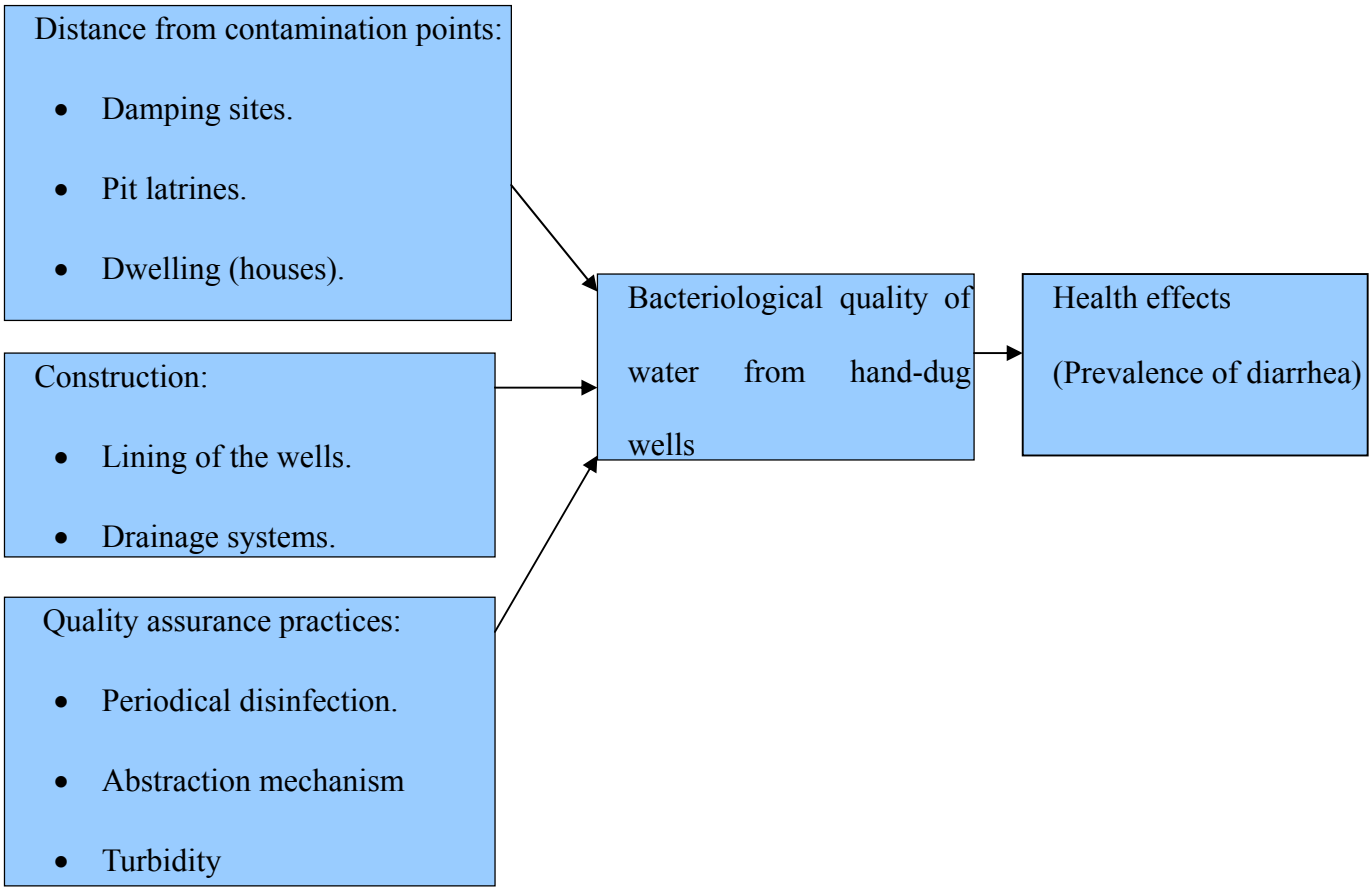
Despite the existence of risks of bacteriological contamination of water from hand-dug wells, there were no records of quality assessment conducted and thus warrant a public health study for the purpose of generating information for risk prevention, mitigation and management. It's envisaged to as well appraise national public health policy related to "self-supply" for water using hand-dug wells. A shared outcome of this study was envisaged to inform relevant local

government authorities and institutions to enforce existing guidelines to maintain standards for the construction of hand-dug wells in peri-urban setting.

This study will act as "Public health whistle blower" to remind service providers and consumers of a progressive Public health risk which ought to be reversed by simply adhering to acceptable global and national standards of construction, siting and maintenance of physical conditions of these facilities alleviate the vicious effects of water borne diseases like diarrhea. Answered questions by this research may also provide other research opportunities in "self supply" for underground water utilization in urban environment.

CONCEPTUAL FRAME WORK

Bacteriological quality of water and its effects on prevalence of diarrhoea in Bweyale Town Council-Kiryandongo district



The conceptual framework above illustrates the relationship between the bacteriological quality of water and the health effects (Prevalence of diarrhea) on the residents of Bweyale Town Council.

The bacteriological quality of water from the hand-dug wells depends on the distances from contamination points, construction of the wells and the quality assurance practices. And this consequently determines the prevalence of diarrhoea which is a health effect.

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

Many scholars have studied water quality and compliances to standards of facility siting and construction for underground water sources and its relationship with urban sprawling. The various scientific ventures aimed at broadening knowledge and share scholastic information to improve the quality of human life through improved water quality and ascertaining that it has met the required minimum acceptability standards had evolved commendable strides. Literature of bacteriological quality of Hand-dug wells water, factors determining the contamination and its effects on the prevalence of diarrhea were discussed below.

2.2 Bacteriological quality of domestic water

Multiple studies have been done on contamination of subsurface and ground water as well as its effect on the health of the population. Sinha *et al*. (1994) provided empirical parameters such as pH, chloride concentration, turbidity, residual chlorine, conductivity as a single water quality index to represent an overall water quality. Twort et al, (1985) exclaimed that Coli form count represents the likelihood of pollution with human and animal Coli form origin while Maier (1999) broadly classified water quality indicators as physical, chemical and biological parameters which further defines the level of acceptability (Swamee and *et al,* 2000).

According to Uganda Water and Sanitation Sector - Performance Report (2006), Masindi District where Bweyale Town Council was formally located complied with bacteriological quality

requirement of <50 E. coli count per 100mls. However, the quality assessment conducted did not relate the outcome to prevalence of diarrhea.

In Uganda, Taylor and Howard (2000) affirmed that groundwater is the most important source of portable water in the rural areas contributing to at least 80% of water supply. A study conducted by Kilink, Jenna (2007) in rural areas of Kiruhura and Lyantonde district found that 90% of 46 water sample had varied levels of contamination with E. coli, However the study never provided precise source of the contamination and the resultant effects on the health of the community.

Most studies of rural water quality have found that protected sources are generally less polluted than unprotected sources. Tomkins et al. (1978) and Wright (1982) both found that protected wells were less contaminated than unprotected wells during the dry season. Isely (1978) and Lehmusluoto (1987) found protected springs to be less contaminated than unprotected springs though in the latter study the difference was not statistically significant.

USEPA (1990) subdivided the substances that contaminate groundwater into two basic categories including naturally occurring and those which are anthropogenic. These naturally occurring substances include iron, calcium, magnesium, while anthropogenic substances are hydrocarbons, pesticides, landfill leachates, salts; bacteria and viruses. These anthropogenic substances are contributing factors to high turbidity values in the wells and other aquatic microscopic organisms (Clesceri, 1989).These contaminants affects the odour, taste and thus affecting the palatability of drinking water. When the palatability of water is rejected, then people tend to seek for alternative water sources which may be unsafe for consumption.

Lack of access to safe water in developing countries often resulted in increased death rates due to preventable water borne diseases. About two million infants die annually (UNICEF, 2005; Cosgrove and Rijsberman, 2000; Gomez and Nakat, 2002) due to diarrhoeal diseases that is partially attributed to safe water stress due to the present rapid global urbanization and subsequent geometric population growth. However, the development of ground water resources for portable use has increased substantially over the last decade especially in developing countries like Uganda.

A good knowledge of the bacteriological, qualities of drinking water is imperative so as to guide on its suitability for human consumption. The need for microbial assessment of water for consumption should be emphasized to reduce possible contamination (Fagade *et al,* 2995) and also to safeguard the health of users (Okonko *et al*, 2008).

2.3 Relationship between water quality and distance from contamination points

There is close relationship that exists between ground water quality and its proximity to the land use such as solid waste land fill, on-site excreta disposal systems and many others. Somjai and Suporn (1993) observed that when the solid waste landfill (open dumping or sanitary landfill) decomposes, the organic and inorganic by-products leach out by the infiltration of rainfall to the surrounding soil contaminating groundwater resources. Zanoni and Fungaroli, (1973) and Kelly, (1976) showed that leachate also enhances the solvency of inorganic substances such as chloride, sulfate, bicarbonate, sodium and potassium of groundwater.

The Proximity of the source of pollutants to ground water quality was demonstrated by Mahedeven and Krishamswamy (1984) assessment in India which showed the level of

underground water contamination significantly increasing with distances from the source pollutants. They found out that 76.80% of the sampled wells got polluted when located close to open drains, 64.40% were polluted when located near a pool of stagnant waste water, while 32.3% got polluted when garbage dump was nearby.

In Nigeria, increased urbanization was found to increase portable water pollution in the urban areas. A study in Ado-Ekiti by O.S. Omotoyinbo (2007) on the level of contamination of Hand-dug well found the total coliform bacteria count in water was exposed to serious and complex contamination and the existence of source pollutant of sewage and faecal materials from man and animals. The research recommended that standard adherences like distance from toilets, damping site and dwelling places were vital. He also recommended that regular monitoring of wells for contaminations were considerably imperative.

2.4 Water quality and quality assurance practice /construction

Edith 2005 observed that the water quality from wells which have aprons, drainages, covers; communal buckets and windlasses on average had no better quality than water from scoop holes whilst a pilot study in Zambia on water self- supply by Nyundu, Sutton (2001) found small upgrading on well structures like head wall and aprons can reduce Coli form counts from 100 -200 Coli form/100ml to less than 10 Coli form/100ml.She also noted that water from Lined wells had relatively better quality compared to unlined wells.

Despite the requirement for regularly upgrading water sources to maintain the level of water quality safe human consumption. Behavioral activities like washing around the water sources,

reluctance to fence the water sources and poor maintenance of drainage continue to undermine water quality due to leachates caused by the afore-mention activities.

Organizational and individual efforts to maintain clean and safe water supply may include chlorination like shock chlorination to improve water quality of traditional sources during emergencies or during resettlement of IDP's and refugees. Post war between Eritrea and Ethiopia also witnessed International Federation of Red Cross Appeal (2001) chlorinated traditional wells in villages to provide safe water to returnees (OCHA, 2000) while the same was done by United Nations International Children Education Fund (UNICEF) in the Somali region (Relief web 2004).

Oxfam Liberia used pot chlorinators in private wells to assure safer water supply to the residents and IDP's of Monrovia after the war when most of the water infrastructure was destroyed due to war (Garandeau, 2004).

One important way of protecting Hand-dug wells water from being contaminated includes appropriate lining of the wells. British standard 5328 in-situ lining and caissoning with concrete mix of 1:2:6 for Cement: Sand: Aggregates (The government of Sudan -Ministry of Irrigation and Water resource, 2005-2006). Regular inspection of the well head for any sign of cracks and any potential pollutant should be part of the operational and maintenance procedure.

The direct contamination of groundwater sources resulting from poor sanitary completion has been linked to both endemic disease and outbreaks. For instance, Olson *et al.* (2002) describe an outbreak of *E. coli* O157:H7 in Alpine, Wyoming, including cases of haemolytic uraemic

syndrome, which was related to consumption of water from a poorly protected spring which sanitary surveys had identified as being at risk from contamination by surface water. Poor sanitary completion measures also appear to have played a role in the Walkerton outbreak in Canada (O'Connor, 2002).

In developing countries, the use of poorly protected groundwater sources has been linked to acute diarrhoeal disease (Trivedi *et al.,* 1971; Nasinyama *et al.*, 2000). Good sanitary completion measures have been shown to be necessary to maintain the quality of water and protect public health (US EPA, 1993; Pedley and Howard, 1997; Robertson and Edberg, 1997). Robertson and Edberg, 1997 acknowledged the effectiveness of sanitary completion in reducing risks of pathogens. However, the risk varies between pathogen types, aquifer types and water source use and thus there is a need for multiple interventions to act as barriers to most pathogen types.

Ground water sources contamination is also dependent on the depth of the wells. Shallow water sources tend to be more prone to contamination than the deep ground water source. This argument was supported by a study conducted by Asimi (1998) which concluded that effluent from abattoir increases chemical oxygen demand, total water hardness, total solids, turbidity and other water quality variables within its vicinity. However, these conditions decrease in importance with depth of water table and depth of wells. An association between water contamination and proximity to towns has previously been reported (Mohammed & Morrison, 1975; Bradley & Emurwon, 1968) but only for rivers and streams.

2.5 Prevalence of diarrhea among users of different water sources.

Though the evidence for reducing diarrhoea in endemic setting by improving the microbiological quality of drinking water has been unclear (Cochrane Collaboration, 2009), many people today die from diseases that can be prevented through access to clean water and basic sanitation.

WHO/UNICEF (2000) puts the figure of those with no access to clean and safe portable water and basic sanitation in 21st century at some 1.1 billion and 2.4 billion people respectively. And if there are no actions taken to address unmet basic needs for water, as many as 135 million will die from water and sanitation related diseases by 2020 (Gleick, 2002).

Water-related diseases are a human tragedy, killing millions of people each year, preventing millions of people more from leading healthy lives and undermining development efforts (Nash, 1993). About 2.3 billion in the world suffer from diseases that are linked to water (Kristof, 1977; United Nations, 1997).

Diarrhoeal diseases are a leading cause of mortality and morbidity children in developing countries (WHO, 2005). World Health Organization report (2002) further projected 13% of all deaths of under five children in developing countries caused by diarrhea mostly due to contaminated food and water. An average young child in the developing world in Asia, sub-Saharan Africa or Latin America, experience four to five episodes of diarrhea per year (Murray and Lopez,1996).

90 percent of all cases of diarrhea can be attributed to three major causes: inadequate sanitation, inadequate hygiene and unclean water (WHO, 1997). Global Water Supply and Sanitation

Assessment (WHO/UNICEF, 2000) estimated there are four billion cases of diarrhoea each year with 2.2 million deaths of which are in children under the age of five. Estimated 35% of the deaths from diarrhoea in children less than five years old are believed to be attributable to acute non-dysenteric diarrhoea, with 45% from persistent diarrhoea and 20% from dysentery (Black 1993). A wide variety of bacterial, viral, and protozoan pathogens excreted in the faeces of humans and animals are known to cause diarrhoea transmitted chiefly through the faecal-oral route (Byers,2001). Among the most important infectious agents are *Escherichia coli, Salmonella sp, Shigella sp, Campylobacter jejuni, Vibrio cholerae, rotavirus, norovirus, Giardia lamblia, Cryptosporidium sp, and Entamoeba histolytica* (Leclerc, 2002).

Health authorities generally accept that microbiologically safe water plays an important role in preventing outbreaks of waterborne diseases (Hunter 1997). Therefore accordingly, WHO's most widely accepted guidelines provides for water quality with no detectable level of harmful pathogens at the point of distribution (WHO, 2004).

In a review of 29 studies of diarrhoea prevalence in Uganda, it was found that the prevalence of diarrhoea in the 2 weeks preceding the surveys was 8.6 -19.5% (Burton and Wamai, 1992). Higher rates of diarrhoea were mainly associated with unprotected sources of water and lack of access to basic sanitation facilities (WHO/UNICEF, 2000).

CHAPTER THREE - METHODOLOGY

3.1 Study design

The study design was Cross – sectional used to collect data on faecal coli form counts, prevalence of diarrhoea, and the factors influencing the quality of hand-dug wells water.

3.2 Study area

Bweyale Town Council is located in Kiryandongo District curved from Masindi District which has a coverage area of 3,609 km square and an estimated population of 270,500 people (National population and housing census, 2002). Bweyale Town Council is about 100 miles North of Kampala along Kampala - Gulu high way on a coordinate of 1° 93' 33",North 32° 13' 33" East) and about 25 kilometers from Kiryandongo District headquarter (1° 51' 12" North, 32° 2' 46" East).

The Town Council is made of 7 (Seven) villages and an estimated population of 67,523 people mainly from the formally insurgent areas of Northern Uganda and West Nile (Local Council I record 2010). It's a host to thousands of refugees from Congo, Kenya, and South Sudan. The area has an average annual rainfall of 1,304 mm per year and the main economic activities are subsistence farming of maize, tobacco, cassava, and sun flowers for food and cash whilst others do retail businesses to fulfill their minimum staple and non staple requirements.

3.3 Population

- Target population**:** All persons who drink water from hand-dug wells.
- Accessible population: All persons/individuals who lived in Bweyale Town Council between June and October, 2011.
- Participating population: All persons who satisfied the selection criteria.

3.4 Selection Criteria

Inclusion criteria:

- Residents who have lived in Bweyale Town Council more than 6 months.
- A household member who was aged 18 years and above and had consented to participate in the study.
- District Health officers, Water officers and hand-dug wells constructors who had worked in the district for the last 2 year.

Exclusion criteria:

- Very sick household member.
- Mentally ill household member.
- Very busy District Health/Water Officers.
- Busy or sick Mason(s).

3.5 Sample size determination

Household sample:-

The sample size for the prevalence of diarrhoea was determined using Keish and Leisli (1965) formula with precisions of $\pm$5% at confidence level of 95 % for household's questionnaires.

$n = Z^2 PQ / D^2$

Where:

n: Sample size

Z: Z value corresponding to the required Confidence level (95%).

P: Maximum variability (0.5)

Q: 1-P

D: Precision of $\pm$ 5%

$n = 1.96^2 0.5*0.5/0.05^2 = 385$ households.

Considering a maximum design effect of 2 (Min WHO recommended design effect), the sample size for household questionnaires was **770** households.

Water samples:-

The sample sizes for the prevalence of diarrhoea was determined using Yamane's (1967) formula $n = N/ [1+N (e)^2]$.

Where N: 118(Local Council I records) and e: 0.05 at Confidence level - 95%. n = 105 samples from Hand-dug wells**.**

3.6 Sampling techniques

Sampling techniques for quantitative data

The researcher used two stage cluster sampling technique. Bweyale Town Council has 7 villages from which the primary clusters were identified using simple random sampling by listing names of the 7 villages on piece of papers, shook in a handy container, threw them on the ground and picked the first three without replacement to ensure equal chance of participation. The secondary clusters were households from the primary clusters picked by tipping a Ballpoint pen in air from LCI Offices in the village. The first household encountered along the direction of the tip of the pen on ground becomes participant number one to be interviewed. From each household interviewed, the Research Assistants repeatedly conducted the same process of tipping a pen to sample the subsequent respondents.

The water sources (Hand-dug wells) for bacteriological quality analysis was again sampled randomly. The Hand-dug wells were identified by names and codes. The codes were listed and picked from the total number of Hand-dug wells found in Bweyale Town Council to get the 105 Hand-dug wells sampled for bacteriological analysis (Coli form count).

Sampling technique for qualitative data

The District Water/ Health officers and local Masons were sampled purposively with the anticipation that they are knowledgeable and in position to provide adequate information towards the research questions.

3.7 Study Variables

Dependent variables:

- Household experience of diarrheal cases in the past 2 weeks prior to the time of interview (Indicator; prevalence of diarrhoea (%).

Independent variables:

- Level of contamination (Coli forms count per 100 ml).
- Factors influencing the bacteriological quality of hand-dug wells waters: Distance from contamination points, construction and quality assurance practices.

3.8 Data collection techniques and Instruments

Quantitative data

During data collection, pretesting exercise was conducted immediately in one of the seven villages in Bweyale Town Council which was not considered among the primary clusters after the training. 5% of the household sample size (39 HHs and 2 KIs) were involved in this exercise. This was meant to assess the reliability and validity of the questionnaires to considerably correct and adequately capture the required data to answer the research questions. These household questionnaires were eventually administered to collect quantitative data from the sampled households in Bweyale Town Council. Household questionnaires were administered at Household level to collect quantitative data from the households.

Samples from the Hand-dug wells were got by collecting samples from spouts for those wells fitted with hand pumps whilst those without hand pumps fitted for abstraction, deep sampling

method was used where sterilized sampling bottles were lowered into the wells to get the samples. All the tops of the autoclaved bottles were wrapped in a foil to avoid mechanical introduction of contaminants into the samples. Using sanitized fabricated metal box with methyl, the sampling bottles with the samples were transported to the National Water & Sewerage Corporation central laboratory in Bugoloby (Kampala District) for bacteriological analysis. The bacteriological water quality was analyzed using the accredited method called "membrane filtration method". In this method, 100 ml of water samples were filtered through absorbent paper membrane with fine pore size to retain all bacteria. Then the absorbent papers with the filtrates were placed on culture media of lauryl sulphate broth and incubated for 16-18 hours at a temperature of 37^0C and 44^oC for *E. coli* and faecal coli form respectively. After the 16-18 hours of incubation, the *E. coli* & faecal colonies with distinct morphological character (Glittering, yellow-greenish and purple colonies of growth) were counted using hand magnifying glass.

Distances of Hand-dug wells from contamination points (latrines, dwelling places, communal and household damping sites) were measured and recorded in meters for every water point sampled for bacteriological quality assessment using 50 meter long tap measures.

For the data on construction, each hand-dug well was assessed for types of liners, drainage conditions and cover of the wells using observation method.

Data collection on quality assurance was equally conducted by observations and interviewing the care takers of the hand-dug wells with emphasis on information for periodic disinfection, liners and abstraction methods.

Qualitative data

Key informant questionnaire guide were used to collect data from the District Water and Health Officers and Masons (Local technicians who constructed the wells). They were purposively selected, briefed about the study and consent obtained. Information was recorded by hand only and not tape recorded due to financial and materials resource constraints.

3.9 Data Management

Quantitative data

Completed questionnaires were checked for missing data and completeness on daily basis after every close of business day. This was followed by coding of data, double entry into SPSS version 10.0 computer software for the required analysis.

Qualitative data

Recorded data was organized into master sheet and then analyzed to inform the quantitative data.

3.10 Data analysis plan

The data were analyzed using SPSS program version 10.0. The following statistical parameters were analyzed for:

Descriptive statistics:

Descriptive statistics were used to summarize continuous characteristics of the study participants into frequency tables.

Bivariate analysis/multivariate

Bivariate analysis was performed to see how *E.coli* counts was associated with prevalence of diarrhoea and similarly applied the same to factors affecting the quality of hand dug well water. All the factors were also fitted into logistic regression (multivariate) to assess if they were significant in influencing bacteriological quality of hand-dug wells. The strengths of association were measured using odd ratio (OR) at 95% confidence interval (CI).

3.11 Quality control techniques

Reliability:

The questionnaires were administered by trained Research assistants with minimum qualification of senior six who worked under close supervision of the principle investigator and an experienced Health worker in Environmental health. The Research assistants were trained on skills of community engagement, interpretation and translation of the questionnaires to avoid influencing the outcome of the studies.

The tools were pre-tested during the training of Research assistants to ensure the tools were understood and translated in the local language correctly. Measurement, recording and observation were some of the skills the Research assistants were trained on.

The investigator ensured good data management practice including data collection, double data entry, cleaning, and storage. The effects of co-founders like using other water sources, hygiene and sanitation practices as well as seasonality on the prevalence of diarrhoea were controlled for during the analysis.

Validity

Validity was enhanced through conducting laboratory test for water samples under a controlled and sanitized environment to guard against contamination of samples during sampling, transportation and culturing. Prior to sample collection, the wells were pumped for approximately 10 minutes to ensure the samples represent the quality of aquifer.

The random sampling process for identifying participants in the study was to strengthen the validity of the study since error due to biases were reduced.

The counting of bacterial colonies was done twice or more using magnifying glasses to ensure enumeration were correctly done.

3.12 Ethical Considerations

The research was conducted cautiously with due consideration to ethical standards and principles of non malfeasance, beneficence as well as autonomy (informed consent). Research Assistants were made to ascent to code of ethics checklist before starting data collection. Training contents for Research Assistants was inclusive of ethical issues.

The research was conducted while upholding the moral, tradition and customary rules and regulations of the community in a manner that did not compromise the scientific inclinations of the research. The investigator ensured adherence to maintaining scientific standards in the methods employed in the collection and analysis of data as well as impartial assessment and dissemination of findings. The involvement of Participants was on the basis of informed consent.

CHAPTER FOUR –DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Descriptive statistics of the study variables

Table 1: Abstraction mechanisms & diarrhoea cases among 771 respondents in Bweyale Town Council.

How drinking water is abstracted	**n = 771**	**%**
Tap	35	4.5
Hand pump	406	52.7
Windlass	7	0.9
Buckets	207	26.9
Motorized	14	1.8
Others	102	13.2
Experience of diarrhoea in the last two weeks		
Yes	172	22.3
No	599	77.7

Of the 771 respondents, 599 (77.7%) admitted they had not experienced diarrhoea cases in the last two weeks before the interview.

Table 2: Distance of hand-dug wells from contamination points in Bweyale Town Council

Nearest dwelling (meters)	**n = 106**	**%**
≤ 30meters	100	94.3
□ 30meters	6	5.7
Nearest House-hold damp pit (meters)		
≤ 30 meters	105	99
□ 30 meters	1	1
Communal damp pit (meters)		
≤ 30 meters	12	11.2
□ 30meters	94	88.6
Nearest latrine (meters)		
≤ 30 meters	106	100.0
□ 30 meters	0	0.0

From the above table (2), of the 106 hand dugs well water sampled on aspects of distance from contamination points,100 (94.3%) were located within a distance of less than 30m from the dwelling places,105(99 %) were sited utmost 30 meters from house hold damping pits, 94 (88.6%) within distance more than 30 meters from communal damping pits, 106 (100%) were sited less or equal 30 meters from latrines.

Table 3: Construction technologies for hand-dug wells in Bweyale Town Council

Well cover	**n = 106**	**%**
Open	2	1.8
Covered concrete	87	82
Covered iron sheet	17	16.
Drainage		
Broken	10	9.4
No drainage	60	56.6
Drainage intact	36	33.9
Well lining		
Concrete in-situ	2	1.89
Concrete liner	5	4.7
Brick work	99	93.4

On aspects of construction technology, 87 (82%) of the Hand-dug wells were covered with concrete slabs, 60 (56.6%) had no drainage, 99 (93.4%) had brick work lining.

Table 4: Quality assurance (Sanitary practices) in relation to Hand-dug wells in Bweyale Town Council.

Period disinfection (last episode)	**n =106**	**%**
≤ 6 Months	101	95.3
> 6 Months	5	4.7
Turbidity		
00 NTU	2	1.8
1-5 NTU	89	83.9
> 5 NTU	15	14.2
Abstraction method		
Windlass	77	72.6
Hand pump	25	23.6
Bucket	4	3.8

Of the 106 Hand-dug wells assessed, 101 (91.5%) reported last episode of disinfection utmost 6 months and 77 (72.6%) reported windlass as the mechanism of abstraction of water from the wells.

Table 5: Bacteriological quality (Total coli form counts) for 106 Hand-dug wells in Bweyale Town Council.

Total coli form count (per 100ml)	**n=106**	**%**
0	79	74.5
1	1	0.9
2	4	3.7
3	2	1.8
4	4	3.7
5	3	2.8
6	2	1.8
7	2	1.8
8	2	1.8
10	2	1.8
13	2	1.8
16	1	0.9
18	1	0.9
30	1	0.9
Total	**106**	**100.0**

From the above table (5), the highest percentage of 74.5% of the water sample had no total coli form detected.

4.2. E. coli count in Hand-dug wells water sample per 100mls.

The frequency table 6 shows the E. coli form count in 106 samples of Hand-dug wells water from Bweyale Town Council.

Table 6:E. coli count in Hand-dug wells samples in Bweyale Town Council

E. Coli count /100mls water sample	**n=106**	**%**
Mild contaminated (1-10 E. cfc/100 mls)	11	10.4
Moderate contaminated (10-20 E. cfc/100 mls)	3	2.8
Highly contaminated (20-50 E. cfc/100mls)	2	1.9
Not Contaminated (0 E. cfc/100mls)	90	84.9

Most of the hand-dug wells (84.9%) have not been detected with medically important bacteria of human faecal origin (E. coli) while 10.4% were mildly contaminated within range not acceptable by WHO limits. However all the 106 hand-dug wells water sampled and tested were acceptable within Uganda's National standard (DWD 2007) for appropriate relaxation limits of ≤ 50 cfc/100mls.

4.3. Prevalence of diarrhoea among users of Hand-dug wells.

Table 7: Diarrhoea cases among 771 who drank water from the Hand-dug wells in Bweyale Town Council.

	Diarrhea in last two weeks		
	Yes	No	Total
Contaminated	58(30.7%)	109(18.7%)	167(21.7%)
Not-contaminated	131(69.3%)	473(81.3%)	604(78.3%)
Total	189(24.5%)	582(75.5%)	771(100%)

Of the 771 respondents interviewed, 167(34.7%) were exposed to contaminated water where as 604(78.3%) were not exposed. Of the 167(21.7%) exposed to contaminated water, only 58(34.7%) experienced diarrhoea in the previous two weeks from the time of interview. Out of the 604(78.3%) exposed to clean water, only 131(21.7%) experienced diarrhoea.

Out of the 189 individuals who reported diarrhoea, a high percentage of 69.3 %(131/189) were not exposed to contaminated water where as 58(30.7%) reported to have experienced diarrhoea and had exposure to contaminated water source.

The prevalence of diarrhoea among the 771 households that participated in the study was **24.5%**

4.4. Association between *E. coli* and prevalence of diarrhoea.

Table 8: Association between E. coli count and cases of diarrhoea among 771 respondents in Bweyale Town Council.

	Diarrhea in last two weeks			
	Yes	No	X^2	P
			1.0426	0.097
> 10cfc/100 mls	182	554		
At most 10 cfc 100mls	6	29		

Ho: There is NO association between the prevalence of diarrhoea and E. coli count among the residents of Bweyale Town Council.

Given the calculated X^2 lies within the acceptance region when compared with χ^2 observed at 0.05 level of significance = 3.841, the null hypothesis is accepted, meaning that E. coli count was not associated with prevalence of diarrhoea.

4.5. Factors that influence the bacteriological quality of Hand-dug wells water**.**

Factors that influence the bacteriological quality of Hand-dug wells water in Bweyale Town Council-Kiryandongo District were fitted into logistic regression and the outcome are in table 9.

Table 9: Factors that influences the bacteriological quality of Hand-dug wells water in Bweyale Town Council.

Variable(Factor)	N	Adjusted OR	95% C.I	P-Value
Abstraction method				
Windlass	77	0.1544	(0.0207-0.19518)	0.0068*
Hand pump	25	1		
Bucket	04	0.000	(0.000 -1.000)	0.0920
Distance - communal damp site				
Utmost 30m	12	1		
More than 30m	94	0.9156	(0.5456-0.9536)	0.0073*
Drainage				
Broken	10	0 .9313	(1.1160-7.4775)	0.0090*
No drainage	60	1		
Intact drainage	36	0.3366	(1.0369-3.0676)	0.0033*
Distance-HH damp sites				
Utmost 30m	105	1.2644	(1.0621-2.573)	0.0051*
More than 30m	01	1		
Distance dwelling				
Utmost 30m	100	1		
At least 30m	06	0.7731	(0.4266 -0.8532)	0.0030*
Distance latrine				
Utmost 30m	106	1.0990	(1.049 -2.142)	0.0080*
At least 30m	00	1		
Period disinfection				
≤ 6 Months	101	1.3165	(1.0737-2.445)	0.0035*
>6 Months	05	1		

Well lining				
Others	07	1		
Brick work	99	0.1820	(0.0343-0.9665)	0.0455*
Turbidity				
Clear(0)	2	1		
Moderate(1-5)	89			
High(>5)	15	1.145	(1.0159-1.2904)	0.0266*
Well cover				
Open	02	1		
At least covered(iron sheet or concrete)	104	0.268	(0.04-0.925)	0.012*

(Others; Well lining=Concrete in –situ, PVC liner, Concrete liner)

Looking at the values of the adjusted odds ratios confidence interval & p values and attaching meaning to each, we can conclude the following;

a) Distance of Hand-dug wells from contamination points:

Distance from communal dumping sites was significantly associated with bacteriological quality; Hand-dug wells sited in a distance of more than 30 meters from the communal dumping sites were less likely to get contaminated compared to those sited more than 30 meters away (AOR = 0.9156 , CI = 0.5456-0.9536, & P = 0.0073).

Distance from house hold dumping sites from hand-dug wells was significant factor in explaining bacteriological quality of water. Water drowned from wells which were in a distance of 30 meters or less from house hold dumping sites was 1.26 more likely to have high bacterial load compared to that water coming from the sources located more than 30 meters

away from house hold dumping sites.(AOR = 1.26,95% C.I = 1.0621-2.573 P = 0.0051*).

The dwellings which were in a distance of more than 30 meters were less likely to have poor bacteriological load quality than dwellings which were in a distance of less than 30 meters (AOR=0.7731,95% CI = 0.4266-0.8532,P = 0.003).

Hand-dug wells within distances of 30 meters or less from latrine were more likely to get contaminated than hand-dug wells with distances more than 30 meters (AOR = 1.099, 95% CI = 1.049-2.142, P = 0.008).

b) Construction technology

Hand-dug wells with drainage intact were less likely to get contaminated than that from wells with no drainage at all (AOR= 0.3366,95% C.I = 1.0369-3.0676 , P = 0.0033).

Similarly hand-dug wells with broken drainage were less likely to get contaminated compared to that from wells with no drainage at all. (AOR = 0.9313, 95% CI: 1.1160 -7.4775, P = 0.0090*).

Hand-dug wells with lining technology including concrete in-situ, concrete liners and PVCs were less likely to have high bacteriological load compared to wells with brick lining (AOR: 0.1820, 95% C.I = 0.0343-0.9665, P = 0.0455) .

Well cover turned out to be significant for influencing the bacteriological quality of hand-dug wells thus water coming from sources that were covered were less likely to get contaminated compared to those left open (AOR = 0.268, 95% CI = 0.04-0.925 P = 0.012).

c) Quality Assurance;

Use of windlass as an abstraction method was less likely to be associated with bacteriological contamination of hand-dug wells compared to hand pumps (AOR = 0.1544, 95% CI = 0.0207-0.19518, P = 0.0068).

Water samples with turbidity 5 NTU were more likely to get contaminated than those with turbidity ≤ 5 NTU (AOR = 1.145, 95% CI = 1.0159-1.2904, P = 0.0266)

CHAPTER FIVE-DISCUSSION

5.0 Introduction

In this chapter, results on bacteriological quality of water from hand-dug wells were discussed and related to previous works of scholars to comprehend the bacteriological quality of hand-dug wells water and its effects on the prevalence of diarrhoea in Bweyale town council.

5.1 E. Coli count in water from Hand-dug wells in Bweyale Town Council.

About 2 of 10 (15.1%) of hand-dug well water samples from Bweyale Town Council contained bacterial coliform above the WHO(1993) stipulated limits for portable water though most of them lies within the National standards of ≤ 50 cfc per 100mls(DWD, 2007) .The *faecal coliform* contamination with >10 tcfc was 6.3% whilst the proportion of highly contaminated water sample with *E. coli* constituted 1.8 % adducible to leachates, seepages and run offs of the polluted environment due to poor sanitary condition or completion of the underground and substructures of the well.

5.2 The prevalence of diarrhoea among the residents of Bweyale Town Council drinking water from Hand-dug wells.

About one in every four respondents reported diarrhoeal diseases in the two weeks before the time of interviews among those who drank water from the Hand-dug wells. Cochrane Collaboration (2009) demonstrated evidence of reducing diarrheal diseases in endemic setting by improving the microbiological quality of drinking water. Meaning the bacteriological quality should meet the minimum quality requirements (WHO, 1993: 0 E. coli & DWD, 2007: <50 cfc/100mls) to reverse the estimated prevalence of diarrhoea among those in Bweyale Town

Council which was slightly under the World Health Organization reference value for rapid health assessment (25%), 3.7 times the national prevalence & over 6.1 times the Central region prevalence (Uganda's National Demographic & Health survey, 2005).

5.3 The relationship of *E.coli* count and the prevalence of diarrhoea among residents drinking water from the Hand-dug wells in Bweyale Town Council.

About nine in every ten of those who had access to highly contaminated water with *E. coli* had diarrhoea compared to three in ten of respondents who had diarrhoea due to exposure to low counts of *E. coli* thus meaning the higher the *E.coli* count in the Hand-dug wells, the higher the chances of getting diarrhoea.

Those individuals exposed to water with more than 10 *E. coli* count were 1.58 more likely to contract diarrhoea compared to those with 10 or less cfc. However, the relationship between *E. coli* count and prevalence was not significant. Although there was no statistical relationship between *E. coli* count and prevalence of diarrhoea, there were other studies that have linked a wide variety of bacterial, viral and protozoa pathogen excreted in human and animal faeces to cause of diarrhoea (Byers, 201I). Among the most infectious agents were *Escherichia coli, Giardia, Salmonella ssp, p, Shigella, rotaviruses and Entamoeba histolytica* (lecerec, 2011).For example *E.coli* was found to be responsible for an outbreak of Haemolytic uraemic syndrome in Alpine Wyoming, which Olson *et al* (2002) related it to consumption of water from a poorly protected spring being predisposed to a risk of contamination by surface water.

5.4 The factors that influence the bacteriological quality of Hand-dug wells water in Bweyale Town Council-Kiryandongo District

Distance of Hand-dug wells from Contamination points and their bacteriological quality

Hand-dug wells water within 30 meters from household damping site was 1.26 times more likely to get contaminated with faecal coli form compared to those ones far away (>30 meters) from the house hold dumping pit. This finding was in line with the similar study conducted by Omotoyinbo (2007) in Nigeria where the level of contamination of Hand-dug well water with total coli form bacteria count in water was due to existence of source pollutant of sewage and faecal materials from man and animals. He recommended adherences to standards like distance from toilets, damping site and dwelling places as vital.

Distances of Hand-dug wells from pit latrines were significant factor in influencing the bacteriological quality of water from the hand –dug wells because sources located within distance less than 30 meters were 1.0990 times more likely to get contaminated with faecal coli form compared to those >30 m away from the latrine. This was congruent to the findings of a study conducted by Mahedeven and Krishamswamy (1984) in India where the level of underground water contamination significantly increasing with distances from the source pollutants like latrines.

Different studies have shown horizontal distances between contamination points such as latrine and water point to influence the level of faecal contamination. The far the horizontal distance, the long distance the pathogen has to travel from the point of entry into the water table to the water point and the more likely the pathogen is likely to die and thus lesser level of

contamination. The results from the central laboratory study have demonstrated that distance from the contamination points were significant determinants on the quality of hand-dug wells water. The study was not conclusive on data to determine the minimum distance between hand-dug wells and contamination points in the locality of the study area and rather continue to advise the minimum recommended distance by Directorate of Water Development Uganda government 30- 50 meters).

Construction technology of Hand-dug wells and bacteriological quality

Sanitary completion of water sources such as deep and shallow wells were exclaimed to be important in sustaining desired water quality. In this study broken & no drainage conditions were more likely to contribute to bacteriological contamination of Hand-dug wells water compared to intact drainage which seemed more efficient in preventing contamination. This finding was in line with a similar pilot study by Nyundu, Sutton (2001) in Zambia on water self supply where she found small upgrading on well structures like aprons and drainage can reduce Coli form counts from 100 -200 Coli form/100ml to less than 10 Coli form/100ml.

Other sanitary completion issues that may add value to improving hand-dug wells water quality may include well cover with slabs to prevent entry of pollutants into the wells. DWD (2007) construction manual provides for 2 m radius slabs from the wall (or parapet) of the well to give protection against infiltration of nearby surface water into the well. There is the need for Protection of Well head area which may includes the apron and the immediate surrounding by fencing off from unauthorized intruders (people and animals).

On the aspects lining technology, 100% faecal contamination were found in the hand-dug wells with brick lining thus implying brick lining predisposes wells to contamination. In Nyundu, Sutton (2001) pilot study in Zambia, water from lined wells had relatively better quality compared to unlined well. Other technology type of lining other than brick lining were found less likely to get contaminated by *faecal coliform* (OR = 0.182) thus exposing it to contamination. The brick lining vulnerability to contamination may be attributed to weak mortar lines between "bricks to bricks" and poor sanitary sealing thus resulting to bacterial percolation into the wells.

Quality assurance practices and bacteriological quality of Hand-dug wells water

Quality assurance practices such as regularly disinfecting (Every ≤ 6 months) and use of improved abstraction methods were found to be significant determinant of bacteriological quality of water. A person collecting water from a source which was not disinfected more frequently (Every 6 months; DWD guideline, 2007) was 1.32 times more likely to drink water contaminated with faecal coli forms compared to water source which was frequently disinfected. UNOCHA (2000) & International Federation of Red Cross Appeal (2001) advised organizational and individual efforts to maintain clean and safe water supply should include chlorination like chock chlorination to improve water quality of traditional sources. Oxfam Liberia used pot chlorinators in private wells to assure safer water supply to the residents and IDP's of Monrovia after the war when most of the water infrastructure were destroyed (Garandeau, 2004).

Water abstraction method plays a crucial role in ensuring acceptable bacteriological quality of underground water sources. Edith (2005) observed that the water quality from wells which have

communal buckets and windlasses on average had no better quality than water from scoop holes in line with the findings of this study where windlass abstraction method turned out to be significant in influencing the bacteriological quality of Hand-dug wells water. Hand pumps provide the most efficient and sanitary method of abstracting water since all the moving parts are encased and prevented from external contamination.

The clarity of water sampled from the hand-dug wells confirms the scanty level of contamination with faecal materials because turbidity stems from the reduction of water transparency due to the presence of particulate matters such as clay, silt, finely divided organic matter, planktonic and other microscopic organisms. These colloidal materials provide adsorption sites for bacteriological/ virological or protozoal germs that may be harmful to health thus high turbidity levels are associated with poor water quality. This was in line with the finding of the study where turbidity were above 5 NTU were found to be 1.145 times more likely to have some bacteria load than the lesser turbid water (< 5 NTU).

5.5 Implications of results in relation to public health

The construction technology, quality assurance and distances from contamination points were found to compromise the bacteriological quality of hand-dug well water with the potential to contribute to the prevalence of diarrhoea.

The users of hand-dug wells as source of drinking water Bweyale Town Council were predisposed to the risk of getting diarrhoea given 15.1% of the Hand-dug wells did not meet WHO (1993) standards for bacteriological quality of drinking water. The presence of faecal

contamination was an indicator that a potential health risk existed for individuals exposed to those water sources.

The diarrhoeal prevalence of 24.5 % qualified for rapid health assessment or active surveillance given it was marginally below the WHO reference value (25%) for rapid Health assessment clearly indicating some degree of public health concerns related to diarrhoeal prevalence in Bweyale Town Council.

Given 93.4% of the hand-dug wells have brick work liners and that it turned out to be significant in influencing the bacteriological quality of hand-dug wells water, unless there is an action to rehabilitate the liners and provide close supervisions of well construction, the chances of being exposed to contaminated drinking water may increase and may ultimately have direct implication on the health of the resident Bweyale town council.

Household damping sites, latrines and human dwelling distances from Hand-dug wells turned out to be significant in influencing bacteriological quality of water and thus poor sitting may promote under ground water contamination and thus negative health effects on the residents of the town council.

5.6 Methodological issues (Limitations)

It was hard for the respondents to differentiate between Hand-dug wells and deep wells by mere observation of the water source super structures (Hand pumps). Some of the Hand-dug wells which had hand pump installed may have been misleading to the respondents (referring to Hand-dug wells installed with hand pumps to deep wells) thus resulting to misinformation and subsequent effects on the outcome of the results.

The results of diarrhoeal prevalence in Bweyale were entirely dependent memory of the respondents to correctly recall the case and correctly defined the conditions as stipulated in this study.

The prevalence of diarrhoea in Bweyale Town Council can't be scientifically associated to the *E.coli* counts in the hand-dug well water because no confirmatory test was performed on the stools from individuals who had experienced diarrhoea.

Deep sampling of water from open and closed wells had been challenging given the required level of sterilization of both strings and bottles to avoid introduction of contaminants into the wells. This may have compromised the outcome of the laboratory test.

Transportation of the water sample under favorable condition (temperature) to the Central laboratory in Kampala may have undermined the bacteriological quality results. Cooler boxes without ice packs were used to maintain the temperature of the samples during transportation to Central laboratory.

Generalizability of the research results may be limited to Bweyale given some of the critical limitations such as sampling process, cold chain management of the water sample during transportation from the field to the Central laboratory as well as coverage and methodology. However, it's a learning experience and useful to influence local decision making at Bweyale town council level and the Kiryandongo District.

CHAPTER SIX-CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Of the Hand-dug wells tested, 15.1% were found to have been contaminated within ranges not acceptable by WHO limits and 84.9% were not detected with coli form contamination. All the 106 Hand-dug wells water samples tested were acceptable within Uganda's national standards for bacteriological water quality given the appropriate relaxation limits (DWD, 2007).

The prevalence of diarrhoea among the residents of Bweyale drinking water from the Hand-dug wells was 24.5% slightly under the WHO reference value for rapid health risk assessment.

There was no association between *E. coli* form contamination of water and prevalence of diarrhoea among those who drank water from the Hand-dug wells.

The Distance of contamination points (Latrines and Household damping sites), construction technology (liner types, drainage, and sanitary completion), and quality assurance (Disinfection frequency, abstraction methods and turbidity) were significantly associated with bacteriological quality of Hand-dug wells water.

6.2 Recommendation

Specific recommendations

Technical review and rehabilitation of the hand-dug wells found with undesired level of faecal coli form contamination to meet the WHO (1993) standards. For those water points with non

preventive source or non-source contamination, users would have to be educated on cheap option of household based water treatment. The owners of the water sources would also be advised to regularly chock the wells with chlorine to suppress the bacterial load in the wells.

Recommended for increased environmental interventions through health education, awareness and sensitization on the need for safe hand-dug wells construction management to mitigate and prevent its negative health impact on the residence of the town council.

The residents have to be educated dispose of their refuses at distances far more than 30 meters from the water sources. Besides rubbish disposal far away from the water sources, latrines construction should be sited a distance away from water sources.

Another intervention would be to promote household water treatment options to promote access to clean and safe water. For example treating water or encourages use of home based water treatment goods such as Bio-sand filters.

Extra-ordinary efforts on technical inputs towards sitting hand-dug wells around Bweyale and outside where there are many unlined pit latrines, damping sites and dwelling following the DWD's underground water source construction and minimum sphere standards to avoid cumulative effect of pollution reaching the water table being significant. Communal or commercial hand-dug wells with high extraction rates should be sited in low populated areas since high rate of extraction increases the hydraulic gradient in the area around the water point increasing the risk of contamination.

There is need for superior support supervision by local authorities on construction of self supply water sources with intention for commercial purposes to adhere to DWD's (2007) & sphere minimum standards (2005) like:

- Increase horizontal separation distances between latrine and water point.
- Move water point higher than latrines.
- Change to a drier form of latrine.
- Increase vertical separation between bottom of pit and water table by using shallower pits or Eco-san sanitation facilities.
- Use of better lining technology for hand-dug wells.

Turbid water points may require application of Aluminum sulphate granule (Alum) to clear the suspension to improve turbidity of the highly turbid water points.

The use of PVC, concrete in-situ and concrete liners other than brick liners would be the best alternative for lining wells. However, improved motor mixture ration (cement: sand) would improve sanitary sealing of the wells from contamination.

Complete sanitary completion of hand dug-wells including better drainage system, grouting and protection from intruders would highly improve the quality of water from the hand-dug wells.

Hand pump as abstraction mechanism would be the best means of abstracting water at an acceptable quality for human consumption.

Provide alternative sources of clean and safe water for the population like deep wells and pipe water distribution with better quality control procedures in place.

Global recommendations

Government and Development partners have responsibility for vigilant public health maintenance including pursuance and providing clean, safe drinking water through provision of enabling environment (relevant policies, laws, adequate funding), appropriate facilities and social mobilization and marketing of safe water sources.

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APPENDICES

Appendix 1: SURVEY TOOLS;

HOUSEHOLD QUESTIONNAIRES

CONSENT STATEMENT.

The purpose of this study is for partial fulfillment of academic requirements for Master of Science in Public Health of International Health Sciences University.

The study is to investigate water and sanitation related issues including the prevalence of diarrhoea among the residents of Bweyale Town Council, bacteriological quality of Hand-dug wellss water as well as clean and safe water management practices. The outcome of the study is expected to guide policy and planning of public water infrastructure in the District as well as inform water related risk management contingency planning process. It is also envisaged to generate further researchable questions which can help in improving self water supply in rural and urban setting.

I regret that your participation in this study will not have any direct personal benefits but as stated earlier may inform and guide planning for water infrastructure for the area. This exercise might take about 5-8 minutes of your time to complete and all information provided will

be strictly treated CONFIDENTIAL and will only be used for this study purpose.

Do you have any question? May I proceed with the interview now??

Yes □ No □ Thank you! Yes □ No □ Thank you! Yes □ No □ Thank you!

Sign:…… **Sign:……** **Sign:……**

Date:…… **Date:……** **Date:……**

Names of interviewer:.....Sub county: **Bweyale Town Council** .Parish:.....Village:……

Household #: …… Date:……	Household #: ……	Household #: ……
Village:…… Hand-dug wells name.....	Village:…… Hand-dug wells name.....	Village:…… Hand-dug wells name.....
Head of HH: Male□ female□	Head of HH: Male□ female□	Head of HH: Male□ female□
Age of respondent:…..Sex of respondent:……	Age of respondent:…..Sex of respondent:……	Age of respondent:…..Sex of respondent:……
How many people slept in this household yesterday?.....	**How many people slept in this household yesterday?.....**	**How many people slept in this household yesterday?.....**
Composition of family; 1.(<5yrs)□. 2.(>5<18yrs)□ 3.(>18< 45 yrs) □4. (> 45 yrs)□	Composition of family; 1.(<5yrs)□. 2.(>5<18yrs)□ 3.(>18< 45 yrs) □4. (> 45 yrs)□	Composition of family; 1.(<5yrs)□. 2.(>5<18yrs)□ 3.(>18< 45 yrs) □4. (> 45 yrs)□

Level of education of respondent: 1. Primary □ 2.Secondary□ 3. University□ 4.None□ 5.Others□.....	Level of education of respondent: 1. Primary □ 2.Secondary□ 3. University□ 4.None□ 5.Others□.....	Level of education of respondent: 1. Primary □ 2.Secondary□ 3. University□ 4.None□ 5.Others□.....
B. Safe drinking water:		
What is the source of your drinking water? **1.** Tap water □; **2**.Shallow well □ **3**.Deep well □; **4. Roof** water catchments □; 5**.** Swamp□ Other □;	What is the source of your drinking water? **1.** Tap water □; **2**.Shallow well □ **3**.Deep well □; **4. Roof** water catchments □; **5.** Swamp□ Other □;	What is the source of your drinking water? **1.** Tap water □; **2**.Shallow well □ **3**.Deep well □; **4. Roof** water catchments □; **5.** Swamp□ Other □;
How do you abstract your drinking water? **1.** Tap □; **2**.Hand pump □ **3**.Deep well with H/pump □; **4.** Windlass □; 5**.**Buckets □ 6. Motorized □; 7.Others □	How do you abstract your drinking water? **1.** Tap □; **2**.Hand pump □ **3**.Deep well with H/pump □; **4.** Windlass □; 5**.**Buckets □ 6. Motorized □; 7.Others □	How do you abstract your drinking water? **1.** Tap □; **2**.Hand pump □ **3**.Deep well with H/pump □; **4.** Windlass □; 5**.**Buckets □ 6. Motorized □; 7.Others □
How much do you pay for 20litre jerrycan?.....UgX	How much do you pay for 20litre jerrycan?.....UgX	How do you pay for 20litre jerrycan?.....UgX
How many liters of clean water did you collect for the family yesterday?..... liters	2. How many liters of clean water did you collect for the family yesterday?.....Liters	2. How many liters of clean water did you collect for the family yesterday?..... liters

3.What is the size of your clean water storage container for your family? (Verify).....	3.What is the size of your clean water storage container for your family? (Verify).....	3.What is the size of your clean water storage container for your family? (Verify).....
5. How frequent do you clean the containers for fetching water? **1.** Once a day □. **2**.Twice a day□. **3**. Every time water is collection□.	5. How frequent do you clean the containers for fetching water? **1.** Once a day □. **2**.Twice a day□. **3**. Every time water is collection□.	5. How frequent do you clean the containers for fetching water? **1.** Once a day □. **2**.Twice a day□. **3**. Every time water is collection□.
6. How do you treat your drinking water? **1.** Boiling □; **2**. Sedimentation □; **3**.chlorinate□; 4 Sun-rays □ **5**.other □.	6. How do you treat your drinking water? **1.** Boiling □; **2**. Sedimentation □; **3**.chlorinate □ ;**4** Sun-rays □ **5**.other □.	6. How do you treat your drinking water? **1.** Boiling □; **2**. Sedimentation □; **3**.chlorinate □ ;**4** Sun-rays □ **5**.other □.
Basic Sanitation.		
1. Where do you defecate (verify)? **1**. Open □ **2.** Pit latrine□ **3.** Water borne toilet □ **4.** Polythene toilet □ **5.** Others □.....	1. Where do you defecate (verify)? **1**. Open □ **2.** Pit latrine□ **3.** Water borne toilet □ **4.** Polythene toilet □ **5.** Others □.....	1. Where do you defecate (verify)? **1**. Open □ **2.** Pit latrine□ **3.** Water borne toilet □ **4.** Polythene toilet □ **5.** Others □.....
If latrine, how many doors(stances)?.....	If latrine, how many doors(stances)?.....	If latrine, how many doors(stances)?.....
If latrine/toilet, who owns the latrine facility? **1**. Own □ **2.** Private business □ **3**. family shared □	If latrine/toilet, who owns the latrine facility? **1**. Own □ **2.** Private business □ **3**. family shared □	If latrine/toilet, who owns the latrine facility? **1**. Own □ **2.** Private business □ **3**. family shared □
3. How many family shares the latrine?.....	How many family shares the latrine?.....	How many family shares the latrine?.....

How do you Handle children faeces? **1.** Bury □ **2.** Dispose of into rubbish bin □ **3**. latrine □ **4.**throw by road side □ **5.**throw in the bush □	How do you Handle children faeces? **1.** Bury □ **2.** Dispose of into rubbish bin □ **3**. latrine □ **4.**throw by road side □ **5.**throw in the bush □	How do you Handle children faeces? **1.** Bury □ **2.** Dispose of into rubbish bin □ **3**. latrine □ **4.**throw by road side □ **5.**throw in the bush □
Does the latrine have Hand washing bay (facility)? (If possible verify) **1.** Yes □ **2**. No □	Does the latrine have Hand washing bay (facility)? (If possible verify) **1.** Yes □ **2**. No □	Does the latrine have Hand washing bay (facility)? (If possible verify) **1.** Yes □ **2**. No □
If yes (and no washing facility at latrine), where do you was? **1.** Communal basin □ **2**. Water from drinking cups □ **3.** Separate jug □	If yes (and no washing facility at latrine), where do you was? **1.** Communal basin □ **2**. Water from drinking cups □ **3.** Separate jug □	If yes (and no washing facility at latrine), where do you was? **1.** Communal basin □ **2**. Water from drinking cups □ **3.** Separate jug □
D. Hygiene		
When do you wash your Hands? **1**. Before eating □; **2.** After eating □; **3.** After visiting the toilet □ **4.** Before breasts feeding □ **5.** Before Handling food □ **6**. Before breasts a child □**7.** Other □;.....	When do you wash your Hands? **1**. Before eating □; **2.** After eating □; **3.** After visiting the toilet □ **4.** Before breasts feeding □ **5.** Before Handling food □ **6**. Before breasts a child □**7.** Other □;.....	When do you wash your Hands? **1**. Before eating □; **2.** After eating □; **3.** After visiting the toilet □ **4.** Before breasts feeding □ **5.** Before Handling food □ **6**. Before breasts a child □**7.** Other □;.....
Has anyone in the family suffered from diarrhea in the past 2 weeks: **1.** Yes □; **2.** No □;	Has anyone in the family suffered from diarrhea in the past 2 weeks: **1.** Yes □; **2.** No □;	Has anyone in the family suffered from diarrhea in the past 2 weeks: **1.** Yes □; **2.** No □;

If yes how many of the household members suffered?.....	If yes how many of the household members suffered?.....	If yes how many of the household members suffered?.....
Who suffered from diarrhoea **1.** (< 5 yrs) **2.** (>5<18 yrs) **3.** (>18 yrs)	Who suffered from diarrhoea **1.** (< 5 yrs) **2.** (>5<18 yrs) **3.** (>18 yrs)	Who suffered from diarrhoea **1.** (< 5 yrs) **2.** (>5<18 yrs) **3.** (>18 yrs)
How do you dispose of your garbage? **1.** Burn □; **2**. Own rubbish pit □;**3**.Communal damping site □; **4.** other□;.....	How do you dispose of your garbage? **1.** Burn □; **2**. Own rubbish pit □; **3**.Communal damping site □; **4.** other□;.....	How do you dispose of your garbage? **1.** Burn □; **2**. Own rubbish pit □; **3**.Communal damping site □; **4.** other□;.....

Appendix 2: HAND-DUG WELLSS SITE ASSESSMENT

Geographical location.		Distance from contamination points				Quality assurance [1]		Construction design		
Name of Hand-dug wellss	Location village	Nearest dwelling (meters)	Nearest latrine (meters)	Nearest House-Hold damp pit (meters)	Communal damp pit (meters)	Abstraction method 1.Windlass, 2.Hand pump 3.Bucket 4. Motorized	Periodic Disinfection Last episode and who did it. 1.x-self 2.x-authorty	Well cover 1. Open 2. Covered-concrete. 3. Covered Iron sheet.	Drainage. 1. Broken. 2.No drainage 3. Drainage - intact.	Well Lining 1. Concrete in-situ. 2.PVC liners 3. Concrete liner. 4. Brick work.

[1] Minimum interim Water Quality requirement according to DWD & MWE (2007): Test water quality twice in a year, Install U2 hand pump and disinfect when ever contaminated and environmental protection including sealing with concrete the surrounding to prevent silting.

Appendix 3: KEY INFORMANT CHECKLIST

DISTRICT WATER AND HEALTH DEPARTMENTS.

CONSENT STATEMENT.

The purpose of this study is for partial fulfillment of academic requirements for Master of Sciences in Public Health of International Health Sciences University.

The study is to investigate water and sanitation related issues including the prevalence of diarrhoea among the residents of Bweyale Town Council, bacteriological quality of Hand-dug wells water as well as clean and safe water management practices. The outcome of the study is expected to guide policy and planning of public water infrastructure in the District as well as inform water related risk management contingency planning process. It is also envisaged to generate further researchable questions which can help in improving self water supply in rural and urban setting.

I regret that your participation in this study will not have any direct personal benefits but as stated earlier may inform and guide planning

for water infrastructure for the area. This exercise might take about 5-8 minutes of your time to complete and all information provided will

be strictly treated CONFIDENTIAL and will only be used for this study purpose.

Do you have any question? May I proceed with the interview now?? THANKS!!!

Yes or No: Sign …… Date…….

DISTRICT KEY INFORMANT CHECKLIST

1. What are the main water sources in Kiryandongo District, Bweyale Town Council?
2. Do you have DWD manual for water source construction in the district?
3. How about a laboratory where you do a routine water quality testing?
4. When did you last conduct a water quality testing exercise in the district?
5. What support does your department offer towards safe water supply to the community in the

   District, Bweyale in terms of:-

   i. Bacteriological water quality management (frequency of sampling at source, household) for Hand-dug wells.
   ii.) Chemical Water quality management (Sampling for chemical analysis).
   iii. Sitting (Measurement from contamination point and dwelling).
   iv. Construction (Lining, depth, sizes of lining rings etc).

6. Challenges encountered when providing support service on water source construction and sitting in the district/ Bweyale in particular?

7. Is there need for improvements to increase quality of services?? What are those areas of improvement?

8. Do you have a plan for Improvement?

9. Any information you would wish to share regarding water and sanitation conditions in the district and its health effects (With recent examples)?

Thank you for your precious time.

Appendix 4: LOCAL MASON CHECKLIST

CONSENT STATEMENT.

The purpose of this study is for partial fulfillment of academic requirements for Master of Sciences in Public Health of International Health Sciences University.

The study is to investigate water and sanitation related issues including the prevalence of diarrhoea among the residents of Bweyale Town Council, bacteriological quality of Hand-dug wells water as well as clean and safe water management practices. The outcome of the study is expected to guide policy and planning of public water infrastructure in the District as well as inform water related risk management contingency planning process. It is also envisaged to generate further researchable questions which can help in improving self water supply in rural and urban setting.

I regret that your participation in this study will not have any direct personal benefits but as stated earlier may inform and guide planning

for water infrastructure for the area. This exercise might take about 5-8 minutes of your time to complete and all information provided will

be strictly treated CONFIDENTIAL and will only be used for this study purpose.

Do you have any question? May I proceed with the interview now?? THANKS!!!

Yes or No: Sign …… Date…….

1 What are the main water sources Bweyale Town Council?

2 Have you participated in the construction of the Hand-dug wellss in the District?

3 How many Masons are there in District or Bweyale Town Council who are involved in the construction of Hand-dug wells?

4 Describe the process of constructing a Hand-dug wells from the time of sitting up to when it is completed. (Guide along these areas)

- Design
- Sitting
- Excavation depth
- Lining
- disinfection
- Covering of wells
- Drainage and sanitation.

5 What materials do you use for construction including for;

i. Lining the hole

ii. Purification of the water in the hole

iii. Covering the hole

iv. Extraction of the water from the hole.

6 What support do you receive from the District or local authority in pursuance of your work of constructing Hand-dug wells

7 What are the challenges you face during the construction of the Hand-dug wells?

Appendix 5: CENTRAL LABORATORY RESULTS

NATIONAL WATER AND SEWERAGE CORPORATION
QUALITY CONTROL DEPARTMENT

Ref; KLA/CL/29A

Date: 29th September, 2011

International Health Sciences University

Re: Research for Mr. ICA DANIEL

This is to confirm that, **Mr. ICA DANIEL**, Reg. No.: **2010-MPH-FT-003**, carried out analysis of water samples from **Kiryandongo District** at our **Central Laboratory, Bugolobi** as part of his Research leading to the award of a **Masters of Science Degree in Public Health**.

Attached herewith are the results obtained.

NATIONAL WATER AND SEWERAGE CORPORATION
29 SEP 2011
THE CENTRAL LABORATORY

Patrick Busingye
For; PRINCIPAL QUALITY CONTROL OFFICER

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN): KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW1	8	4	1	2.07	200.32	3	2	6.2
HDW2	0	0	0	0.82	52.032	3	2	6.7
HDW3	5	2	1	3.84	106.816	3	2	5.5
HDW4	18	6	4	40.1	163.20	3	2	7.1
HDW5	0	0	0	6.04	50.048	3	2	6.3
HDW6	0	0	0	2.18	38.912	3	2	6.2
HDW7	4	2	0	1.38	55.936	3	2	7.4
HDW8	0	0	0	5.6	68.224	3	2	6.1

NATIONAL WATER AND SEWERAGE CORPORATION
29 SEP 2011
THE CENTRAL LABORATORY

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN): KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW9	8	3	0	4.59	76.48	3	2	6.3
HDW10	3	0	0	3.21	40.32	3	2	6.4
HDW11	0	0	0	1.89	73.024	3	2	6.8
HDW12	13	8	03	4.05	66.24	3	2	6.5
HDW13	10	6	2	0.4	32.576	3	2	6.4
HDW14	0	0	0	0.68	66.24	3	2	7.0
HDW15	16	08	01	1.14	47.616	3	2	6.0
HDW16	05	03	01	4.85	62.272	3	2	5.9

NATIONAL WATER AND SEWERAGE CORPORATION
29 SEP 2011
THE CENTRAL LABORATORY

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN): KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW17	0	0	0	18.10	72.128	3	2	6.2
HDW18	02	0	0	4.02	65.92	3	2	7.0
HDW19	0	0	0	5.2	98.368	4	2	6.4
HDW20	07	04	01	6.13	113.728	3	2	5.3
HDW21	0	0	0	0.39	76.8	4	2	6.2
HDW22	0	0	0	11.9	403.84	4	2	4.9
HDW23	0	0	0	1.78	90.688	3	2	6.4
HDW24	0	0	0	20.7	59.584	3	3	6.7

NATIONAL WATER AND SEWERAGE CORPORATION
23 SEP 2011
THE CENTRAL LABORATORY

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN); KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW25	13	08	04	4.78	061.504	3	2	6.4
HDW26	0	0	0	1.04	130.81	3	2	6.0
HDW27	0	0	0	1.34	129.28	3	2	6.0
HDW28	0	0	0	5.55	247.04	3	2	6.9
HDW29	07	04	01	4.10	61.696	4	1	6.6
HDW30	0	0	0	10.0	36.672	3	2	5.9
HDW31	0	0	0	0.57	68.672	3	2	6.1
HDW32	0	0	0	1.57	99.136	3	2	6.6

NATIONAL WATER AND SEWERAGE CORPORATION
29 SEP 2011
THE CENTRAL LABORATORY

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN): KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW33	06	03	01	2.95	323.2	3	2	7.5
HDW34	0	0	0	2.8	64.896	4	2	6.2
HDW35	0	0	0	0.66	60.544	3	2	6.3
HDW36	0	0	0	5.98	53.824	3	2	6.2
HDW37	0	0	0	4.9	35.008	3	2	6.0
HDW38	0	0	0	1.07	99.52	3	2	6.63
HDW39	0	0	0	12.9	110.784	3	2	7.0
HDW40	0	0	0	1.23	149.12	3	2	7.4

NATIONAL WATER AND SEWERAGE CORPORATION
29 SEP 2011
THE CENTRAL LABORATORY

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN): KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW41	0	0	0	5.19	114.24	3	2	6.9
HDW42	0	0	0	1.1	43.2	3	2	6.6
HDW43	0	0	0	3.13	72.384	3	2	6.4
HDW44	0	0	0	2.2	62.528	3	2	6.5
HDW45	0	0	0	1.6	70.72	3	2	6.8
HDW46	0	0	0	2.82	53.632	3	2	6.8
HDW47	0	0	0	4.8	74.688	3	2	6.5
HDW48	0	0	0	1.07	49.984	3	2	6.6

NATIONAL WATER AND SEWERAGE CORPORATION
29 SEP 2011
THE CENTRAL LABORATORY

WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN): KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW49	05	04	01	3.3	48.512	3	2	6.4
HDW50	0	0	0	1.06	46.08	3	2	6.2
HDW51	0	0	0	1.9	71.168	1	2	6.4
HDW52	0	0	0	0.9	109.76	3	2	6.5
HDW53	0	0	0	1.05	60.864	3	2	6.2
HDW54	0	0	0	8.64	120.832	1	2	6.6
HDW55	0	0	0	1.74	43.64	3	2	6.4
HDW56	0	0	0	1.30	51.04	3	2	6.1

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Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW57	0	0	0	1.08	136.21	3	2	6.8
HDW58	0	0	0	2.61	141.02	3	2	6.2
HDW59	0	0	0	1.14	98.34	3	2	6.4
HDW60	04	02	01	0.94	36.31	3	1	6.1
HDW61	0	0	0	2.20	73.40	3	2	6.3
HDW62	02	01	0	4.10	84.0	3	1	5.3
HDW63	04	02	01	3.80	130.94	3	2	5.5
HDW64	0	0	0	1.04	121.31	3	2	5.8

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Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW65	0	0	0	1.96	126.3	3	2	6.4
HDW66	0	0	0	2.10	121.0	3	2	6.1
HDW67	0	0	0	4.10	131.4	3	2	5.7
HDW68	0	0	0	3.60	121.40	3	2	5.8
HDW69	0	0	0	5.21	146.3	3	2	5.9
HDW70	10	06	03	11.40	151.6	3	2	7.1
HDW71	0	0	0	4.16	126.0	3	2	7.0
HDW72	0	0	0	1.40	113.6	3	2	6.8

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Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW73	0	0	0	4.36	63.81	3	2	5.80
HDW74	02	01	0	1.31	136.19	3	2	6.81
HDW75	0	0	0	3.14	58.31	3	2	6.94
HDW76	0	0	0	2.84	69.34	3	2	7.13
HDW77	0	0	0	1.34	130.4	3	2	6.5
HDW78	0	0	0	3.60	94.3	3	2	6.2
HDW79	0	0	0	1.06	110.8	3	2	5.5
HDW80	06	03	02	5.80	119.8	3	2	5.9

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Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW81	0	0	0	1.60	94.01	3	2	6.9
HDW82	0	0	0	0.94	51.09	3	2	7.1
HDW83	0	0	0	1.09	68.40	3	2	6.40
HDW84	0	0	0	1.10	71.01	3	2	6.8
HDW85	0	0	0	0.92	50.34	3	2	6.4
HDW86	0	0	0	1.93	130.1	3	2	5.6
HDW87	0	0	0	2.4	121.4	3	2	5.8
HDW88	0	0	0	2.91	114	3	2	6.3

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Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW89	0	0	0	3.1	130.20	3	2	6.1
HDW90	0	0	0	5.2	141.0	3	2	6.2
HDW91	0	0	0	1.6	119.30	4	3	5.4
HDW92	0	0	0	3.60	121.60	4	2	5.8
HDW93	0	0	0	3.40	118.30	3	2	6.2
HDW94	02	0	0	0.64	81.30	5	2	5.8
HDW95	04	02	01	1.73	64.0	1	2	5.9
HDW96	0	0	0	3.10	64.8	3	2	5.4

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WATER SAMPLE DATA SHEET (FOR PATRICK TO FILL IN) KENEDY DOES THE TASTE AND SMELL FOR EACH SAMPLE DELIVERED.

Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HDW97	0	0	0	3.8	79.80	3	2	6.4
HDW98	30	16	08	24.0	386	5	2	7.0
HDW99	0	0	0	1.81	40.8	3	2	6.3
HDW100	0	0	0	2.10	68.30	3	2	6.8
HDW101	0	0	0	3.4	84.0	3	2	6.9
HDW102	0	0	0	3.1	98.0	3	2	6.8
HDW103	03	01	0	2.4	91.3	1	3	6.3
HDW104	0	0	0	1.11	131	3	2	6.1

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Water Sample #	Total coliform count (per 100ml)	Faecal coliform count (per 100ml)	E.Coli count (per 100ml)	Turbidity (NTU)	TDS (mg/l)	Taste. 1) Salty 2) Bitter 3) Flat 4) Sweet 5) Rusty	Smell. 1) "Rotten eggs" 2) Flat Smell 3) Irritating	pH (1-14)
HSW105	0	0	0	3.1	140.3	2	1	6.8
HSW106	0	0	0	3.0	131	3	2	5.9

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