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By

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B.S., University of South Florida, 2019

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

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Abstract

Factors Associated with Household Water Quality in Rwandan Low-Income Households: A Cross-Sectional Analysis

By Katherine Millsaps

Background: Access to safe water is a human right and is one of the focuses for public health work and policies as it is included in the Sustainable Development Goal 6.1. The consumption of poor-quality water that has been contaminated with fecal matter from humans or animals puts humans at risk for diarrheal diseases and other illnesses that are linked to waterborne pathogens.

Aim: The aim of this study is to identify the factors associated with household drinking water quality among low-income Rwandan households. This was done by describing the household and water sample characteristics and using statistical modeling to determine which factors are associated with water quality. Additionally, water quality will be explored for differences across the 5 provinces of Rwanda.

Methods: The data used in this study were collected from a cross-sectional study in May and June of 2013 through a blend of random and convenience sampling with 480 households from 120 villages. Enumerators collected data from a household survey (i.e. household information, sociodemographic, water practices) as well as a water sample from drinking water. Thermotolerant coliforms (TTC) were used as a proxy indicator for water quality. The data were analyzed using crude and multivariate log binomial and linear regression models to find positive and negative predictors for both binary and log transformed continuous TTC.

Results: From the crude models, the factors associated with poor drinking water quality at the household level were storage container mouth type, toilet facility type, water source type, water fetching time, water fetching distance, purchasing water, SES quartile, and seasonality. In the linear regression, there were four predictors of TTC: water source type, SES quartile, seasonality, and province. The multivariate log binomial regression model did not identify any statistically significant associations.

Discussion: This analysis between household and water sample characteristics with water quality at a household level supports the conclusion that these household and source factors can influence fecal contamination, especially water source type and seasonality. Additionally, there should be future studies conducted to better understand the variation in water quality across provinces.

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List of Abbreviations

CFU: Colony Forming Unit

DALYs: Disability- Adjusted Life-Years

EPEC: Enteropathogenic *Escherichia coli*

ETEC: Enterotoxigenic *Escherichia coli*

EWSA: Energy, Water, and Sanitation Authority

HSW: Household Stored Water

HWF: Hierarchy Well-Formulated

JMP: Joint Monitoring Programme for Water Supply, Sanitation and Hygiene

LMIC: Low- and Middle-Income Countries

LRT: Likelihood Ratio Test

MDG: Millennium Development Goals

MINALOC: Ministry of Local Government

MINECOFIN: Ministry of Finance and Economic Planning

MINEDUC: Ministry of Education

MININFA: Ministry for Infrastructure

MoH: Ministry of Health

NISR: National Institute of Statistics of Rwanda

PoU: Point- of- Use

PR: Prevalence Ratio

SDG: Sustainable Development Goals

SES: Socioeconomic Status

SMDW: Safely Managed Drinking Water

TTC: Thermotolerant Coliforms

UN: United Nations

UNICEF: United Nations Children's Fund

VDP: Variance Decomposition Proportions

WASAC: Water and Sanitation Corporation

WASH: Water, Sanitation, and Hygiene

WHO: World Health Organization

1. Background

1.1 Global Information on Safe Water

Safe drinking water has been recognized as a human right as an essential part of human and environmental health and is vital to sustainable development globally (WHO & UNICEF, 2017; Shields et al., 2015; Bain et al., 2020). Access to safe drinking water has long been at focus of global policy and public health efforts, particularly in the last 50 years as indicated by the 1980s International Drinking Water Supply and Sanitation Decade, the Millennium Development Goals (MDGs) of 2000 and currently through the United Nations' (UN) Sustainable Development Goals (SDGs) established in 2015 (Shields et al., 2015). The SDG targets 6.1 and 6.2 aim to ensure availability and sustainable management of water for all by achieving universal and equitable access to affordable safely managed drinking water (SMDW) services by 2030 (WHO & UNICEF, 2017 & Bain et al., 2020). The Joint Monitoring Program for Water Supply, Sanitation and Hygiene (JMP) of the World Health Organization (WHO), along with the United Nations Children's Fund (UNICEF), have been globally monitoring and reporting on access to safe drinking water to track the progress of the SDGs, in addition to developing drinking water guidelines and indicators (Shields et al., 2015).

In developing countries, acute microbial diarrheal diseases are a major public health problem due to the lack of access to clean water and sanitation creating an environment for waterborne infections to be common, especially among those with the lowest finical resources and poorest hygienic facilities (Cabral, 2010). 6.8 billion people, 90% of the global population, have access to at least basic drinking water services, leaving 7.6 million people without access to safe drinking water (UNICEF & WHO, 2019). According to the JMP, there are nearly 600 million people globally who reported using surface water or unimproved drinking water sources. In 2017, 96.53% of urban worldwide households had access to safely managed or basic drinking water sources, which is reduced to 81.2% of rural households. There were 4,796,243,523 households with access to piped drinking water, while only 2,175,617,410 households used non-piped drinking water globally (JMP, 2017).

Those who are not using improved or basic drinking water sources are at a higher risk of consuming low microbiological quality water. In 2019, the rate of DALYs was 1244.3 per 100,000 for exposure to unsafe water, sanitation, and handwashing with nearly 80,000 of these DALYs attributed to enteric infections. Exposure to unsafe water source is a level 3 risk and was attributed to 1.23 million deaths in 2019 (Murray, et al., 2020). The greatest microbial risk is associated with the ingestion of fecally contaminated water, either from humans or animals (Clasen et al., 2015). The main etiologic agents associated with gastroenteritis are rotavirus, enterotoxigenic *Escherichia coli* (ETEC), enteropathogenic *Escherichia coli* (EPEC), *Cryptosporidium*, norovirus GI and II, and enteric adenovirus types 40 and 41 (Levine et al., 2012). Diarrheal episodes can last for several days and deplete the body of water, electrolytes, and salts resulting in severe dehydration, fluid loss, and in extreme cases, death (WHO, 2017). Enteric infectious that cause mild-to moderate episodes of diarrhea have been linked to developmental issues, especially in young children. Malnutrition and environmental enteropathy are both possible consequences of diarrhea, contributing to the malabsorption of nutrients which can lead to poor cognitive development, growth faltering, low birth weights, intrauterine growth retardation, and death (Blössner & de

Onis, 2005; Rogawski & Guerrant, 2017). There is a cyclic relationship with diarrhea and malnutrition as diarrhea is one of the major causes of malnutrition while malnourished children are more at risk for having diarrheal illnesses (WHO, 2017).

Diarrheal diseases were ranked 5th in the top causes of disability-adjusted life-years (DALYs) in 2019 for all ages, accounting for 3.2% of all DALYs (Vos et al.,2020). It was ranked 3rd in 2019 for children under 10 but was ranked lower for all other age groups (Vos et al., 2020). While diarrheal illness remains near the top DALYs causes, it is also in the 10 most important contributors to the overall declining burden since 1990 (Vos et al., 2020). In 2015, there were 1.1 million diarrheal disease caused deaths out of the 1.25 million deaths due to inadequate water source found from the global burden of disease study (Forouzanfar et al., 2016). Deaths caused by diarrheal diseases accounted for 3.36% of total deaths globally in 2013 of which 82.2% were attributed to the risk factor of using unsafe water sources. This increases when only looking at LMIC to 4.97% of all deaths caused by diarrheal disease with 83.82% attributed to unsafe water sources (IHME, 2015). Over 502,000 diarrhea deaths were estimated to be caused by unsafe drinking water in 2012 among low- and middle- income countries (LMIC) (Prüss-Ustün et al, 2014).

The WHO approved fecal indicator used as a proxy for microbial water quality in this study is thermotolerant coliforms (TTC) as it is an acceptable alternative to testing for *E.coli* and other waterborne bacterial pathogens. TTCs are total coliform bacterial that can ferment lactose at 44-45^{o} C and are seldomly found in the absence of fecal waste contamination (WHO, 2011). By WHO standards for safe drinking water, TTC cannot be detectable in 100 ml samples for verification of microbiological water quality; together with guidelines on chemical content, it is one of the recommended parameters for monitoring the risk of waterborne diseases (WHO, 2011). TTC is an appropriate indicator for the presence of the following bacterial pathogens: *Campylobacter* spp., *Escherichia coli, K.pneumoniae, Salmonella* spp., and *Shigella* spp. (WHO, 2011). These pathogens are commonly transmitted through fecal-oral pathways by person-to person contact or contaminated food or water with the strain varying from their original source being shed by a human or from animals such as cows, sheep, pigs, birds, and poultry (WHO, 2011). The WHO developed water quality risk categories according to the level of TTC CFUs per 100 mLs: Low risk (<1 TTC CFU/100 mL), Intermediate Risk (1 – 10 TTC CFU/100 mL), High Risk (10 – 100 TTC CFU/ 100 mL) and Very High Risk (>100 TTC CFU/ 100 mL) (WHO, 2011).

In low-income settings where piped water is unavailable or intermittent, householders must collect and transport water from a source and then store and access the water throughout the day. Numerous studies have shown that household drinking water is at risk for microbial contamination during and after collection from a main source, regardless of the original source's contamination or lack thereof (Wright et al., 2004). This type of post-source contamination has resulted in the consumption of unsafe drinking water from storage vessels within the household and may negate the efforts of water source interventions for quality and treatment. Several studies have shown PoU samples to have reduced microbiological water quality compared to that of the original source (Clasen, 2015). Additionally, Wright et al. (2004) was unable to find a situation where the water quality improved significantly from the source to the PoU while half the studies investigated had higher contamination levels for PoU than their sources.

The aim for this paper is to 1) analyze data collected on low-income Rwandan household practices and characteristics to identify factors associated with household water quality and 2) explore how water quality may differ based on province. This includes drinking water storage container type, treatment, access method, and storage time, household toilet facility type and sharing status of the facility, handwashing practices and frequency, household SES level, presence of animals, household flooring material, and water source type along with fetching factors like time (minutes) and distance (miles) from the household.

1.2 Rwanda, Water and Waterborne Diseases

Rwanda is a rapidly growing country located in East-Central Africa and is one of the African countries with the highest population density (Tsinda & Abbot, 2018). This country has high altitude levels nationally with a tropical temperate climate. Rwanda has 4 seasons through the year with a bimodal pattern of rainfall: 2 rainy seasons,1 large season from March to May and 1 short season from September to December, and 2 dry seasons (Didier et al., 2016). The number of Rwandan households is expected to increase from 2.4 million in 2012 to 5.3 million by 2032 mainly in urban areas. This quick population growth, in addition to the gaps in access to SMDW services already present, will increase the demand for water, sanitation, and hygiene (WASH) facilities and will require over 300 million USD to build and maintain basic

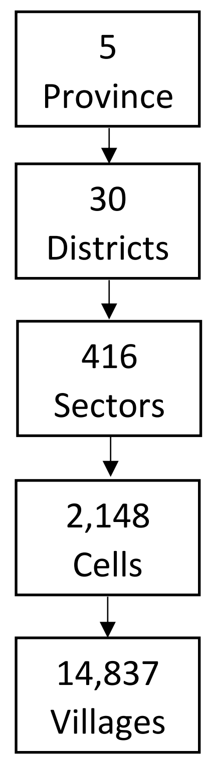

Figure 1: Rwanda's Structural Division

coverage on WASH amenities and safely managed drinking water services each year until 2030 to reach the SDG targets (Tsinda & Abbot, 2018).

In the 2005 reform, Rwanda has been divided into 5 provinces, one of which includes the capital – Kigali City. The geographic distribution of the provinces can been seen in Map 1. The provinces are further broken down into 30 districts. These districts are split inro 416 sectors which contain 2,148 cells collectively. Finally, within the cells there are 14,837 villages (Figure 1). There are also 2 layers of government, central and local, which are assisted by 6 administrative entities since the decentralization journey that started in 2001 (Republic of Rwanda, 2021).

Map 1: Provinces of Rwanda (Retrieved From: worldatlas.com/maps/rwanda)

In 2017, according to the JMP, only 57.71% of Rwanda's population had access to at least basic drinking water with 14% using unimproved drinking water sources. This is an increase in access from 2000 where only 45.44% of the population has access to basic drinking water. In rural areas, only 52.64% has access to basic drinking water while 82.24% of the urban population had access to safely managed or basic drinking water. Only 6.59% of Rwanda's urban population used unimproved drinking water sources in comparison to the 15.63% of the rural population. In 2017, 4,545,438 households in Rwanda have piped drinking water while 5,156,863 households used non-piped drinking water. The 5 provinces in Rwanda have varying coverage for basic and safely managed drinking water: 81.23% for Kigali City, 67.89% of Western province, 58.01% of the Northern province, 52.62% for the Southern province, and 51.82% of the Eastern province. The provinces with the highest reported use of surface water or an unimproved drinking water source was the Northern province at 27.83%, the Southern province at 27.53%, and the Eastern province at 22.95%. In comparison, only 17.14% of the Western province and 3.98% of Kigali City used unimproved or surface water sources (JMP, 2017).

Diarrheal disease was the 4th leading cause of all death in Rwanda in 2009 and the 3rd leading risk factor the drove the most death and disability was WASH (IHME, 2018). Deaths caused by diarrheal diseases accounted for 6.3% of all deaths in Rwanda in 2013 with 84.06% of those deaths attributed to the risk of having an unsafe water source. This burden increased to 10% of deaths for children under 5 and 10.96% of deaths for children between the ages of 5 and 14 with minimal variation between sex (IHME, 2015). In 2017, 57% of households were using basic drinking water services while 62% were reported to use basic sanitation services. Only 13% of rural households were using an improved water source located on plot while this number increased to 36% of urban households (GoR, 2018). Approximately 47.3% of Rwanda's population had access to an improved water supply within 500 meters of their homes (NISR, 2016) while 49% of households will spend 30 minutes or more on a round-trip to their water source (NISR, 2015). The number of households increased from 47% in 2010/11 to 84.8% in 2013/14 with access to improved drinking water when time and distance to the source was not considered (NISR, 2016). Unsafe water is ranked third as a risk-factor for disease in Rwanda while diarrhea in children under 5 is the leading cause of mortality and accounts for 9% of overall deaths (Forouzanfar et al., 2016). Kirby et al., (2016) found that 75% of households in a national cross-sectional study in Rwanda had detectable TTC contamination in their drinking water while only 24.9% of households met the WHO Guidelines for safe drinking water.

1.3 Factors Associated with Fecal Contamination of Household Drinking Water

There is a large body of evidence on the factors associated with fecal contamination of drinking water at the household level. These are summarized in Figure 2 and are described in detail in this section.

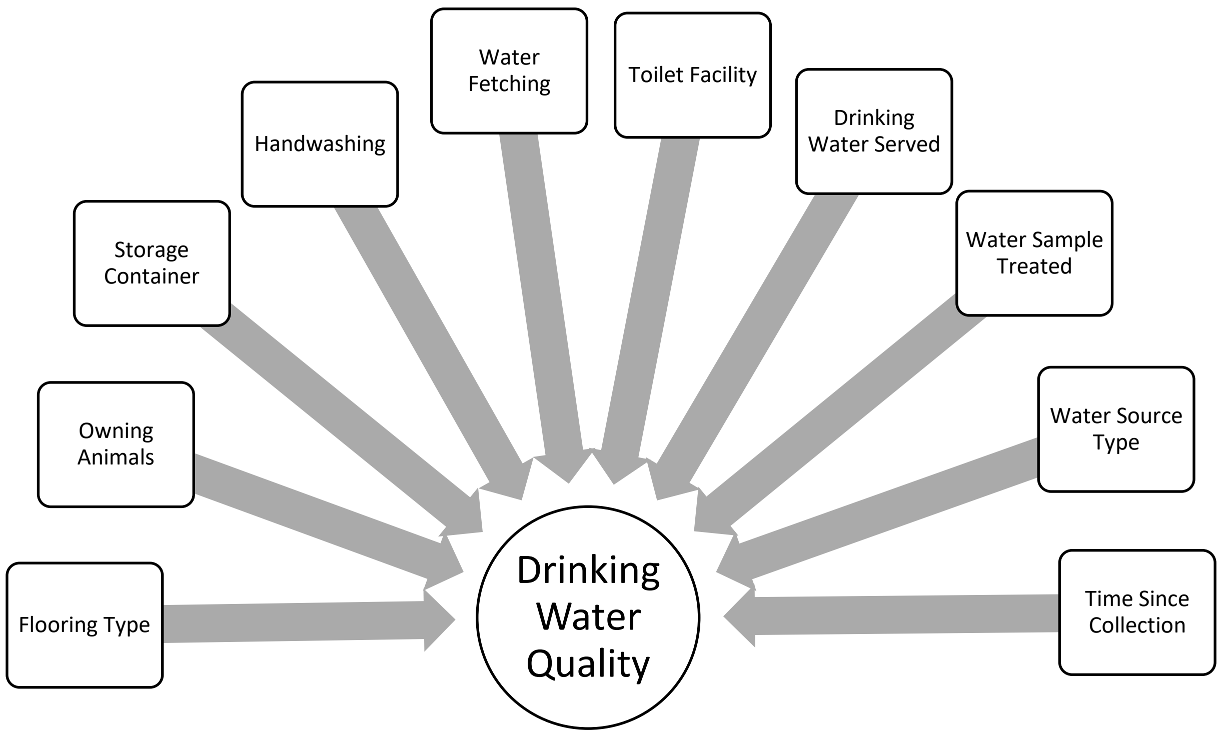

Figure 2: Identified Fecal Contamination Factors of Interest Impacting Household Drinking Water

1.3.1 Flooring Type

Soil and flooring have been found to have be a source with large numbers of fecal microbes, but these microbes are rarely ingested thus it remains a low-risk pathway for transmitting enteric pathogens even though the exposure frequency to this source is high especially for young children who tend to play on the floor (Wang et al.,2017). Harris et al. (2016) found 25% of household flooring samples positive for *E.coli* present and 27% had ruminant-associated bacterial target. Villages with high amounts of open defecation and less access to latrines were more likely to have higher fecal exposure from soil and floor due to more direct contact with feces (Wang el al., 2017).

1.3.2 Owning Animals

Waterborne bacterial disease-causing pathogens can be shed from animal feces and if they pollute water sources due to improper handling of waste, can contaminate drinking water (WHO, 2011). Animals commonly found on plot in Rwanda include chickens, pigs, sheep, goats, and cows, all of whom are known to carry various strains of *Salmonella* spp and *E.coli* (WHO, 2011). Domestic animal exposure has been found to have a positive association with enteric pathogens, especially between poultry and human campylobacteriosis (Zambrano et al., 2014). Kirby et al. (2016) found that chicken ownership was a risk factor associated with intermediate to high risk TTC contamination (>10 TTC/mL) of Rwandan household drinking water samples. Effective household fecal management needs to include animal sources to prevent contamination, not only human fecal sources (Harris et al., 2016).

1.3.3 Storage Container

The two major characteristics of storage containers used for drinking water explored in this study is the type of mouth (narrow vs wide) and if the container is covered. While some studies have not seen an association between household water storage practices with water quality (Kirby et al., 2016) others have found stored water samples to be frequently contaminated with *E.coli* (McGuinness, 2020). Badowski et al. (2011) found that even if households report using covered storage container to prevent contamination while in the home, several households were documented to be using uncovered storage bins. This study also found participants aware of the importance of safe drinking water but lacked acknowledgement of possible recontamination of drinking water from household members once it was stored (Badowski et al., 2011).

1.3.4 Handwashing

During the collection, transport, and storage of drinking water, the cleanliness of hands can be a factor with microbial contamination (Pickering et al., 2010). Hands are a link between environmental sources for enteric pathogens and oral ingestion since they are the central hub in the fecal microbes transfer network connecting all fecal exposure pathways (Wang et al., 2017). Pickering et al. (2010) found a positive correlation between levels of fecal contamination on mother's and children's hands with the quality of stored water. Handwashing before cooking or handling food products and before eating can reduce exposure to fecal contamination and are more protective compared to washing hands after eating (Wang et al., 2017). Additionally, insufficient handwashing was identified as a risk factor associated with enteric infections (Murray et al., 2020).

1.3.5 Water Fetching

The distance to and time taken to reach water sources for drinking water collection impacts the quantity of water in the home as well as the microbial water quality at risk for recontamination during transport. The average distance one-way to the water source for households with moderate-to-severe diarrhea was 200m and decreased to 117 m for households without diarrhea (Nygren et al., 2016). Pickering and Davis (2012) found a determinate of health in children under 5 to be the time spent walking to a household's main water source. There was a 41% reduction in children diarrhea prevalence associated with a 15-minute decrease in one-way walking time. In addition, the UN includes in the definition of improved water sources that they need to be within a 30-minute round-trip of travel time from the household.

1.3.6 Toilet Facility Type

Household toilet facility type should be taken into consideration when looking at post-collection contamination factors since there is a risk of coming into contact with human fecal waste which is known to contain bacterial pathogens that allow for waterborne transmission (WHO, 2011) . The JMP ladder for sanitation was used to classify the various toilet facility types for analysis either as open defecation, unimproved, or improved. Open defecation is defined as the disposal of human feces in fields, forests, bushes, open bodies of water, beaches, and other open spaces or with solid waste. A nationally representative study of household drinking water in Rwanda found that open waste dumping and use of unimproved toilet facilities were risk factors associated with thermotolerant coliform contamination levels (Kirby et al., 2016). Unimproved sanitation facilities are pit latrines without a slab or platform, hanging latrines, or bucket latrines. These toilet types will not completely protect against the risk of encountering fecal matter for users as well as the risk of environmental contamination. Improved sanitation facilities will avoid human contact with excreta if they are being safely managed, minimizing the risk of water contamination later due to unwashed hands interacting with stored water or directly contaminating water sources due to improper handling of excreta. The JMP further breaks down the improved facilities by limited, basic or safely managed status based on waste removal and if a facility is being shared with other households. For the purposes of this study shared status was looked at as a separate factor so the facility types considered to be improved are flush/pour flush to piped sewer system, septic tanks or pit latrines; ventilated improved pit latrines, composting toilets or pit latrines with slabs (UNICEF & WHO, 2019).

1.3.7 Accessing Drinking Water

The manner in which drinking water is access in the household has become the inspiration for several point-of-use interventions to improve microbiological water quality. There is a significant increase of *E.coli* concentration from the water source to the drinking cup and about 2/3rds od drinking vessels were found to be contaminated with *E.coli* from Rufener et al. (2010). Badowski et al. (2011) reported that some households tried to limit the means of accessing the stored drinking water by having a single cup tied to the storage bin that could not be drunk from thus forcing the member seeking water to pour it into another vessel for consumption.

1.3.8 Water Treatment

The microbial water quality of drinking water has been found to be improved by household water treatment, though methods such as boiling, filtration, or chemical disinfection like chlorination. These treatment methods enable the removal, killing, or inactivation of microbial fecal pathogens at the household level and reduce the risk of recontamination (Clasen, 2015). Drinking water has been found to be the only type of water undergoing any type of PoU treatment in households (Badowski et al., 2011). Distribution and promotion of chlorination products, flocculation, disinfection sachets, and point-of-use filtration systems were found to probably reduce diarrhoea (Clasen et al., 2015). It is important to note that these methods are dependent on consistent, long-term use for water treatment to be effective in improving drinking water quality (Clasen, 2015).

1.3.9 Water Source Type

Exposure to unsafe drinking water sources was identified as a risk factor associated with enteric illness (Murray et al., 2020). Shields et al. (2015) found that samples collected from piped water sources had significantly lower odds of contamination than non-piped water sources both at the source and household level. Kirby et al. (2016) found an increased odd of TTC contamination in households who did not use piped or rain/bottled water sources as well as a significant increase in odds of

TTC contamination for those using surface water sources. The WHO has categorized the type of water sources for drinking water into improved and unimproved sources. SMDWs include the water sources that fall into the improved category: Piped water into dwelling, yard, or plot; public tap or standpipe; tubewell or borehole; protected dug well; protected spring; and rainwater collection. The water source types that are considered to be unimproved are: unprotected dug wells; unprotected spring; cart with small tank or drum provided by water vendor; tanker truck or drum provided by water vendor; and bottled water (WHO, 2011). For this study, data was collected on each individual water source type based on the water source for the household water sample taken but have been placed into their respective WHO categories for analysis.

1.3.10 Time Since Water Collection

The time since household drinking water was collected from the main water source has been shown to have an effect on water recontamination (Wright et al., 2004). There have been studies that have shown an increase in water contamination over time at a household level. The amount of time in storage can be influence by seasonality as well due to the availability to water (Roberts et al., 2001).

2. Methods

2.1 Study Design

This is a secondary analysis of data collected from a study conducted in Rwanda to collect baseline data on cooking fuel, cooking practices, and water treatment practices to guide a carbon offset program. For the purposes of this paper, "water source" is used to refer to the point of collection for the household outside of the home while "household sample" will be referring to the sample enumerators collected during their visit for the qualitative questionnaire from drinking water sources within the household.

There were 6 main objectives of this cross-sectional study: (i) Examine current fuel and cooking practices; (ii) Examine heating and lighting practices; (iii) Examine household drinking water, sanitation, and hygiene practices, including water fetching, treatment, and storage; (iv) Examine household stored drinking water quality and percentage of households have access to clean water by Rwanda Ministry of Infrastructure (MinInfra) standards (0 coliform forming units [CFU/ml]); (v) Examine drinking water source quality; and (vi) Examine potential relationships of these determinates on self-reported health outcomes, community health worker treatment, and clinic visits. This analysis will focus on objectives 3 and 4 by looking for associations with factors of household level water quality based on data from household surveys and household drinking water samples. To accomplish this goal, we will use both descriptive statistics and statistical modeling to explore the findings of the data and discover areas for future research.

2.2 Sampling Strategy

The implementer of the study, DelAgua, wanted a household and main source water sample collected along with the household survey in all 30 districts of Rwanda. Figure 3 displays the geographic hierarchy in Rwanda. The implementer outlined the sampling process as randomly selecting 2 villages within each of the 30 districts, with these villages being from non-adjacent cells to increase geographic distribution and representation across a district. In addition, for each village already selected, another village in each cell was randomly selected in order to include the number of water sources sampled. There was a total of 4 villages in each of the districts with approximately 3-5 household surveyed within each village and 12-20 per district. Households were randomly selected from a master list of households under *ubudehe* categories 1 and 2 (2012 version), the two poorest wealth categories according to the

Government of Rwanda. The unit of analysis for this study is the household. This sampling strategy was unconventional and lead to convenient sampling based on which households had a respondent home and who wanted to participate. Enumerators had to work through the randomized list until enough households had been interviewed for each village. Sample weights were not developed so this study is not generalizable on a national level due to the inability to find parameter estimates.

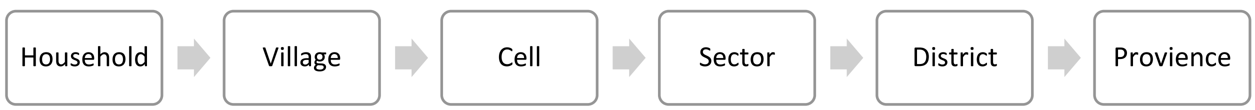

Figure 3: Geographic Hierarchy in Rwanda (Republic of Rwanda, 2021)

A limitation of this sampling design is that it is not self-weighting and cannot be representative of the larger population since it established non-probability sampling. They were unable to develop population-weighted sampling due to the lack of accurate population data at the village level available at the time of study design. Thus, it resulted in unequal probability of selection of villages regardless of the randomly selected households within each village.

2.3 Sample Size

The study collected information from 480 households from 120 villages based on sample size calculations for analyzing household water quality and survey objectives. The sample size was determined by using the calculation for a single proportion with 95% confidence as follows: $n = \frac{(1.96)^2 pq}{d^2}$; where p is the proportion of intrest with q=1-p and d=margin of error. The proportion of intrest for this study is the percent of households that have 0 theromotolerant coliforms (TTC) without a water filter. Thermotolerant coliforms is a World Health Organization (WHO) prescibed inficator of faecal contamination. It was determined that 21% of households without water filters had 0 TTC based on household water quality sampling in Rwanda by LSHTM. Using a 5% marginal error, the completed equation used to determine sample size was $n = \frac{(1.96)^2(0.21)(0.79)}{(0.05)^2} = 255$. Due to the data cleaning process and some data set merging issues, the study sample for this analysis is 443 households that have both households survey data and water sample information. (Figure 4) While this sample size is smaller than the ogrinally calculated one, it still provides reasonable amount of data for the description of the study population as well as finding possible assoications with water quality samples.

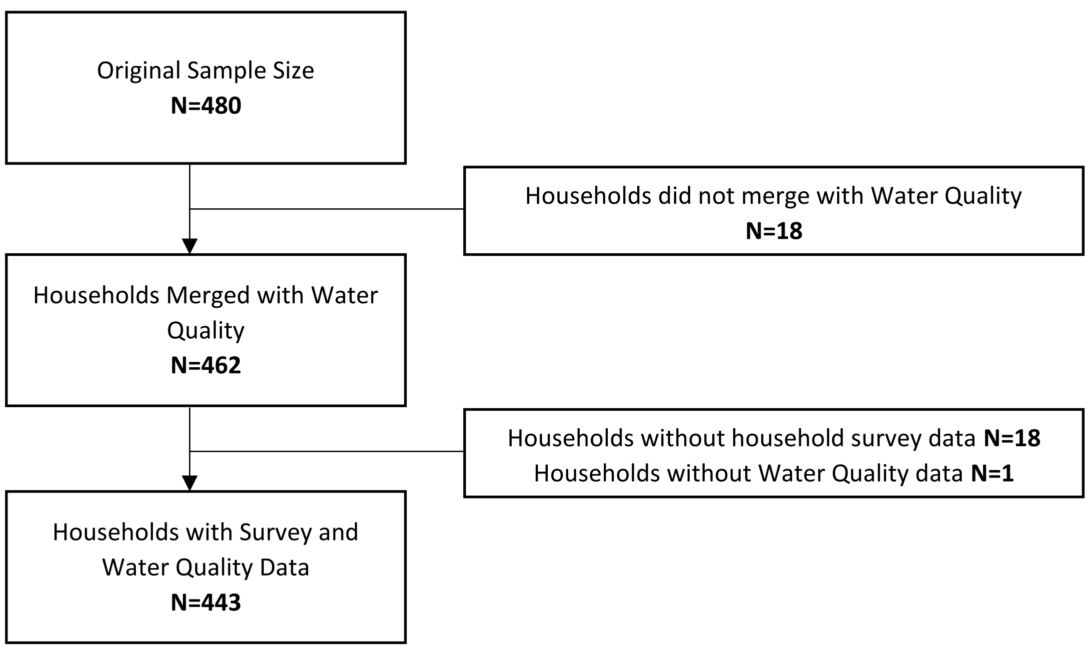

Figure 4: Sample Size Reduction Process

2.4 Sampling

Enumerators from DelAgua collected household surveys between May 16th, 2013 till June 16th, 2013 and collected water samples at the household on the same day as the questionnaire. Water samples were analyzed during the same time frame. The study time was toward the end of one of Rwanda's 2 rainy seasons, the March to May long rain season (Ntwali et al., 2016). Enumerators visited 120 villages across all 30 districts of the 5 provinces within Rwanda (Figure 5). Household belongs to either *Ubudehe* categories 1 or 2, a socio-economic classification system developed by the Ministry of Finance and Economic Planning and the Ministry of Local Government for collective action and mutual support (RGB, 2017). A household's *Ubudehe* category is determined by their perceived poverty and vulnerability status on a scale of 1 (most vulnerable) to 6 (least vulnerable. In 2013, 62.9% of *Ubudehe* 1 households fell into the bottom 2 wealth quintile along with 53.6% of *Ubudehe* 2 households (NISR, 2015).

Kigali	Northern Province	Southern Province	Eastern Province	Western Province
•Gasabo	•Burera	•Gisagara	•Bugesera	•Karongi
•Kicukiro	•Gakenke	•Huye	•Gatsibo	•Ngororero
•Nyarugenge	•Gicumbi	•Kamonyi	•Kayonza	•Nyabihu
	•Musanze	•Muhanga	•Kirehe	•Nyamasheke
	•Rulindo	•Nyamagabe	•Ngoma	•Rubavu
		•Nyanza	•Nyagatare	•Rusizi
		•Nyaruguru	•Rwamagana	•Rutsiro
		•Ruhango		

Figure 5: List of Districts by Province (Republic of Rwanda, 2021)

2.5 Measures

2.5.1 Household Surveys

Once a household consented to the study, the female head of household or other adult respondent was administered a survey which covered household demographics, socioeconomic status, cooking, lighting, and household drinking water practices, self-reported responded health, and child health, if children under 5 was a member of the household. Enumerators entered the survey data using DoForms™ software on smartphones who were trained by staff from London School of Hygiene and Tropical Medicine and also entered in observational data for each household visited. This analysis will pull variables from the survey sections on household demographics, household assets, handwashing practices, drinking water fetching, storage, and treatment practices.

2.5.2 Water Sample Collection and Processing

After the household drinking water practices section of the household survey, the enumerator made a request for a drinking water sample at the household and from the source used for the household's drinking water. Water samples were collected using sterile Whirl-Pak bags (Nasco, Fort Atkinson, WI) and placed on ice after collection for transportation. Water samples were processed within 6 hours of collection and examined for fecal contamination using TTC as an indicator. Membrane filtration (APHA 2001) was used on membrane lauryl sulphate medium (Oxoid Limited, Basingstoke, Hampshire, UK) by a DelAgua field incubator (DelAgua Water Testing Limited). If drinking water samples appeared turbid, 20 mL or 10 mL samples were used instead of 50 mL. Sample blanks were directed to be done routine each day but this has not been confirmed either due to the lab tech not writing this information down or not entering in the data from the blanks.

2.6 Data Management

To facilitate analysis, several variables required data cleaning, re-coding, and manipulation. This was preformed using STATA (64 bit, version 16) and will be described in this section.

2.6.1 Respondent Variables

Responded level of schooling was transformed into a binary variable as well as a categorical one to combine the response choices to be more manageable. For the binary variable responses were split into never completing primary school and any level of education above and including primary school completion. The categorical variable was split into 0) no schooling, 1) some preschool/ completed preschool/ some primary, 2) completed primary, 3) some vocational/completed vocational/some secondary, and 4) completed secondary and higher. The age of respondents was calculated by subtracting the year of birth from the date of the survey, 2013. For those who did not know their data of birth and responded with age in years, those values were replaced to be included in the respondent age variable.

2.6.2 Household Variables

The village of the household was collected by name and by an id number and both were used to cross-reference to correct mistakes that might have occurred during data entry to get the number of villages down to the intended 120 villages. Household flooring material was transformed into a binary variable by natural flooring materials such as earth, sand, or animal dug or as other types of materials such as wood, palm, ceramic tiles, cement, or bricks. Information from the household's *ubudehe* category, respondent's education level, and household assets such as, electricity, owning land, radio, phones, mattress, and bicycle, were used to develop a proxy variable for the socioeconomic status of the household. Flooring materials and owning animals were not used in the development of the proxy as they are being examined in the regression models independently. A Principal Component Analysis was conducted using the correlation matrix, so all variables had equal weight (Vyas & Kumaranayake, 2006). The scores given to each variable were then used to develop a continuous SES variable which was then used to categorize households which will be used in analysis. Due to the distribution of the SES proxy with the new scores, 41% of the population all fell within the same value, thus quartiles were developed instead of quintiles.

2.6.3 Household WASH Variables

Household toilet facilities were broken down into a categorical variable based off WHO/ UNICEF JMP's sanitation facility ladder classification scheme monitoring. Open defecation accounted for those who had no facilities or used bush/field; Unimproved facilities were pit latrines without a slab or platform, hanging latrines, or bucket latrines; Improved facilities were flush/pour toilets, ventilated pit latrines, pit latrines with slabs, or composting toilets. The 13 questioned handwashing occasions were entered in as a single string variable and had to be recoded into individual binary variables. They were then combined to find the total number of reported handwashing at critical times.

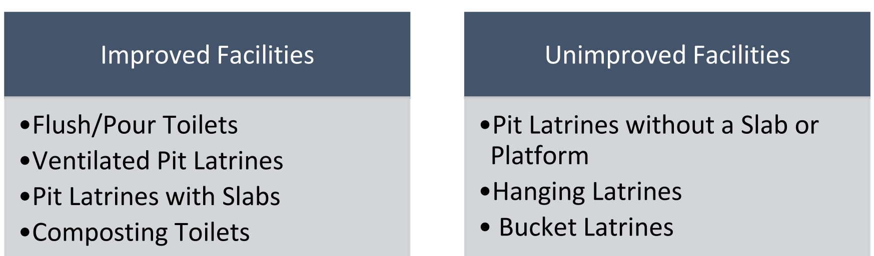

Figure 6: Improved and Unimproved Toilet Facilities per WHO/UNICEF JMP

2.6.4 Water Sample Variables

The household drinking water source responses were combined into a binary variable following WHO/ UNICEF JMP's water quality ladder classification scheme. Unimproved sources included surface water, unprotected spring, unprotected dug well, while improved water sources included protected springs, public tab/standpipe, rainwater, handpump, piped water, and protected dug/covered well (WHO,2011). The source information for the water sample collected at the households, some responded with same as usual source for rainy season or dry season and extra cleaning had to be performed to acquire the actual water source type as some participants responded with "Same source as usually used for drinking/other purpose water during rainy/dry season" rather than explicitly stating the source type for the sample collected. The value was populated based on the season of the survey and their response to what type of source was used in each season if different sources were used.

In a similar manner, the information for the distance and time taken to get to the water source was filled in from previous questions when needed. The distance to the water source was further broken down into a binary variable dependent on if it was more or less than 500 meters away based of the continuous distribution. The same was done for the time taken for a round trip dependent on if it was more or less than 30 minutes based off the original distribution. This time cut off is due the UN's inclusion of an improved water source being within a 30-minute round trip of the household. Seasonality was developed based off of the month when the water samples were collected. Samples collected in May were considered to be during the rainy season and samples collected in June were considered to be during the dry season. This categorization is based off the typical rainy and dry seasons Rwanda experiences annually.

Improved	Unimproved
•Protected Springs •Public Tap/ Standpipe •Rainwater •Hand Pump •Piped Water •Protected Dug/ Covered Well	•Surface Water •Unprotected Spring •Unprotected Dug Well

Figure 7: Improved and Unimproved Water Sources per the WHO/UNICEF JMP

2.6.5 Water Quality Variables

Thermal tolerant coliforms [TTC], a WHO-approved indicator of fecal contamination, was used as a proxy for waterborne-pathogen indicator organisms for modeling various characteristics potentially associated with water quality since there is a lack of a comprehensive method to estimate specific pathogens. We replaced the TTC CFU values where samples had too many colonies to count (TNTC) set at 300 CFU per mLs tested. The samples where no contamination was detected were set at 0.5 CFU per mLs tested, which is half the lower detection limit for membrane filtration. Any samples that tested less than 100 mL due to various dilutions being use had the TTC value converted to be reflective of 100 mL. Once these changes were made, we converted the counts into log10 TTC CFU/100 mL for analysis. The values were transformed to log10 to help achieve a normal distribution but TTC values still did not approximate a normal distribution after transformation. The transformation did improve the distribution but not by much due to the high number of samples with zero TTC/CFUs reported. Histograms of original water quality and log transformed can be found in Appendix 6.2. In addition, a binary variable and categorical variable were developed from the TTC CFU/100 mL to be used in modeling as well as descriptive statistics. The binary variable was dependent on if the water sample has no detectable TTC contamination (<1 TTC CFU/100 mL) or detectable TTC contamination (>=1 TTC CFU/100 mL). The categorical variable followed the cut points of the WHO drinking water risk groups: 1) Low Risk, <1 TTC CFU/100 mL; 2) Intermediate Risk, 1 – 10 CFU/100 mL; 3) High Risk, 11 - 100 CFU/100 mL; and 4) Very High Risk, >100 CFU/ 100 mL (WHO, 2011).

2.7 Data Analysis

Data were analyzed using STATA (64 bit, version 16) for descriptive analysis and SAS 9.4 for statistical modeling. The term “household characteristics” refers to the data collected from the DelAgua Household Survey, which can be found in the appendix with the questions used in this analysis. “Water Samples” refers to the samples collected from each household once the survey was completed, which thermotolerant coliform counts are the bacteria colony counts of the samples.

Continuous variables had mean and standard deviation reported while categorical and binary variables frequency and percentage reported. Two-sample t-test with equal variances were used to find the significance in the difference in mean for the continuous variables using H_0: diff=0 where diff=mean (non-contaminated water households)-mean (contaminated water households). Histograms of the distribution of continuous variables can be found in Appendix 6.2 which were used to develop categorical schemes described in the data manipulation section previously. To find the significance of the difference in proportions for household characteristics between the quality of water in the households, a two-sample t-test of proportions was preformed looking at H_0: diff=0 where diff=proportion (non-contaminated water households)-proportion (contaminated water households). Geometric mean, upper and lower 95% CIs and IQR was reported for the level of contamination from the water samples collected by province and water source type. Microsoft Excel was used to develop a histogram showing the distribution of water quality risk categories by province. At a level of $p <= 0.05$, results were statistically significant.

The relationship between the identified covariates and the water quality of the household samples were explored using a multivariate adjusted log binomial regression model and a multivariate adjusted linear regression model, dependent on the type of outcome measure. Since the outcome, having >=1 TTC CFU/100mL, is not rare (59.4% of households), log binomial regression was used for estimates with the binary water quality outcome. For the log-transformed continuous water quality outcome, multivariate linear regression was performed. Crude models were run for each of the predictors as well as for all possible effect modifiers or confounders.

After considering the literature, flooring type, owning animals, storage container mouth type, storage container covering, handwashing materials, handwashing frequency, toilet facility type, sharing toilet facilities, manner of serving drinking water, water source type, time since water collection, distance to water source, time to water source, water treatment, and manner for obtaining drinking water were included as covariates. The socioeconomic status proxy, seasonality, and province were included as potential effect modifiers or confounders. This process started with an examination for multicollinearity between the involved variables. A correlation matrix of Pearson Correlations was developed using PROC CORR, and variables were considered highly correlated with each other if they had a value of 0.8 or higher. Next, PROC REG was used to evaluate the variance inflation factor and tolerance. Variables were dropped if they had a variance inflation factor more than 10 or a tolerance value below 0.1

(Schreiber-Gregory, 2017). If variables were dropped due to a collinearity issue, the diagnosis test was rerun with the refitted model.

For all predictors used in the models, possible interaction terms were developed based on the literature and the DAG created for this study (Appendix 6.1). An interaction assessment was conducted on the initial model after the collinearity examination using a chunk test followed by backwards elimination if the likelihood ratio test (LRT) shows statistically significance of effect modification from one of the 30 product terms. The interaction term that was the least statistically significant and had a p>a, where a=0.1, was removed from the model and re-evaluated until all product terms reached statistical significance. Once the interaction assessment was complete, the models were assessed for confounding from the remaining variables, using the model after the interaction assessment as the gold standard for all others to be compared with for log binomial regression. Partial F-tests were conducted to examine the significance of the possible confounders for linear regression. All models retained variables needed to ensure that they were hierarchically well-formulated (HWF). Once a final model was selected, it was run to find prevalence ratios for the overall study population as well as for each province. This finalized model was used to run adjusted multivariate regression models to report beta values, 95% CI and p-value for all variables used in the model.

2.8 Ethics

Participants, either the male or female head of household, the primary cook of each participating household, or another adult, provided written informed consent. If they could not sign their name, they provided a thumbprint and literate witness signed on their behalf after ensuring total comprehension. The initial study protocol was reviewed and approved by the ethics committee at London School of Hygiene and

Tropical Medicine (LSHTM) (No.9069) and the Rwanda National Ethics Committee (No.460/2013).

3. Results

3.1 Study Population

A total of 443 households from 120 villages and all 30 districts were included in analysis as they met the eligibility criteria of currently having drinking water available at the household and a completed household questionnaire by a respondent at least 16 years of age. Target enrollment of 3-5 households per village was attained for 99 villages, with 14 being under 3 households and 7 exceeding 5 households. 91.7% of respondents were female with a mean age over 50 years old. 45.2% of respondents never attended or completed primary school with only 1.6% reported completing some secondary or higher education. The majority of the households fell under *ubudehe* category 2 as only 16.9% came from *ubudehe* category 1. The average number of occupants per household was 3.9 and did not differ based on water quality. Not all households had a child under the age of 5 but 151 households did (34.1%).

There was a low level of reported access to electricity since only 33 households (7.5%) overall confirmed this. The most reported household asset was owning a radio at 38.6% overall but was lower for households that met WHO guidelines at 33.9% compared to noncompliant households at 41.8%. 89.2% of all households reported to own land but it was slightly increased for households that had detectable TTC contamination (91.3%) compared to households without any detectable TTC contamination (86.1%). Owning animals was more common in households with <=1 TTC/100 mL than households with >1 TTC/100 mL at 45.3% and 36.7% retrospectively.

Household Characteristic, %(n)	All Households (N=443)	Households with <1 TTC CFU/100mL (N=180)	Households with >=1 TTC CFU/100mL (N=263)	p-value of difference
Respondent Information				
Mean Age of Respondent (SD)	50.1 (0.9)	52.9 (1.5)	48.2 (1.1)	0.012*
Respondents, Female	91.7% (406)	92.8% (167)	90.9% (239)	0.477
Respondent never attended school	45.2% (200)	48.3% (87)	43.0% (113)	0.265
Respondent completed primary	14.5% (64)	10.0% (18)	17.5% (46)	0.028*
Respondent completed some secondary or higher	1.6% (7)	1.7% (3)	1.5% (4)	0.904
Respondent at least completed primary	18.9% (84)	13.9% (25)	22.4% (59)	0.024*
Household information				
Province				
Kigali	7.9% (35)	6.7% (12)	8.7% (23)	0.426
Northern	17.2% (76)	25.6% (46)	11.4% (30)	0.0001*
Southern	27.5% (122)	31.7% (57)	24.7% (65)	0.108
Eastern	23.9% (106)	4.4% (8)	37.3% (98)	0.0001*
Western	23.5% (104)	31.7% (57)	17.9% (47)	0.001*
Households in *Ubudehe* 1	16.9% (75)	21.7% (39)	13.7% (36)	0.029*
Mean number of occupants (SD)	3.9 (0.1)	3.9 (0.2)	3.9 (0.1)	0.803
Mean number of adults 18 + (SD)	2.0 (0.1)	2.0 (0.1)	2.0 (0.1)	0.923
Mean number of children under 5 (SD)	0.4 (0.03)	0.4 (0.04)	0.5 (0.04)	0.112
Has electricity	7.5% (33)	7.8% (14)	7.2% (19)	0.828
Shares Toilet Facility	21.2% (94)	22.2% (40)	20.5% (54)	0.669
Practicing Open Defecation	7.0% (31)	5.6% (10)	8.0% (21)	0.325
Unimproved Toilet Facility	82.6% (366)	80.0% (144)	84.41% (222)	0.229
Improved Toilet Facility	10.2% (45)	13.9% (25)	7.6% (20)	0.032*
Dedicated Handwashing Facility	1.8% (8)	1.1% (2)	2.3% (6)	0.364
Households who buy water	20.8% (92)	26.7% (48)	16.7% (44)	0.011*
Natural Flooring Material	92.8% (411)	90.0% (162)	94.7% (249)	0.062
Has Radio	38.6% (171)	33.9% (61)	41.8% (110)	0.092
Has Phone	29.3% (130)	27.2% (49)	30.8% (81)	0.417
Has Mattress	32.1% (142)	30.0% (54)	33.5% (88)	0.443
Has Bicycle	5.4% (24)	2.2% (4)	7.6% (20)	0.014*
Owns Land	89.2% (395)	86.1% (155)	91.3% (240)	0.087
Owns Animals	41.8% (185)	36.7 % (66)	45.3% (119)	0.072

Table 1: Survey respondent and household characteristics. *statistically significant p-value

The characteristics that had a statistically significant difference of the mean or proportion between the household water sample contamination groups are respondent age (p-value=0.012), respondent completed primary school (p-value=0.028), respondent at least completed primary school (p-value=0.024), Northern province (p-value=0.0001), Eastern province (p-value=0.0001), Western province (p-value=0.001), *Ubudehe* category (p-value= 0.029), improved toilet facility (p-value= 0.032), buying water (0.011), and owning a bicycle (p-value=0.014). Additional household characteristics are found in Table 1.

3.2 Handwashing Trends

Handwashing practice information was collected from 441 households, the 2 that did not provide information were removed from this portion of the analysis. The handwashing occasion that had the highest response rate was after waking up in the morning at 81.2% while the lowest reported handwashing occasion was after cooking from 20 households (4.5%). The response differs based on household water sample contamination for before eating with those with no detectable TTC/ 100 mL at 82.8% (149 households) and those with TTC contamination at 75.1% (196 households). Reported handwashing after defecation is substantially low overall (19.1%) but is slightly higher for households with detectable contamination (21.8%). When looking at households who have animals (185 households), there was a low overall report (7.6 %) but it was higher for households with >=1 TTC/100 mL at 10.1%. From the 151 households that contained at least 1 occupant that was a child under 5 years old, the most commonly reported handwashing occasion was before feeding the child with 27.2% overall, 21.8% for household with no detectable contamination, and 30.2% for households with detectable contamination. There was not a statistically significant difference for any of the handwashing occasions between household water sample contamination groups. Additional details on the trends of handwashing practices are in Table 2.

Handwashing Occasion, %(n)	All Households (N=441)	Households with <1 TTC CFU/100 mL (N=180)	Households with >=1 TTC CFU/100mL (N=261)	p-value for difference of proportions
After Waking Up in the Morning	81.2% (358)	79.4% (143)	82.4% (215)	0.439
Before Eating	78.2% (345)	82.8% (149)	75.1% (196)	0.055
After Eating	23.1% (102)	23.9% (43)	22.6% (59)	0.753
After Cultivating	45.6% (201)	42.8% (77)	47.5% (124)	0.327
After Handling Rubbish	19.3% (85)	20.6% (37)	18.4% (48)	0.571
After Defecation	19.1% (54)	15.0% (27)	21.8% (57)	0.072
Before Cooking	19.9% (79)	15.0% (27)	19.9% (52)	0.185
After Cooking	4.5% (20)	5.0% (9)	4.2% (11)	0.697
After touching an animal	7.6% (14/185)	3.0% (2/66)	10.1% (12/119)	0.082
	All Households with at least 1 child under 5 (N=151)	**Households with <1 TTC CFU/100 mL and at least 1 child under 5 (N=55)**	**Households with >=1 TTC CFU/100mL and at least 1 child under 5 (N=96)**	**p-value for difference of proportions**
Before Feeding a Child	27.2% (41)	21.8% (12)	30.2% (29)	0.265
Before Bathing or Cleaning a Child	10.6% (16)	12.7% (7)	9.4% (9)	0.520
After Bathing or Cleaning a Child	7.3% (11)	5.5% (3)	8.3% (8)	0.512

Table 2: Self-Reported Trends in Handwashing Occasions by Household Water Sample Contamination.

3.3 Water quality results

Drinking water samples were collected from 443 households. When breaking down the samples into the WHO microbiological risk categories, 40.63% of all households (180 households) met WHO Guidelines of no detectable TTC contamination in 100 mL while 27.77% (123 households) of samples were considered high risk with >100 TTC/100 mL. Samples from the Northern and Western Provinces had the highest proportion of samples with no detectable TTC contamination. The province with the lowest proportion of samples meeting WHO guidelines was the Eastern Province with 7.5% of samples having no detectable TTC contamination. The Eastern Province also had the highest proportion of samples with a very high-risk contamination >100 TTC/100 mL (56.6%). Table 2 displays more details about the number of household water sample in WHO risk categories can be seen in Figure 8.

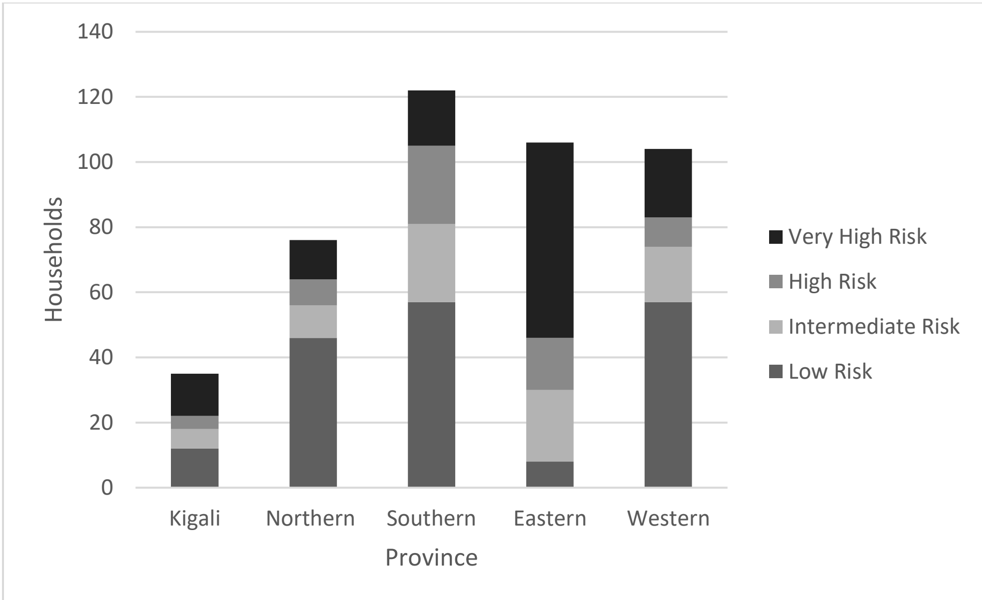

Figure 8: Distribution of Household Water Samples of Microbiological Risk Groups by Province

The geometric mean water quality overall was 7.9 TTC/100 mL (95% CI 6.1 – 10.3 TTC CFU/100 mL), with the Eastern Province having the highest contamination compared to other provinces (62.0 TTC CFU/100 mL; 95% CI 38.9 TTC CFU/100 mL). The province with the lowest contamination compared to the others is the Northern Province with a mean of 2.7 TTC CFU/100 mL (95% CI 1.6 – 4.7 TTC CFU/100 mL). Although water source type was self-reported can could be subject to misclassification, there is evidence that household water samples fetched from improved water source types were less contaminated than the household water samples collected from unimproved water sources with a mean TTC CFU/100 mL of 5.3 (95% CI 4.0 – 6.9 TTC CFU/100 mL) and 62.3 (95% CI 33.8 – 114.8 TTC CFU/100 mL) respectively. Supplementary details on the patterns of mean water quality and other statistics can be found in Table 3.

	n	Geometric Mean (CFU/100 mL)	Lower 95% CI	Upper 95% CI	Median (CFU/ 100 mL)	IQR (CFU/100 mL)
Overall	443	7.9	6.1	10.3	4	0.5 - 124
Kigali Province	35	12.1	4.4	33.2	6	0.5 - 262
Northern Province	76	2.7	1.6	4.7	0.5	0.5 – 14
Southern Province	122	4.2	2.7	6.4	2	0.5 - 30
Eastern Province	106	62.0	38.9	98.7	139	8 – 560
Western Province	104	3.9	2.3	6.6	0.5	0.5 – 39
Reported Water Source						
Unimproved *	67	62.3	33.8	114.8	114	18 – 382
Improved *	372	5.3	4.0	6.9	2	0.5 - 50

Table 3. Household drinking water quality by province and reported water source type. * Improved and Unimproved water sources according to JMP guidelines.

3.4 Factors being used in regression modeling

Table 4 lists out the reporting frequency of variables identified in Figure 2 which are being used in logistic regression models to explore any associations they might have with household water sample quality. Natural flooring (earth, sand, or animal dung) was reported by 90% of households without detectable TTC contamination but was slightly higher in households with detectable contamination (94.7%). 45.3% of households with >= 1 TTC CFU/100 mL in water samples collected reported owning animals while only 36.7% of households with <1 TTC CFU/100 mL. The average SES proxy value was higher for households with contamination in the water sample compared to household without contaminated water samples, 4.7 (SD 0.1) and 4.3 (SD 0.1) correspondingly.

The majority of storage containers has narrow mouth openings, 98.9% for households without detectable contamination and 95.1% for households with detectable contamination. There was lower reporting on having covered storage containers for household with a risk of contamination compared to household with low risk for contamination, 22.8% and 27.2% respectively. Similarly, 82.5% of households with detectable TTC in water samples reported having water and soap for handwashing while only 78.3% of households with no detectable TTC reported this. There is a strong change of over reporting on this factor since not all enumerators were able to confirm the presence of water, soap, or handwashing infrastructure in the homes. Households with <1 TTC CFU/ 100 mL reported 5.6% practicing open defecation, 80.0% with unimproved, 13.9% improved, and 22.2% shared toilet facilities. In comparison, households with >= 1 TTC CFU/ 100 mL reported 8.0% open defecation, 84.4% unimproved, 7.6% improved, and 20.5% shared toilet facilities. The majority of households reported pouring water from the storage container rather than drinking directly from or dipping a cup into the container, 91.1 % and 8.3% for no detectable TTC contamination samples while contaminated sample households reported 89.4% and 9.1%.

Households with no detectable TTC contamination reported collecting drinking water from an improved water source more than households with detectable TTC contamination, 94.4% compared to 76.8% respectively. In contrast, 21.7% of households that are noncompliant with WHO drinking water guidelines reported collecting from unimproved water sources but was lower for households who met the WHO drinking water guidelines at 5.6%. The average time since the household drinking water sample was collected was higher for households with detectable TTC contamination (18.5; SD 2.6) than households without detectable TTC contamination (13.5; SD 1.3). Households without the presence of contamination more commonly had a water source within 500 meters (40.0%) yet had a higher average distance to the source (774.3 meters, SD 322.1) compared to households with fecal contamination present in the drinking water sample (29.3%; 746.7 meters, SD 70.2). The average time taken for a round trip from the household to the water source was lower for households without contamination than those with contamination, 28.5 (SD 2.7) and 37.7 (SD 2.6) minutes respectively, yet this was reversed when looking at percentage of household that had a round trip less than 30 minutes with 29.7% of contaminated sample households and only 20.6% of non-contaminated sample households.

It was more common for all households to collect their drinking water than purchase it but more frequent amongst households with >=1 TTC CFU/100 mL (82.9%). Regardless of household sample water quality, there was extremely low reporting on treatment of the sample. Households without levels of contamination in water samples, more commonly were collected in the dry season comparted to households with contaminated water samples, 78.3% and 55.9% respectively. This relationship was reversed when looking at the samples collected in the rainy season, being more commonly from households with contaminated water samples (44.1%) compared to those without (21.7%).

The characteristics that had a statistically significant difference at $p<0.05$ of the mean or proportion between the household water sample contamination groups are using an improved toilet facility (p-value=0.032), water sample type (p-value=0.0001), water source distance less than 500 meters (p-value=0.047), mean time to water source (p-value=0.016) as well as water source less than 30 minutes (p-value=0.006),manner of obtaining water (p-value=0.011), mean SES proxy value (p-value=0.011), and seasonality (p-value=0.0001). Additional details of the factors used in the modeling can be found in Table 4.

Modeling Variable, % (n)	Households with <1 TTC CFU/100 mL (N=180)	Households with >=1 TTC CFU/100mL (N=263)	p-value for difference of proportions
Flooring Type			
Natural (Earth/Sand/Animal Dung)	90.0% (162)	94.7% (249)	0.062
Others (Wood/Palm/Ceramic Tiles/ Cement/ Brick)	10.0% (18)	5.3% (14)	0.062
Own Animals			
Yes	36.7% (66)	45.3% (119)	0.072
Chickens	4.4% (8)	8.4% (22)	0.107
Mean number of animals (SD)	2.4 (0.2)	3.6 (0.6)	0.151
Storage Container Type			
Wide Mouth	0.6% (1)	2.3% (6)	0.145
Narrow Mouth	98.9% (178)	95.1% (250)	
Covered Container	27.2% (49)	22.8% (60)	0.339
Handwashing			
Water Only	21.7% (39)	17.1% (45)	0.230
Water and Soap	78.3% (141)	82.5% (217)	
Mean for reported during critical times (SD)**	2.8 (0.1)	2.9 (0.1)	0.490
Toilet Facility Type			
Open Defecation	5.6% (10)	8.0% (21)	0.325
Unimproved	80.0% (144)	84.4% (222)	0.229
Improved	13.9% (25)	7.6% (20)	0.032 *
Shared	22.2% (40)	20.5% (54)	0.669
Manner for Serving Drinking Water			
Pour	91.1% (164)	89.4% (235)	0.749
Drink from/ dip cup into container	8.3% (15)	9.1% (24)	
Household Water Sample Source Type			
Unimproved	5.6% (10)	21.7% (57)	0.0001*
Improved	94.4% (170)	76.8% (202)	
Time Since Water Collected			
Mean hours (SD)	13.5 (1.3)	18.5 (2.6)	0.134
Water Fetching			
Mean Distance to Source (SD) (meters)	774.3 (322.1)	746.7 (70.2)	0.924
Water Source Less then 500 meters	40.0% (42)	29.3% (77)	0.047*
Mean Time to Source (SD) (mins)	28.5 (2.7)	37.7 (2.6)	0..016*
Water Source Less then 30 minutes	20.6% (37)	29.7% (78)	0.006*
Manner for Obtaining Drinking Water			
Purchase	26.7% (48)	16.7% (44)	0.011*
Collect	73.3% (132)	82.9% (218)	
Household Water Sample Treated	3.9% (7)	5.3% (14)	0.464
Mean SES Proxy Value (SD)	4.3 (0.1)	4.7 (0.1)	0.011*
Season			
Rainy	21.7% (39)	44.1% (116)	0.0001*
Dry	78.3% (141)	55.9% (147)	

Table 4: Modeling Variables by Household Water Sample Contamination. *Significant p-value **Since not all households had children under 5 or owned animals, the handwashing occasion involving children or animals were not taken into account in development of handwashing proxy indicator.

3.5 Log Binomial Regression

3.5.1 Crude Log Binomial Regression

Variable	Crude Models	Beta	95% CI	p-value
Not Natural Flooring Material	$\ln(P(TTC=1)) = \alpha + \beta_1 FLOOR$	-0.33	-0.73, 0.08	0.1112
Own Animals	$\ln(P(TTC=1)) = \alpha + \beta_1 OWNAN$	0.14	-0.01, 0.29	0.0684
Storage Container Narrow Mouth	$\ln(P(TTC=1)) = \alpha + \beta_1 MOUTH$	-0.39	-0.61, -0.18	0.0003*
Storage Container Covered	$\ln(P(TTC=1)) = \alpha + \beta_1 COVERED$	-0.10	-0.29, 0.10	0.3075
Handwashing Materials Available	$\ln(P(TTC=1)) = \alpha + \beta_1 HW\_MAT$	0.14	-0.08, 0.36	0.2178
Handwashing Frequency	$\ln(P(TTC=1)) = \alpha + \beta_1 HW\_FRQ$	0.02	-0.05, 0.08	0.6261
Improved Toilet Facility	$\ln(P(TTC=1)) = \alpha + \beta_1 TOILET\_T$	-0.19	-0.35, -0.02	0.0298*
Toilet Facility Shared	$\ln(P(TTC=1)) = \alpha + \beta_1 TOILET\_S$	-0.04	-0.24, 0.15	0.6745
Drinking Water Served by Pour	$\ln(P(TTC=1)) = \alpha + \beta_1 WTR\_SEV$	-0.08	-0.32, 0.16	0.5238
Improved Water Source	$\ln(P(TTC=1)) = \alpha + \beta_1 SAM\_SC$	-0.46	-0.59, -0.33	<0.0001*
Time Since Collection	$\ln(P(TTC=1)) = \alpha + \beta_1 CO\_HRS$	0.0005	-0.001, 0.002	0.6226
Fetching Distance >=500 meters	$\ln(P(TTC=1)) = \alpha + \beta_1 FETCH\_D$	-0.14	-0.29, 0.02	0.0801
Water Fetching Time >=30 mins	$\ln(P(TTC=1)) = \alpha + \beta_1 FETCH\_T$	-0.19	-0.34, -0.03	0.0174*
Water Purchased	$\ln(P(TTC=1)) = \alpha + \beta_1 BUY\_CO$	-0.27	-0.49, -0.04	0.0225*
Water Treated	$\ln(P(TTC=1)) = \alpha + \beta_1 SAM\_TR$	0.12	-0.19, 0.43	0.4442
SES Quartiles	$\ln(P(TTC=1)) = \alpha + \beta_1 SES\_Q$	0.05	0.01, 0.10	0.0299*
Rainy Season	$\ln(P(TTC=1)) = \alpha + \beta_1 SEASON$	0.38	0.24, 0.53	<0.0001*
Province	$\ln(P(TTC=1)) = \alpha + \beta_1 PROVINCE$	0.04	-0.02, 0.09	0.2352

Table 5: Estimates from Crude Log Binominal Regression Models *statistically significant p-value

Crude log binominal regression models were run for each of the predictors as well as for the potential effect modifiers, this information is displayed in Table 5. The variables that had a statistically significant relationship with water quality were storage containers with narrow mouths (p-value=0.0003), improved household toilet facility (p-value=0.0298), improved water source (p-value<0.0001), water fetching time more or equal to 30 minutes(p-value=0.0174), purchasing water (p-value=0.0225), SES quartile status (p-value= 0.0299), and rainy season (p-value <0.0001). The factors that contributed to lower levels of TTC concentration are non-natural flooring materials, narrow mouthed storage containers, covered storage containers, improved toilet facilities, shared toilet facilities, serving water by pouring it, improved water source, fetching distance more or equal to 500 meters, fetching time more or equal to 30 minutes, and purchased water. The factors contributing to higher levels of TTC concentration are owning animals, having handwashing materials available, handwashing frequency, hours since water was collected, treated water sample, SES quartile status, rainy season and province.

3.5.2 Multivariable Log Binomial Regression

This model below was used to evaluate the associations between water quality of household drinking water (binary) with flooring type, owning animals, storage container mouth type, storage container covering, handwashing materials, handwashing frequency, toilet facility type, sharing toilet facilities, manner of serving drinking water, water source type, time since water collection, distance to water source, time to water source, water treatment, and manner for obtaining drinking water, while considering potential effect modification of this correlation by socioeconomic status, seasonality, and province.

Initial Model

$$\ln (P(TTC=1)) = \alpha + \beta_1 FLOOR + \beta_2 OWNAN + \beta_3 MOUTH + \beta_4 COVERED + \beta_5 HW\_MAT + \beta_6 HW\_FRQ + \beta_7 TOILET\_T + \beta_8 TOILET\_S + \beta_9 WTR\_SEV + \beta_{10} SAM\_SC + \beta_{11} SAM\_TR + \beta_{12} CO\_HRS + \beta_{13} FETCH\_D + \beta_{14} FETCH\_T + \beta_{15} BUY\_CO + \gamma_1 SES + \gamma_2 SEASON + \gamma_3 PROVINCE + \delta_1 FLOOR*SES + \delta_2 OWNAN*SES + \delta_3 MOUTH*SES + \delta_4 COVERED*SES + \delta_5 HW\_MAT*SES + \delta_6 HW\_FRQ*SES + \delta_7 TOILET\_T*SES + \delta_8 TOILET\_S*SES + \delta_9 WTR\_SEV*SES + \delta_{10} SAM\_SC*SES + \delta_{11} SAM\_TR*SES + \delta_{12} CO\_HRS*SES + \delta_{13} FETCH\_D*SES + \delta_{14} FETCH\_T*SES + \delta_{15} BUY\_CO*SES + \delta_{16} FLOOR*SEASON + \delta_{17} OWNAN*SEASON + \delta_{18} MOUTH*SEASON + \delta_{19} COVERED*SEASON + \delta_{20} HW\_MAT*SEASON + \delta_{21} HW\_FRQ*SEASON + \delta_{22} TOILET\_T*SEASON + \delta_{23} TOILET\_S*SEASON + \delta_{24} WTR\_SEV*SEASON + \delta_{25} SAM\_SC*SEASON + \delta_{26} SAM\_TR*SEASON + \delta_{27} CO\_HRS*SEASON + \delta_{28} FETCH\_D*SEASON + \delta_{29} FETCH\_T*SEASON + \delta_{30} BUY\_CO*SEASON + \delta_{31} FLOOR*PROVINCE + \delta_{32} OWNAN*PROVINCE + \delta_{33} MOUTH*PROVINCE + \delta_{34} COVERED*PROVINCE + \delta_{35} HW\_MAT*PROVINCE + \delta_{36} HW\_FRQ*PROVINCE + \delta_{37} TOILET\_T*PROVINCE + \delta_{38} TOILET\_S*PROVINCE + \delta_{39} WTR\_SEV*PROVINCE + \delta_{40} SAM\_SC*PROVINCE + \delta_{41} SAM\_TR*PROVINCE + \delta_{42} CO\_HRS*PROVINCE + \delta_{43} FETCH\_D*PROVINCE + \delta_{44} FETCH\_T*PROVINCE + \delta_{45} BUY\_CO*PROVINCE$$

3.5.3 Multicollinearity Evaluation

A correlation matrix was developed and can be found in Appendix 6.3 using Pearson Correlation. While there were multiple variables with statistically significant relationships, none were considered to be highly correlated with each other as all values were less than 0.8. After the multicollinearity diagnostics were conducted, none of the predictors or effect modifiers were dropped from the modeling process as all variance inflation factors were under 10 (min=1.08, max=1.51) and all tolerance values were above 0.1 (min=0.66, max=0.92).

3.5.4 Interaction Assessment

Interaction was assessed for all predictors for impacts from the effect modifiers, SES quartiles and seasonality by running the full model as well as a reduced model without any of the interaction terms. Storage Container Mouth Type did not produce values when in an interaction term with season or province, thus these product terms were eliminated before the chunk test. The likelihood ratio test produced a Chi-Square value of 61.77 with 43 degrees of freedom and a p-value of 0.0317, promoting the process of backward elimination to start dropping product terms. In the end, all product terms were removed since they were all p>a with a=0.1.

3.5.5 Confounding Assessment

<u>Gold Standard Model</u>

$$\ln (P(TTC=1)) = \alpha + \beta_1 FLOOR + \beta_2 OWNAN + \beta_3 MOUTH + \beta_4 COVERED + \beta_5 HW\_MAT + \beta_6 HW\_FRQ + \beta_7 TOILET\_T + \beta_8 TOILET\_S + \beta_9 WTR\_SEV + \beta_{10} SAM\_SC + \beta_{11} SAM\_TR + \beta_{12} CO\_HRS + \beta_{13} FETCH\_D + \beta_{14} FETCH\_T + \beta_{15} BUY\_CO + \gamma_1 SES + \gamma_2 SEASON + \gamma_3 PROVINCE$$

Using the gold standard model developed from the interaction assessment, SES quartiles, seasonality, and province are eligible to be investigated for confounding. Table

6 displays the various models that were used to investigate the possibility of cofounding by removing the possible confounders. The data did not suggest evidence of confounding by socioeconomic quartiles, so it was removed from the final model. However, based off evidence in the literature and the confounding assessment results, seasonality and province were retained for the final multivariate log binomial regression model.

Model #	Variables in Model	Variable Dropped from Model	PR	95% CI	Within 10% of Gold Standard?	Experience of Confounding by Dropped Variable?
1	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q, SEASON, PROV		0.85	0.58, 1.25		
2	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SEASON, PROV	SES_Q	0.87	0.60, 1.28	Yes	No
3	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q, PROV	SEASON	0.78	0.52, 1.16	Yes	No
4	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q, SEASON	PROV	0.79	0.50, 1.25	Yes	No
5	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, PROV	SES_Q, SEASON	0.81	0.55, 1.20	Yes	No
6	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SEASON	SES_Q, PROV	0.84	0.55, 1.26	Yes	No
7	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q	SEASON, PROV	0.73	0.46, 1.15	No	Yes
8	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO	SES_Q, SEASON, PROV	0.80	0.54, 1.19	Yes	No

Table 6: Confounding Assessment of Multivariate Log Binomial Regression Models

3.5.6 Adjusted Multivariate Log Binomial Regression

Final Model – Binary

$$\ln(P(TTC=1)) = \alpha + \beta_1 FLOOR + \beta_2 OWNAN + \beta_3 MOUTH + \beta_4 COVERED + \beta_5 HW\_MAT + \beta_6 HW\_FRQ + \beta_7 TOILET\_T + \beta_8 TOILET\_S + \beta_9 WTR\_SEV + \beta_{10} SAM\_SC + \beta_{11} SAM\_TR + \beta_{12} CO\_HRS + \beta_{13} FETCH\_D + \beta_{14} FETCH\_T + \beta_{15} BUY\_CO + \gamma_1 SEASON + \gamma_2 PROVINCE$$

The PR for the full model listed above is 0.88, yet this was not found to be statistically significant with a 95% CI (0.60,1.28) and a p-value=0.4979. Due to missing values, this is representative for 442 households included in this analysis. Table 7 shows beta estimates for each of the covariates in the final model. None of the values were statistically significant but we did find which factors contributed to a reduction or increase in water contamination. Factors associated with lower water contamination levels are non-natural flooring material, narrow mouthed storage containers, covered storage containers, improved toilet facilities, improved water source, water fetching distance more that 500 meters from household, fetching time more than 30 minutes from household, and water that was purchased. The factors associated with higher water contamination levels are owning animals, having handwashing materials, handwashing frequency, sharing a toilet facility, pouring drinking water to serve it, treating the water sample, rainy season samples, and province. The lack of significance among the predictors may be due to the variability in the data and wide confidence intervals.

Variable	Beta	95% CI	p-value
Not Natural Flooring Material	-0.06	-0.03, 0.03	0.5098
Own Animals	0.02	-0.02, 0.05	0.6088
Storage Container Narrow Mouth	-0.05	-0.19, 0.10	0.7502
Storage Container Covered	-0.01	-0.05, 0.03	0.8375
Handwashing Materials Available	0.01	-0.03, 0.06	0.7847
Handwashing Frequency	0.005	-0.01, 0.02	0.7895
Improved Toilet Facility	-0.02	-0.07, 0.03	0.6455
Toilet Facility Shared	0.005	-0.04, 0.05	0.9141
Drinking Water Served by Pour	0.02	-0.05, 0.08	0.7839
Improved Water Source	-0.08	-0.14, -0.02	0.1688
Water Sample Treated	0.06	-0.04, 0.16	0.5413
Time Since Collection	0.0003	-0.0005, 0.001	0.7415
Fetching Distance >=500 meters	-0.001	-0.05, 0.04	0.9775
Water Fetching Time >=30 mins	-0.02	-0.06, 0.03	0.6718
Water Purchased	-0.01	-0.06, 0.04	0.8118
Rainy Season	0.08	0.03, 0.12	0.0909
Province	0.02	0.002, 0.03	0.2635

Table 7: Factors Associated with Water Quality for a Binary Outcome

3.6 Linear Regression

3.6.1 Crude Linear Regression

Variable	Crude Models	Beta	95% CI	p-value
Not Natural Flooring Material	$(\log TTC) = \alpha + \beta_1 FLOOR$	-0.16	-0.60, 0.28	0.4842
Own Animals	$(\log TTC) = \alpha + \beta_1 OWNAN$	0.19	-0.04. 0.42	0.1046
Storage Container Narrow Mouth	$(\log TTC) = \alpha + \beta_1 MOUTH$	-0.74	-1.37, -0.12	0.0204*
Storage Container Covered	$(\log TTC) = \alpha + \beta_1 COVERED$	-0.01	-0.28, 0.25	0.9203
Handwashing Materials Available	$(\log TTC) = \alpha + \beta_1 HW\_MAT$	0.21	-0.08, 0.50	0.1475
Handwashing Frequency	$(\log TTC) = \alpha + \beta_1 HW\_FRQ$	0.07	-0.03, 0.17	0.1913
Improved Toilet Facility	$(\log TTC) = \alpha + \beta_1 TOILET\_T$	-0.29	-0.56, -0.01	0.0401*
Toilet Facility Shared	$(\log TTC) = \alpha + \beta_1 TOILET\_S$	-0.10	-0.38, 0.18	0.4742
Drinking Water Served by Pour	$(\log TTC) = \alpha + \beta_1 WTR\_SEV$	-0.10	-0.48, 0.28	0.6193
Improved Water Source	$(\log TTC) = \alpha + \beta_1 SAM\_SC$	-1.07	-1.37, -0.78	<.0001*
Time Since Collection	$(\log TTC) = \alpha + \beta_1 CO\_HRS$	0.001	-0.002, 0.004	0.5987
Fetching Distance >=500 meters	$(\log TTC) = \alpha + \beta_1 FETCH\_D$	-0.26	-0.51, -0.02	0.0312*
Water Fetching Time >=30 mins	$(\log TTC) = \alpha + \beta_1 FETCH\_T$	-0.34	-0.58, -0.10	0.0053*
Water Purchased	$(\log TTC) = \alpha + \beta_1 BUY\_CO$	-0.35	-0.63, -0.07	0.0138*
Water Treated	$(\log TTC) = \alpha + \beta_1 SAM\_TR$	0.19	-0.35, 0.73	0.4846
SES Quartiles	$(\log TTC) = \alpha + \beta_1 SES\_Q$	0.09	0.02, 0.16	0.0146*
Rainy Season	$(\log TTC) = \alpha + \beta_1 SEASON$	0.61	0.38, 0.84	<.0001*
Province	$(\log TTC) = \alpha + \beta_1 PROVINCE$	0.08	-0.01, 0.17	0.0955

Table 8: Estimates from Crude Linear Regression Models *statistically significant p-value

Crude linear regression models were run for each of the predictors as well as for the potential effect modifiers, this information is displayed in Table 8. The variables that had a statistically significant relationship with water quality were storage containers with narrow mouths (p-value=0.0204), improved household toilet facility (p-value=0.0407), improved water source (p-value<0.0001), water fetching distance more or equal to 500 meters (p-value = 0.0312), water fetching time more or equal to 30 minutes(p-value=0.0053), purchasing water (p-value=0.0138), SES quartile status (p-value= 0.0146), and rainy season (p-value <0.0001). The factors that contributed to lower levels of TTC concentration are non-natural flooring materials, narrow mouthed storage containers, covered storage containers, improved toilet facilities, shared toilet facilities, serving water by pouring it, improved water source, fetching distance more or equal to 500 meters, fetching time more or equal to 30 minutes, and purchased water. The factors contributing to higher levels of TTC concentration are owning animals, having handwashing materials available, handwashing frequency, hours since water was collected, treated water sample, SES quartile status, rainy season, and province.

3.6.2 Multivariate Linear Regression

The model below was used to evaluate the associations between water quality of household drinking water (continuous) with flooring type, owning animals, storage container mouth type, storage container covering, handwashing materials, handwashing frequency, toilet facility type, sharing toilet facilities, manner of serving drinking water, water source type, time since water collection, distance to water source, time to water source, water treatment, and manner for obtaining drinking water, while considering potential effect modification of this correlation by socioeconomic status, seasonality, and province.

Initial Model

$$(\log TTC) = \alpha + \beta_1 FLOOR + \beta_2 OWNAN + \beta_3 MOUTH + \beta_4 COVERED + \beta_5 HW\_MAT + \beta_6 HW\_FRQ + \beta_7 TOILET\_T + \beta_8 TOILET\_S + \beta_9 WTR\_SEV + \beta_{10} SAM\_SC + \beta_{11} SAM\_TR + \beta_{12} CO\_HRS + \beta_{13} FETCH\_D + \beta_{14} FETCH\_T + \beta_{15} BUY\_CO + \gamma_1 SES + \gamma_2 SEASON + \gamma_3 PROVINCE + \delta_1 FLOOR*SES + \delta_2 OWNAN*SES + \delta_3 MOUTH*SES + \delta_4 COVERED*SES + \delta_5 HW\_MAT*SES + \delta_6 HW\_FRQ*SES + \delta_7 TOILET\_T*SES + \delta_8 TOILET\_S*SES + \delta_9 WTR\_SEV*SES + \delta_{10} SAM\_SC*SES + \delta_{11} SAM\_TR*SES + \delta_{12} CO\_HRS*SES + \delta_{13} FETCH\_D*SES + \delta_{14} FETCH\_T*SES + \delta_{15} BUY\_CO*SES + \delta_{16} FLOOR*SEASON + \delta_{17} OWNAN*SEASON + \delta_{18} MOUTH*SEASON + \delta_{19} COVERED*SEASON + \delta_{20} HW\_MAT*SEASON + \delta_{21} HW\_FRQ*SEASON + \delta_{22} TOILET\_T*SEASON + \delta_{23} TOILET\_S*SEASON + \delta_{24} WTR\_SEV*SEASON + \delta_{25} SAM\_SC*SEASON + \delta_{26} SAM\_TR*SEASON + \delta_{27} CO\_HRS*SEASON + \delta_{28} FETCH\_D*SEASON + \delta_{29} FETCH\_T*SEASON + \delta_{30} BUY\_CO*SEASON + \delta_{31} FLOOR*PROVINCE + \delta_{32} OWNAN*PROVINCE + \delta_{33} MOUTH*PROVINCE + \delta_{34} COVERED*PROVINCE + \delta_{35} HW\_MAT*PROVINCE + \delta_{36} HW\_FRQ*PROVINCE + \delta_{37} TOILET\_T*PROVINCE + \delta_{38} TOILET\_S*PROVINCE + \delta_{39} WTR\_SEV*PROVINCE + \delta_{40} SAM\_SC*PROVINCE + \delta_{41} SAM\_TR*PROVINCE + \delta_{42} CO\_HRS*PROVINCE + \delta_{43} FETCH\_D*PROVINCE + \delta_{44} FETCH\_T*PROVINCE + \delta_{45} BUY\_CO*PROVINCE$$

3.6.3 Multicollinearity Assessment

A correlation matrix was developed and can be found in Appendix 6.4 using Pearson Correlation. While there were multiple variables with statistically significant relationships, none were considered to be highly correlated with each other as all values were less than 0.8 or greater than -0.8. After the multicollinearity diagnostics were conducted, none of the predictors or effect modifiers were dropped from the modeling process as all variance inflation factors were under 10 (min=1.08, max=1.50) and all tolerance values were above 0.1 (min=0.66, max=0.92).

3.6.4 Interaction Assessment

Interaction was assessed for all predictors for impacts from the effect modifiers, SES quartiles and seasonality by running the full model as well as a reduced model without any of the interaction terms. Storage Container Mouth Type did not produce values when in an interaction term with season or province, thus these product terms were eliminated before the chunk test. The likelihood ratio test produced a Chi-Square value of 61.77 with 43 degrees of freedom and a p-value of 0.0317, promoting the process of backward elimination to start dropping product terms. In the end, all product terms were removed since they were all p>a with a=0.1.

3.6.5 Confounding Assessment

Gold Standard Model

$$(\log TTC) = \alpha + \beta_1 FLOOR + \beta_2 OWNAN + \beta_3 MOUTH + \beta_4 COVERED + \beta_5 HW\_MAT + \beta_6 HW\_FRQ + \beta_7 TOILET\_T + \beta_8 TOILET\_S + \beta_9 WTR\_SEV + \beta_{10} SAM\_SC + \beta_{11} SAM\_TR + \beta_{12} CO\_HRS + \beta_{13} FETCH\_D + \beta_{14} FETCH\_T + \beta_{15} BUY\_CO + \gamma_1 SES + \gamma_2 SEASON + \gamma_3 PROVINCE$$

Using the gold standard model developed from the interaction assessment, SES quartiles, seasonality, and province are eligible to be investigated for confounding. Table 9 displays the various models that were used to determine the significance of each variable on explaining the variation of the model through partial F-tests. By rejecting the null hypotheses for SES quartile (F-value= 4.60, p-value=0.0325), we conclude there is a significant linear association between SES and water quality, while controlling for other predictors and should be retained in the final model. The null hypothesis was rejected for seasonality as well (F-value= 17.33, p-value <.0001), so it will be retained in the final model as there is a significant linear association with water quality. Finally, province will also be retained in the final model, as the null hypothesis from the F-test was rejected (F-value=10.25, p-value=0.0015) suggesting a significant linear association between household province and water sample quality.

Model #	Variables in Model	Variable Dropped from Model	H_0 and H_A	F-Value	p-value	Decision
1	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q, SEASON, PROV					
2	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SEASON, PROV	SES_Q	H_0: $\gamma_1=0$ H_A: $\gamma_1\neq0$	4.60	0.0325*	Reject H_0
3	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q, PROV	SEASON	H_0: $\gamma_2=0$ H_A: $\gamma_2\neq0$	17.33	<0.0001*	Reject H_0
4	FLOOR, OWNAN, MOUTH, COVERED, HW_MAT, HW_FRQ, TOILET_T, TOILET_S, WTR_SEV, SAM_SC, SAM_TR, CO_HRS, FETCH_D, FETCH_T, BUY_CO, SES_Q, SEASON	PROV	H_0: $\gamma_3=0$ H_A: $\gamma_3\neq0$	10.25	0.0015*	Reject H_0

Table 9: Results from Partial F Tests for Linear Regression *statistically significant p-value

3.6.6 Adjusted Multivariate Linear Regression

Final Model

$$(\log TTC) = \alpha + \beta_1 FLOOR + \beta_2 OWNAN + \beta_3 MOUTH + \beta_4 COVERED + \beta_5 HW\_MAT + \beta_6 HW\_FRQ + \beta_7 TOILET\_T + \beta_8 TOILET\_S + \beta_9 WTR\_SEV + \beta_{10} SAM\_SC + \beta_{11} SAM\_TR + \beta_{12} CO\_HRS + \beta_{13} FETCH\_D + \beta_{14} FETCH\_T + \beta_{15} BUY\_CO + \gamma_1 SES + \gamma_2 SEASON + \gamma_3 PROVINCE$$

TTC was modeled on covariates determined from previous interaction and confounding analysis. The form of the model used for multivariate linear regression can be seen above. The results are shown in Table 10 below. There were four variables found to be statistically significant predictors of TTC while controlling for other variables: Sample Water Source (p<0.0001), SES quartile (p-value0.325), Seasonality (p<0.0001) and Province (p-value=0.0015). The variables that contributed to a reduced TTC concentration were non-natural flooring materials, narrow mouthed storage containers, having handwashing materials available, improved household toilet facility, toilet facility shared, improve water sample source, fetching distance more or equal to 500 meters, fetching time more or equal to 30 minutes, and purchased water. All other variables, owning animals, covered storage containers, handwashing frequency, how water is severed, water sample treated, hours since water sampled collected, household SES quartile, rainy season, and household province, contributed to an increase in TTC concentration in household water samples.

Variable	Beta	95% CI	p-value
Not Natural Flooring Material	-0.13	-0.61, 0.34	0.5809
Own Animals	0.07	-0.15,0.29	0.5432
Storage Container Narrow Mouth	-0.60	-1.26,0.06	0.0763
Storage Container Covered	0.10	-0.16, 0.35	0.4549
Handwashing Materials Available	-0.005	-0.28, 0.27	0.9740
Handwashing Frequency	0.07	-0.03, 0.17	0.1510
Improved Toilet Facility	-0.21	-0.49, 0.07	0.1361
Toilet Facility Shared	-0.02	-0.28, 0.24	0.8855
Drinking Water Served by Pour	0.19	-0.20, 0.58	0.3353
Improved Water Source	-0.99	-1.29,-0.69	<.0001*
Water Sample Treated	0.30	-0.24, 0.84	0.2795
Time Since Collection	0.0007	-0.003, 0.004	0.6633
Fetching Distance >=500 meters	-0.02	-0.28, 0.25	0.974
Water Fetching Time >=30 mins	-0.24	-0.51, 0.03	0.0807
Water Purchased	-0.04	-0.32, 0.25	0.8044
SES Quartile	0.08	0.01, 0.15	0.0325*
Rainy Season	0.52	0.28, 0.77	<.0001*
Province	0.15	0.06, 0.24	0.0015*

Table 10: Factors Associated with Water Quality *statistically significant p-value

4. Discussion

The purpose of this analysis was to describe and detect factors associated with water quality in low-income Rwandan homes. Secondly, we wanted to identify any provincial differences in water quality using thermotolerant coliforms as a WHO approved proxy indicator as both a binary and log-transformed continuous outcome.

Compared to the literature these results were different for drinking water quality. The overall water quality from household water samples was relatively good with nearly 41% of samples having no detectable concentration of TTC. Previous research found only 24.9% of household drinking water to have no detectable TTC in samples (Kirby et al., 2016). Additionally, the literature shows that 42.5% of households were considered to be categorized high risk, yet here we found only 27.8% of samples with >100 TTC/100 mL (Kirby et al., 2016). Rwanda's national standards for drinking water is and the WHO standard is <1CFU/100mL (WHO,2011). Since over half of the households did not meet these standards, there is reason for concern even if TTC concentrations do not directly correlated to the presence of specific enteric pathogens. This indicates a need for better water treatment practices either at the source or point-of use to increase the removal of bacteria present in the water even if the number of households within the standard is growing and the high-risk household number could be reducing.

Results showed variation in water quality based on the province of households. The Eastern Province had the higher concentration of TTC in household water samples with a geometric mean of 62.0 which is nearly 5 times more than the next highest province contamination geometric mean for Kigali Province at 12.1 TTC CFUs/100 mL. The northern province has the highest proportion of households which were in the WHO's low risk category at 60.5% of household water samples while the eastern province has the lowest proportion for this category with 7.5% of households being low risk. In contrast, the eastern province had the highest proportion of very high-risk household water samples with 56.6% while the southern province had the lowest proportion of high-risk household with 13.9%. One thing to note when comparing water quality across the provinces is Kigali city only has 3 districts included in it meaning only 35 households represent this entire province compare to the others with nearly 100 households each, contributing to wide confidence intervals for this province. These numbers, in combination with the distribution in Figure 8 and the significant difference in Table 1 for 3 of the 5 provinces, provide evidence of water quality disparities geographically in Rwanda.

While this investigation was not able to identify the exact route of bacterial contamination of household water, several household and water source factors were examined for predictive associations with water quality of household samples. There are several studies in the past that have examined the determinates of water quality at a household level. Zin, et al., found storage duration, inadequate handwashing, higher temperatures, and narrow mouthed or covered storage containers to impact the microbial contamination of stored household water. The source of water, distance to water source, place and duration of water storage were also found to impact household water quality (Boateng et al., 2013). Nahayo, et al, found that during the rainy season, water collected in the Eastern province of Rwanda had higher levels of heavy metals.

In this study, we found some predictors similar to that of past studies and a few that were different. The crude models found that narrow mouthed storage containers, improved household toilet facilities, improved water sources, fetching time, fetching distance, purchased water, SES quartile, and season to have statically significant relationships with water quality individually. The results from the multivariate linear regression suggested that water sample source type, SES quartile, season, and province are associated with TTC concentration while controlling for other variables.

4.1 Limitations

Study findings should be interpreted with caution as no casual effects were looked at, merely correlations and prevalence between water quality outcomes and household/ water sample characteristics. Since the data collected was in a cross-sectional study, only data frequency and trends can be described in analysis with the potential of generating etiologic hypotheses. Additionally, since sample weights were not developed, the results cannot be generalized outside of the study population. This is a recommendation for future work done with the data in order to have results that reflect the overall population better. Sample weights were not developed due to the unconventional sample strategy used and would require a geographical aspect instead of only using nationally representative population data on *Ubudehe* categories.

There were several sources of bias throughout the data collection process. Since most of the questions were self-reported, behaviors and habits that are perceived to be "good" might have been over reported whereas habits that are perceived to be "bad" might be under reported to avoid judgement from the enumerators. In addition, individual households were enrolled based on convince sampling, as it was dependent on who was home and available to participate with the questionnaire allowing for selection bias. There may also be some instances where the main person responsible for water fetching was not home or is not the head of household to answer questions and the person who responded instead could have false information or as a possible source for recall bias. With the cross-sectional nature of the original study, there is a chance of selective survival bias impacting those who were able to participate. Finally, this study can be biased by seasonality as it was conducted at the end of a rainy season so other studies should be conducted during the dry season to see if there are different factors associated and if there if a difference in overall water quality based on the season.

There were several data merging issues that resulted in limitations of analysis and interpretations. For example, main water source samples were collected but could later not be linked to the households thus reducing the ability to estimate the contamination levels of the original water source to infer if the household water samples had any difference after collection (i.e. if household characteristics directly lead to more contaminated drinking water). The sample size used in this analysis was also reduced to merging issues with household water samples or technological problems during survey collections resulting in half completed responses. This resulted in a sample size smaller than the intended one based on original sample size calculations. Data entry by several different enumerators lead to spelling errors in district name and other survey report disparities such as the lack of enumerator observational data. This deficiency in observational data, prevented the confirmation of the participants self-reported assets and behaviors.

The dichotomization of variables could have influenced the study results. Several variables that had multiple categories or were originally continuous were manipulated into binary variables when used in the statistical modeling which could either be over estimating relationships or hiding significant ones.

Using thermotolerant coliforms as a proxy for water quality has a softness to it since it cannot directly be linked to specific waterborne pathogens as it merely indicates the presence of fecal contamination in the water sample. There was also an issue with the distribution of water quality data since the water quality testing process examined various volumes of the samples resulting in spikes at the limits of detections after conversion and skewing the distribution.

There are a few limitations with using log binominal regressions to estimate the prevalence ratios. The confidence intervals produced may overstate the precision of the estimated PR since they can be narrower than they should be. Additionally, log binomial regression models may not always converge due to the sparseness of data or distribution of data values. This can be compensated for by reworking models using Poisson regression with robust variance estimates.

4.2 Future Directions

Firstly, for this data to be more generalizable and to better assist with targeted interventions for the population studied here, valid sample weights need to be calculated so this data can serve as a baseline. Additionally, this study was conducted nearly 10 years ago so updated information surrounding water quality of stored household drinking water, main water sources, and characteristics of household and the health of their occupants is also recommended to provide the most useful information to guide future programs. An updated version of this survey can also estimate the progress in access to improved water sources, toilet facilities and handwashing materials to make better suggestions for policies for reaching the SDG goal 6.

The water quality had high variability across the different provinces, while this may be due to the limitations of the study size not being calculated to report by province and not applicable to the whole population, further studies to investigate the possibilities of this are recommended. A focus on disparities on access to basic level or higher water sources and toilet facilities, and seasonal TTC concentrations is supported from the evidence presented in this paper.

There needs to be more exploration into point-of-use water treatment options targeted to this population. The low reporting of water samples treated showcased the gaps in access or knowledge about water treatment practices and benefits. While using improved water sources showed a reduction in TTC levels, this does not mean the water directly from the source is within the safety standards and will need additional treatment to prevent adverse health events associated with the consumption of contaminated drinking water.

This study was not designed to identify the exact pathways in which water contamination occurs, but these predictors can be targeted in future studies to confirm their impact on contamination levels. There has been success of identifying community specific contamination pathways of concern through the SaniPath Exposure Assessment Tool, but this has not yet been done in Rwanda, and would also be curious to see similar studies done by province since there was evidence of differences in water quality (Raj et al., 2020). Additionally, future research can investigate these factors effects on each other to see if there are any synergistic or antagonistic relationships with these factors and water quality.

4.3 Conclusion

Although, these results suggest the possibility of water quality in Rwanda improving from studies previous conducted, there are still too many households that do not have access to safe drinking water. We found the possibility of water quality predictors when looked at alone to be narrow mouthed storage containers, improved household toilet facilities, improved water sources, fetching time, fetching distance, purchased water, SES quartile, and season. When controlling for other variables, these predictors shifted to be water sample source type, SES quartile, season, and province. In particular, these findings highlighted the variation in water quality between the provinces which will be of value to the Rwandan Ministry of Health for future policy changes and infrastructure building to tackle the public health challenges that surround the consumption of contaminated water.

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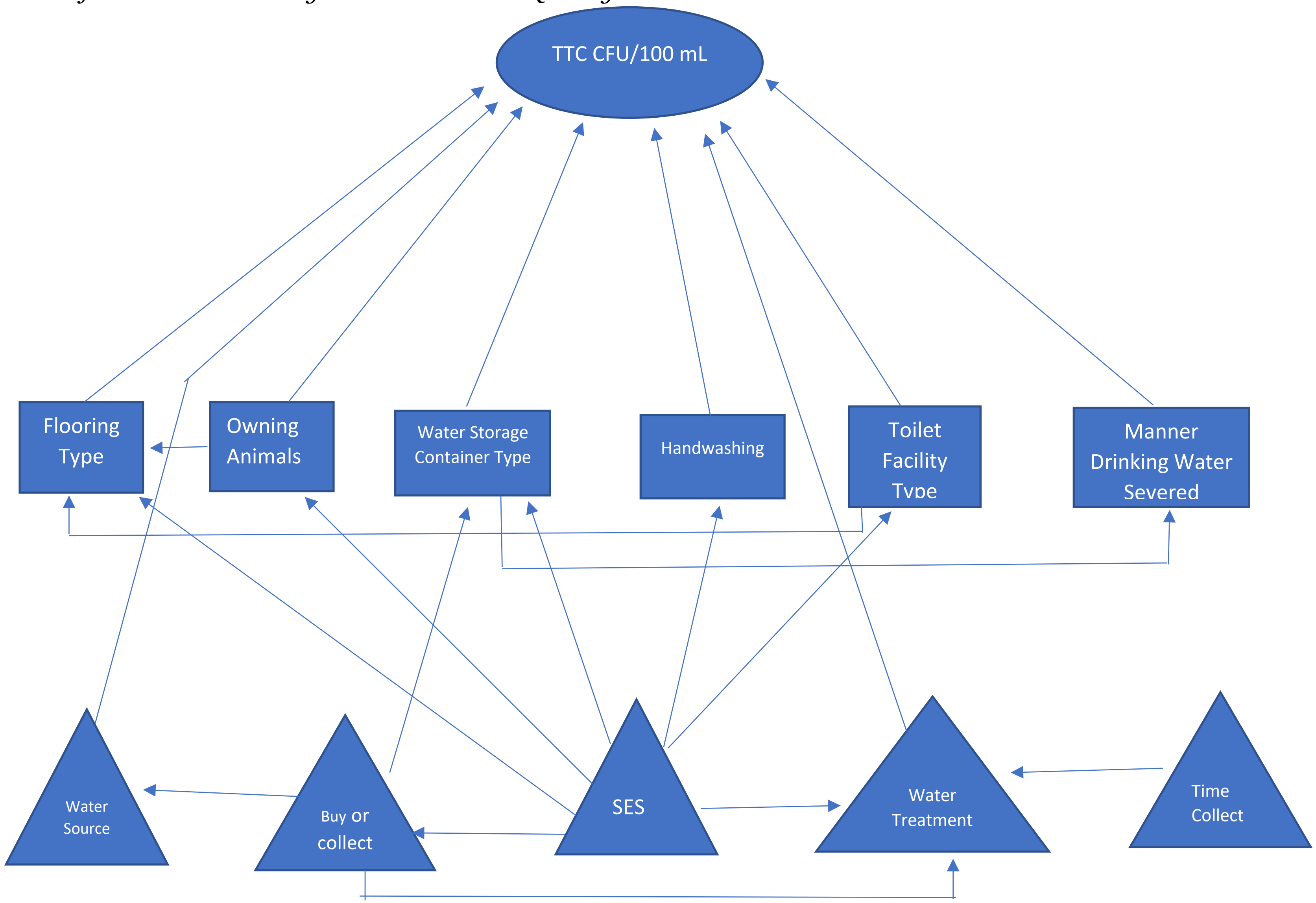
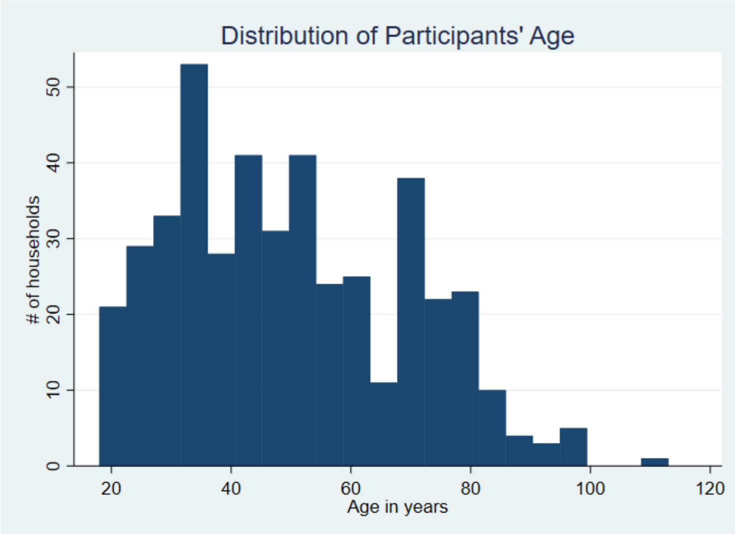
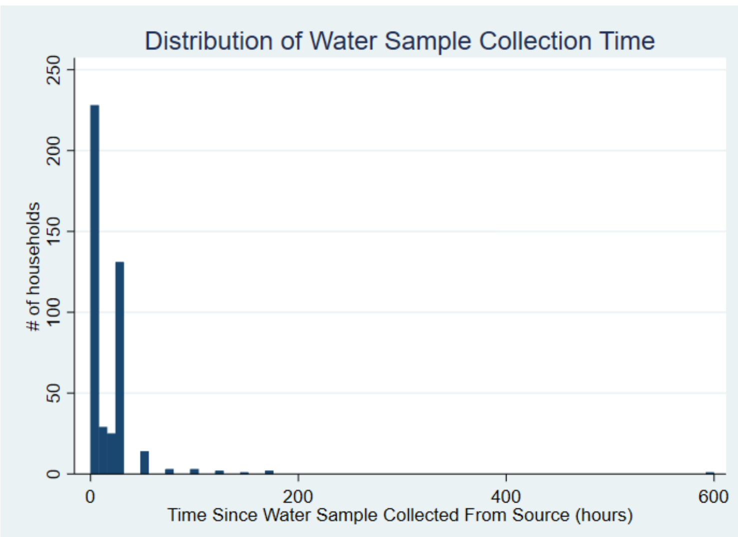
6. Appendix

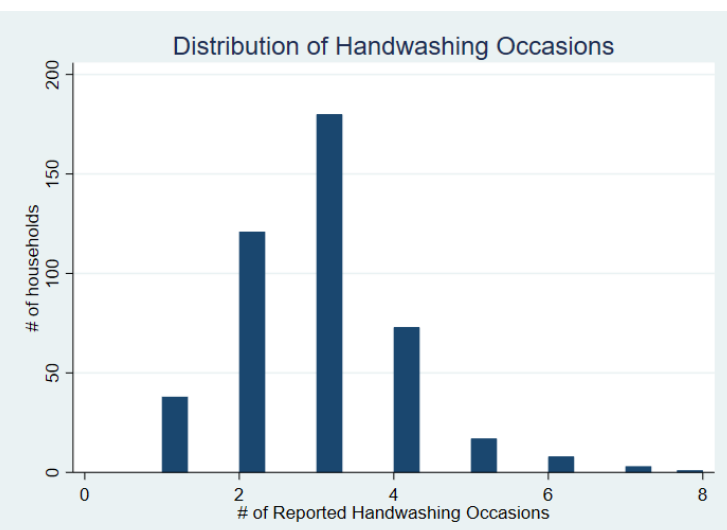
6.1 DAG of Variables Involving Household Water Quality

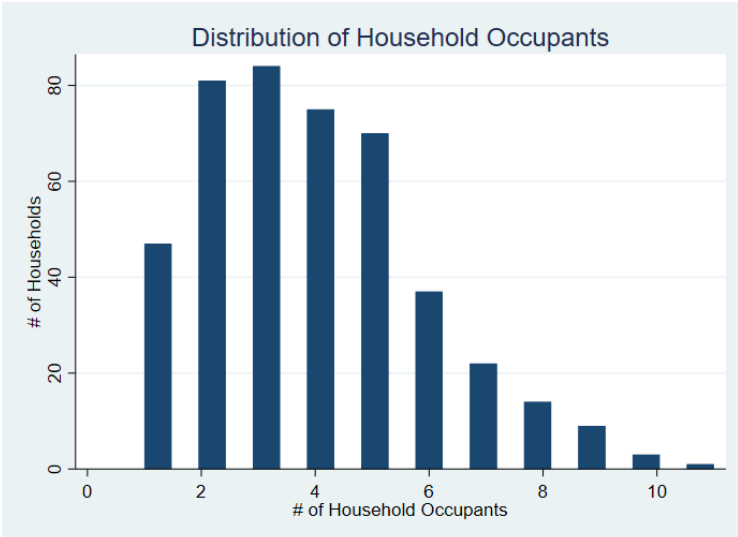


6.2 Distribution of Continuous Variables

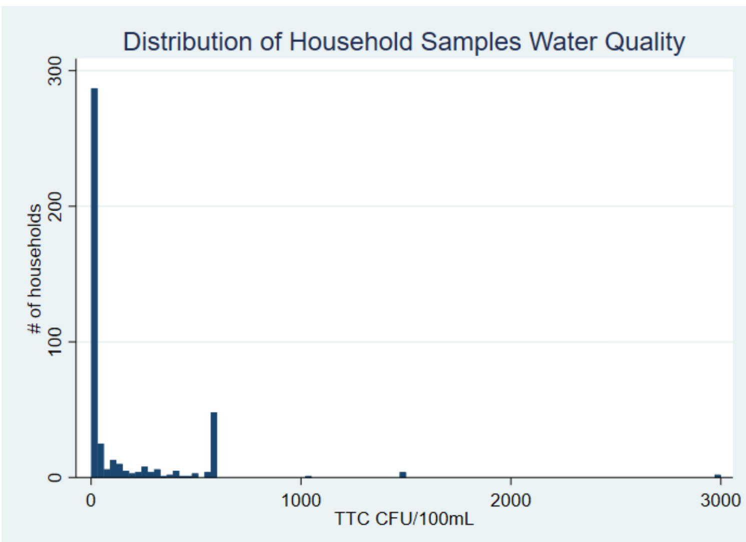




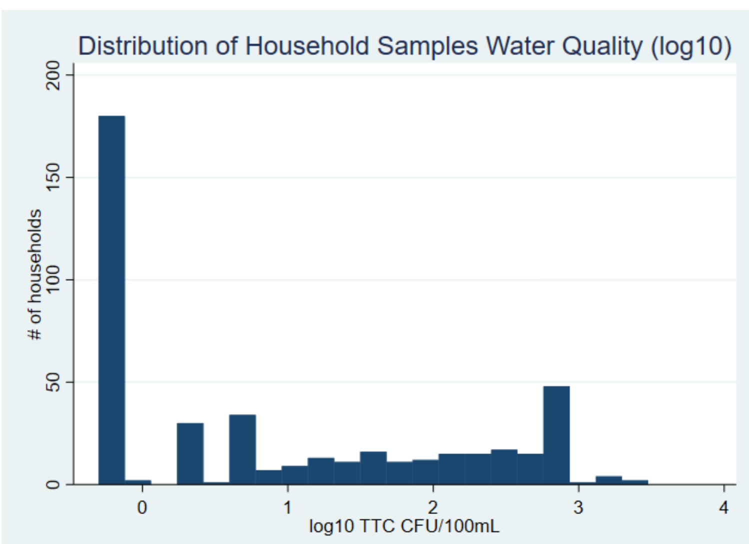




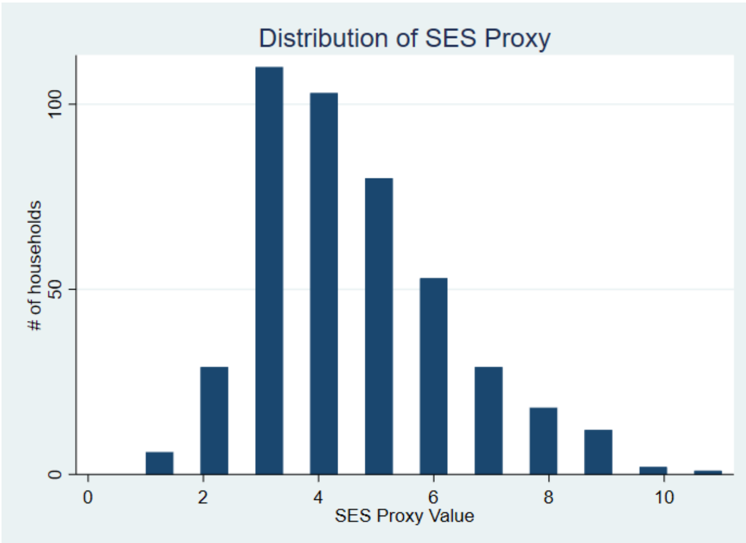
Distribution of Household Occupants
# of Households
0
20
40
60
80
0
2
4
6
8
10
# of Household Occupants

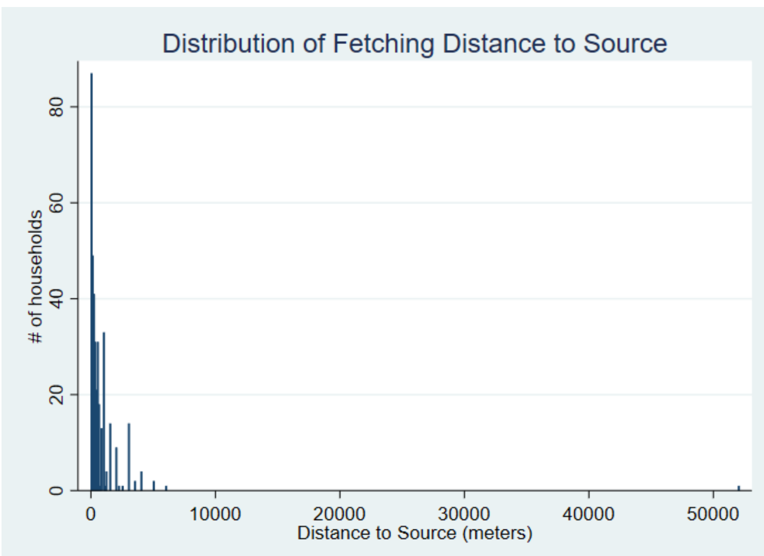


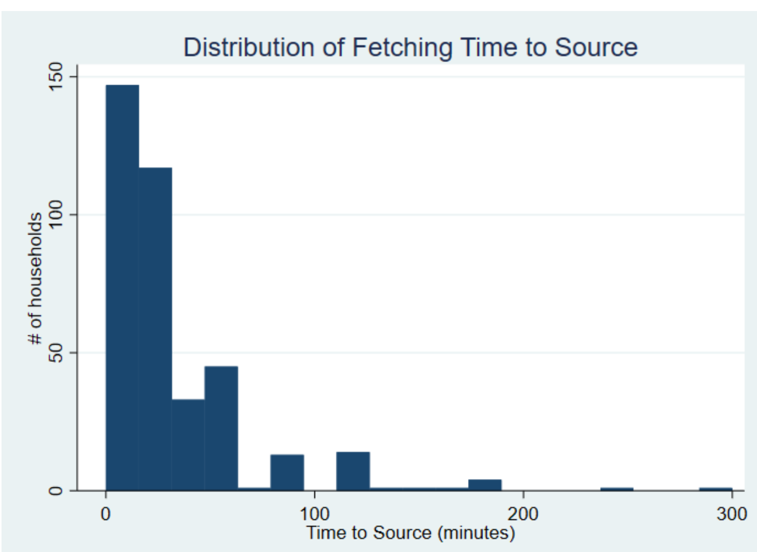
Distribution of Household Samples Water Quality
# of households
0
100
200
300
0
1000
2000
3000
TTC CFU/100mL



Distribution of Household Samples Water Quality (log10)
# of households
0
50
100
150
200
0
1
2
3
4
log10 TTC CFU/100mL


Distribution of SES Proxy
# of households
0
50
100
0
2
4
6
8
10
SES Proxy Value


Distribution of Fetching Distance to Source
# of households
0
20
40
60
80
0
10000
20000
30000
40000
50000
Distance to Source (meters)


Distribution of Fetching Time to Source
# of households
0
50
100
150
0
100
200
300
Time to Source (minutes)

6.3 Correlation Matrix- Binary

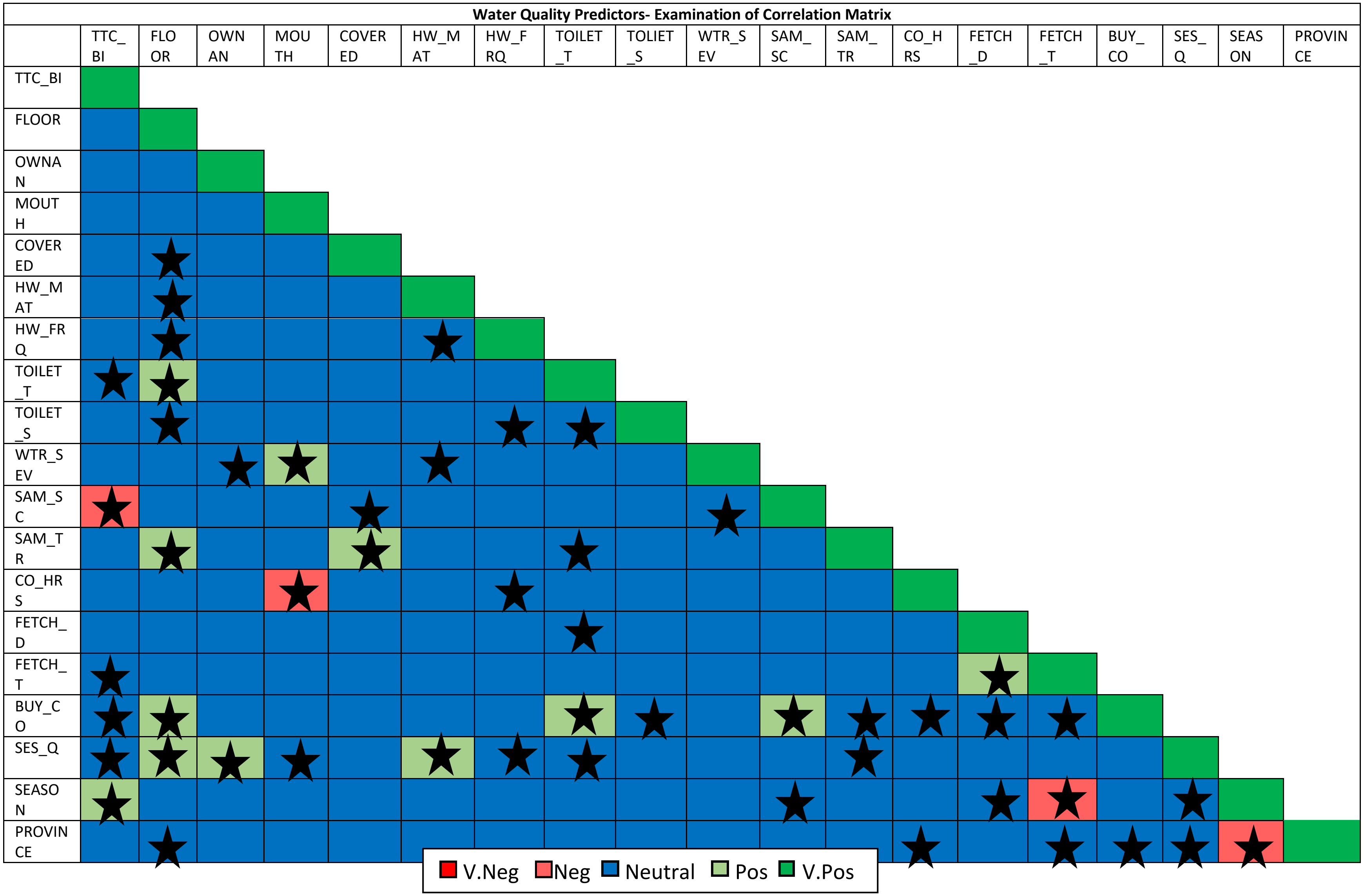


Figure 9: Water Quality Predictors for Binary Outcome – Examination of Correlation Matrix. Very Negative (-1, -0. 6) Negative (-0.6, -0.2) Neutral (-0.2, 0.2) Positive (0.2, 0.6) Very Positive (0.6, 1). Stars represent p-value <0.05

6.4 Correlation Matrix- Continuous

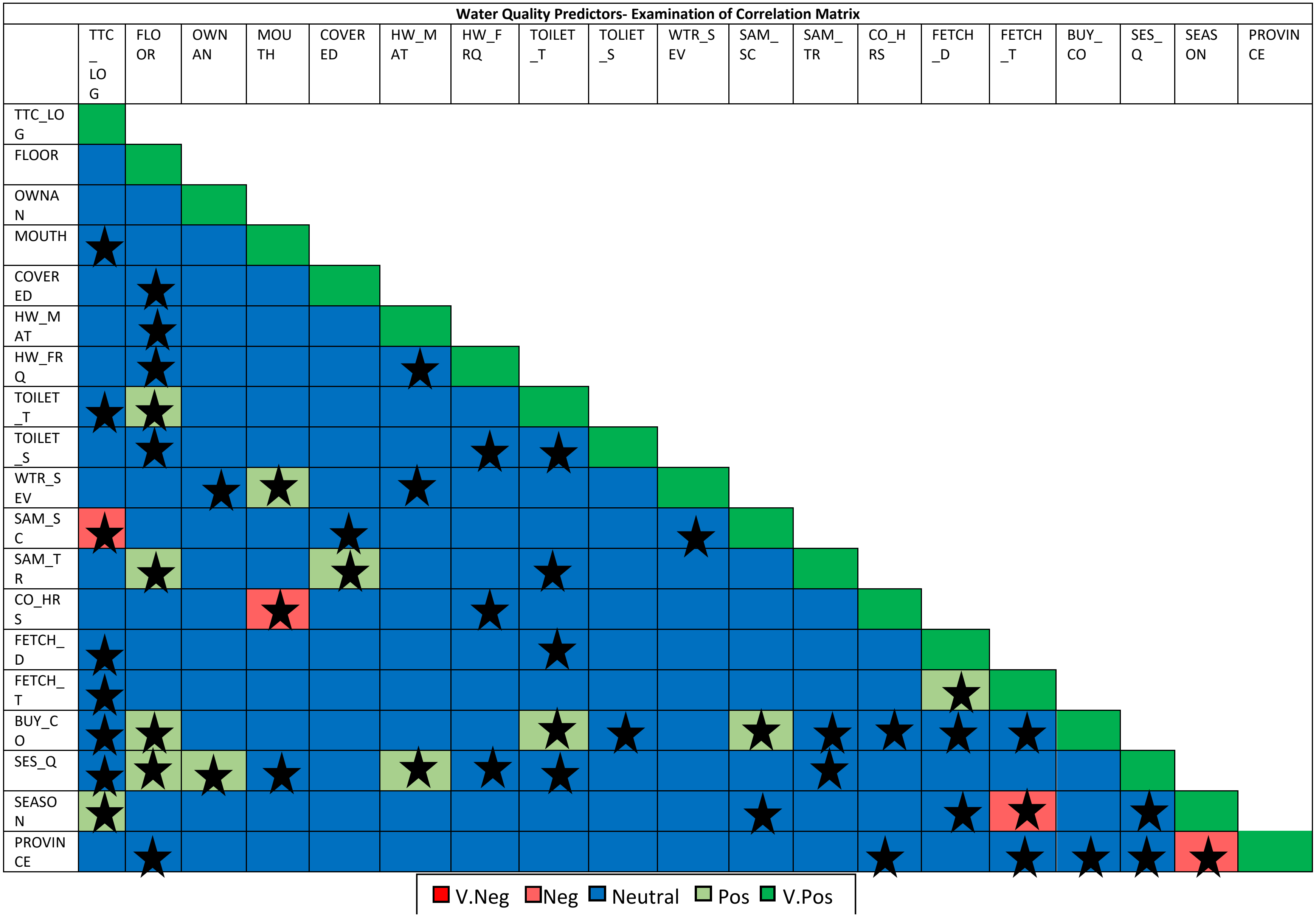


Figure 10: Water Quality Predictors for Continuous Log Transformed Water Quality Outcome – Examination of Correlation Matrix. Very Negative (-1, -0. 6) Negative (-0.6, -0.2) Neutral (-0.2, 0.2) Positive (0.2, 0.6) Very Positive (0.6, 1). Stars represent p-value <0.05

6.5 Codebook

Variable Name	**Variable Code**	**Coding**
Buy or Collect Water	BUY_CO	1= Collect 2= Purchase
Storage Container Covered	COVERED	0= No 1= Yes
Hours Since Collection	CO_HRS	Continuous
Fetching Distance	FETCH_D	0= less then 500 meters 1= eq/more than 500 meters
Fetching Time	FETCH_T	0=1ess than 30 minutes 1= eq/more 30 minutes
Flooring Material	FLOOR	0 = Natural 1= Non-Natural
Household ID	HHID	Numeric
Handwashing Material	HW_MAT	0= Water Only 1= Water and Soap
Handwashing Frequency	HW_TOT	Continuous
Own Animals	OWNAN	0= No 1=Yes
Province	PROV	1= Kigali 2= Northern 3= Southern 4= Eastern 5= Western
Sample Source Category	SAM_SC	0= Unimproved 1= Improved
Sample Source Type	SAM_SOU	1= Piped Water 2= Public tap/ Standpipe 3= Hand Pump 4=Protected dug/ Covered Well 5= Protected Spring 6= Rainwater 8= Unprotected Dug Well 9= Unprotected Spring 11= Surface Water 12= Other
Sample Water Treatment	SAM_TR	0= No 1= Yes
Seasonality	SEASON	0= Dry 1= Rainy
SES	SES	Continuous
SES Quartiles	SES_Q	1= 1st quartile 2= 2nd quartile 3= 3rd quartile 4= 4th quartile

Storage Mouth Type	ST_TYP	0= Wide Mouth 1=Narrow Mouth
Toilet Shared	TOILET_S	0= No 1= Yes
Toilet Type	TOILET_T	0= Open Defecation 1= Unimproved 2= Improved
TTC Binary	TTC_BI	0= <1 TTC CFU/100 mL 1= >=1 TTC CFU/100 mL
TTC Log10	TTC_LOG	Continuous
TTC Risk Categories	TTC_RISK	0=<1 TTC CFU/100 mL 1=>= 1 CFU/100 mL 2=>=10 CFU/100 mL 3=>= 100 CFU/ 100 mL
Ubudehe Category	UBUDEHE	1 or 2
Manner of Drinking Water Served	WTR_SEV	0= Drink from container/ dip cup in 1= Pour Water
Respondent Age	Age_years	Continuous
Respondent Sex	Resp_sex	1= Female 2= Male
Respondent Education Binary	Resp_edu_bi	0= less then primary 1= completed primary or higher
Respondent Education Categories	Resp_edu_cat	0= no schooling 1= less then primary 2= completed primary 3= vocational or some secondary 4= completed secondary or some college
Total Household Occupants	Household_total	Continuous
Household Occupants over 18	Adults18over	Continuous
Household Occupants under 5	Children_u5	Continuous
Household Electricity	Household_electricity	0= No 1= Yes
Handwashing Facility	Hw_place	0= No 1= Yes
Radio	Radio	0= No 1= Yes
Phone	Phone	0= No 1= Yes
Mattress	Mattress	0= No 1= Yes
Bicycle	Bicycle	0= No 1= Yes
Own Land	Ownlandplot	0= No 1= Yes
Own Chickens	Ownchickens	Continuous
Total Animals	Total_animlas	Continuous

Distance to Water Source	Sample_fetch_dis	Continuous
Time to Water Source	Sample_fetch_time	Continuous
HW: After Waking Up	Hwindicator1	0= No 1= Yes
HW: Before Eating	Hwindicator2	0= No 1= Yes
HW: After Eating	Hwindicator3	0= No 1= Yes
HW: After Cultivating	Hwindicator5	0= No 1= Yes
HW: After Handling Rubbish	Hwindicator6	0= No 1= Yes
HW: After Defecation	Hwindicator7	0= No 1= Yes
HW: Before Cooking	Hwindicator8	0= No 1= Yes
HW: After Cooking	Heindicator9	0= No 1= Yes
HW: After Touching Animal	Hwindicator12	0= No 1= Yes
HW: Before Feeding Child	Hwindicator4	0= No 1= Yes
HW: Before Cleaning Child	Hwindicator10	0= No 1= Yes
HW: After Cleaning Child	Hwindicator11	0= No 1= Yes

6.6 DelAgua-LSHTM Gap Phase Household Survey

Gap Water Phase
Baseline Stove and Water Practices Survey
Individual Questionnaire 2013.05.15 V2

INFORMED CONSENT FOR HOUSEHOLD WATER SAMPLING STUDY
(Version: 15-05-2013)

I am here on behalf of the DelAgua Health Program in cooperation with the Ministry of Health. You are invited to participate in a research study as a volunteer because you live in this village which has been selected to participate in a household survey project. Before you decide whether to participate, you need to understand the purpose of the study, what is expected of you, and how it may affect you.

This study will evaluate your household environment. Ubudehe 1+2 households in this village are randomly selected to participate. All households who choose to participate in this study will be interviewed at home by a technician from DelAgua Health Program in order to ask you questions about your water activities at home, and also to take a sample of your drinking water. This will be a one-time visit.

If you agree to participate, you will be asked to answer questions about water, sanitation and hygiene practices, and general questions about your household. A sample of your drinking water will be collected. These activities may take up to 60 minutes of your time. Your name and the location of your home will be collected, however for privacy purposes, this information will only be used by DelAgua Health Program Staff. The location of your household will not be associated with your name or any identifying information in any results of the study. The results of the water quality will be shared with your village at the end of the study.

Your participation is completely voluntary. You may decline to answer any question that is asked of you. You may end your participation at any time. No compensation for your pa. There is no charge to participate. By participating in this survey, you will help us to gather data on water practices to help facilitate future water-related projects in Rwanda.

If you have questions related to the study please contact Jean Ntazinda of the Del Agua Health and Development Program at 0788481439.

If you have any questions related to your rights as a participant, contact Dr. Justin WANE, the chairperson of Rwanda Ethics Committee at 0788500499 or the secretary of RNEC Dr. Emmanuel NKERAMIHIGO at 0788557273.

You may keep this information sheet for your records.

Do you have any questions?

*Are you 18 years of age or older? 1. Yes 2. No (→ Terminate the interview)

Do you consent to participate in this study?

I consent to participate in the DelAgua Health Program Study.

ENUMERATOR

NAME:____

SIGNATURE:_________________________

THUMBPRINT IF UNABLE TO SIGN

WITNESS

NAME:____

SIGNATURE:_________________________

DATE: __ __ / __ __ / __ __ __ __

UBURENGANZIRA BWO KUGIRA URUHARE MU NYIGO KU MIKORESHEREZE Y'AMAZI MU INGO (Version: 15-05-13)

Ndi hano mpagarariye "Delagua Health Program" ku bufatanye na Minisiteri y'Ubuzima. Tubararikiye kugira uruhare mu inyigo y'ubushakashatsi nk'umukorerabushake kuko utuye muri uyu mudugudu watoranyijwe kugira uruhare muri iyi nyigo y'ikusanyamukuru mu ingo.

Mbere guhitamo niba wagira uruhare muri iyi gahunda, ukeneye kubanza gusobanukirwa intego y'iyi nyigo, icyo utegerejweho n'inyungu wabibonamo.

Iyi nyigo izagenzura imiterere y'urugo rwawe. Muri uyu mudugudu, ingo ziri mu rwego rwa 1 & 2 z'ubudehe zatoranyijwe hafashishijwe tombora. Ingo zose zihitamo kugira uruhare muri iyi gahunda ziragirana ikiganiro n'umutekinisiye uturutse muri "Delagua Health Program" Kugirango abaze ikoreshwa ry'amazi mu rugo rwawe, anafate urugero (echantillon) rw'amazi munywa. Iri sura rizaba rimwe.

Niwemera kugira uruhare muri iyi gahunda, urasabwa gusubiza ibibazo byerekeranye n'amazi, isukura, ibikorwa by'isuku n'ibibazo rusange ku rugo rwawe. Turaza gufataho ku mazi yawe yo kunywa. Ibi bikorwa bitwara iminota igera kuri 60 y'umwanya wawe. Amazina yawe n'ay'aho utuye biraza kwandikwa. Ariko ku mpamvu z'ibanga ryawe, ayo makuru azakoreshwa n'abakozi ba DelAgua gusa. Amazina yawe n'ay'aho utuye ntibizahuzwa n'andi makuru bifite aho bihuriye mu cyegeranyo cy'iyi nyigo. Ibizava muri iyi nyigo ku bwiza bw'amazi bizamenyeshwa umudugudu wawe ku musozo w'iyi nyigo .

Kwitabira iyi gahunda n'ubushake busesuye. Ushobora guhitamo kudasubiza ikibazo cyose ubajijwe. Ushobora guhagarika uruhare rwawe muri iyi gahunda igihe icyari cyo cyose. Uruhare rwawe muri iyi nyigo ntiruhemberwa. Mu kugira uruhare muri iyi nyigo uzaba udufashije gukusanya amakuru ku mikoreshereze y'amazi bikazafasha imishinga ijyanye n'amazi mu Rwanda mu gihe kiri imbere.

Uramutse ugize ikibazo kijyanye n'iyi nyigo wahamagara Jean NTAZINDA, umukozi wa "DelAgau Health and Development Programs" kuri Tel: 0788481439

Uramutse ugize ikibazo cyerekeranye n'uburenganzira bwawe nk'uwagize uruhare muri iyi nyigo, wabaza Dr. Justin WANE, Umuyobozi mukuru wa Komite y'Igihugu ishinzwe kurengera abakorerwaho ubushakashatsi kuri Tel: 0788500499 cyangwa Dr. Emmanuel NKERAMIHIGO, Umunyabanga wa Komite y'Igihugu ishinzwe kurengera abakorerwaho ubushakashatsi Tel: 0788557273

Uru rupapuro warubika ku mpamvu zawe.

Hari ikibazo waba ufite?

*Ufite imyaka 18 cg irenga? 1. Yego 2. Oya (→ TERMINATE INTERVIEW)

Wemeye kugira uruhare muri iyi nyigo?

Nemeye kugira uruhare mu nyigo ya "DelAgua Health Program"

UKUSANYA AMAKURU:

Amazina:…………………………………………………

Umukono:………………………………………………..

UMUTANGA BUHAMYA:

Amazina:…………………………………………………

Umukono:………………………………………………..

Itariki: ……/……../2013

THUMBPRINT IF UNABLE TO SIGN NAME

BEGIN DOFORM SURVEY

Date of Interview ____________ (format: DD/MM/YY) [AUTO STAMP]

Time interview started: ____________ (format: hh:mm) [AUTO STAMP]

Section A: General Information

SAY: In the next set of questions I am going to ask you general questions about you and your household.

A1	ENUMERATOR NAME. HINT: SELECT FROM LIST	
A2	HOUSEHOLD ID. HINT: FROM ID SHEET. 3-DIGIT VILLAGE CODE + 2 DIGIT HOUSHEOLD CODE.	|__|__|__| - |__|__|
A3	RELATIONSHIP OF RESPONDENT TO HEAD OF HOUSEHOLD.	[1] Respondent is head of household [2] Wife [3] Husband [4] Mother [5] Father

		[6] Sister [7] Brother [8] Daughter [9] Son [10] Other, specify ______
A4	HEAD OF HOUSEHOLD FULL NAME Relevance: Only if respondent is not equal to head of household.	
A5	What ubudehe category does this household belong to? HINT: DO NOT ASK RESPONDENT. RECORD FROM HOUSEHOLD ID SHEET.	1. 1 2. 2
A6	RESPONDENT LAST (FAMILY) NAME	
A7	RESPONDENT FIRST NAME.	

A8	DISTRICT:	
A11	UMUDUGUDU	
A12	UMUDUGUDU ID HINT: RECORD FROM ID SHEET [101-999 ALLOWED]	|__|__|__|

Section B: Household Socio-demographic Characteristics

B1	Ni abantu bangahe bafite myaka 18 no hejuru muri uru rugo bahaba igihe kinini mu mwaka? / How many adults 18 years and older live in this household the majority of the year? Hint: Do not include people who are only home during holidays	
B2	Ni abana bangahe bari munsi y'imyaka 5 baba muri uru rugo bahaba igihe kinini mu mwaka? / How many young children under 5 years of age live in this household the majority of the year? Hint: Do not include people who are only home during holidays	
B3	Ni abana bangahe bari hagati y' imyaka 5-17 baba muri uru rugo bahaba igihe kinini mu mwaka ? / How many children 5-17 years live in this household the majority of the year?	

B4	CALCULATE THE TOTAL NUMBER OF PEOPLE IN THIS HH AND CONFIRM	
B.5	Ni ikihe kiciro wagaru kiyemo wiga? / What is the highest level of schooling you have had?	[1] No schooling [2] Some preschool [3] Completed preschool only [4] Some primary [5] Completed primary only [6] Some vocational school [7] Completed vocational school [8] Some secondary [9] Completed secondary [10] Some college [11] Completed college (has degree) [99] Don’t know
B6	Ufite umugabo/umugore mubana? Do you have a living partner?	[1] YES [2] NO
B.6A	Ni ikihe cyiciro umugabo/umugore mubana yagarukiyemo yiga? / What was the highest level of schooling your partner has had? Relevance: Only if respondent has living partner.	[1] No schooling [2] Some preschool [3] Completed preschool only [4] Some primary [5] Completed primary only [6] Some vocational school [7] Completed vocational school [8] Some secondary [9] Completed secondary [10] Some college [11] Completed college (has degree) [99] Don’t know

B7	OBSERVE: SEX OF RESPONDENT Hint: OBSERVE.	1. Male 2. Female
B8	Wavutse mu wuhe mwaka? / In what year were you born? Hint: IF DON’T KNOW WRITE 99	|__|__|__|__|
B9	Ufite imyaka ingahe? / How old are you? Hint: IN YEARS. IF DON’T KNOW WRITE 99. Relevance: only if respondent doesn’t know birth year. [18-99 ALLOWED]	
B10	Urugo rwawe rwaba rufite amashanyarazi? / Does your household have electricity?	[1] YES [2] NO
B11	Ni ibihe bikoresho muri ibi bikurikira waba ufite mu rugo rwawe? / Which of the following items do you have in your household?	1. Radiyo / Radio 2. Televiziyo / Television (Relevance: has electricity) 3. Terefone igendanwa / Mobile Telephone 4. Terefone itagendanwa / Non-mobile Telephone

		5. Firigo / Refrigerator (Relevance: has electricity) 6. Matora / Mattress 7. Igare / Bicycle 8. Igare rikururwa n'inyamanswa / Animal Drawn Cart 9. Moto / Motorcycle/scooter 10. Imodoka / Car/Truck (Hint: OBSERVE) 11. Ubwato bwa moteri / Boat with a motor 12. Ubwato budakoresha moteri / Boat without a motor 13. Taxi / Small bus (Hint: OBSERVE)
B13	Urugo rwanyu rwaba rufite ubutaka/Ikibanza? / Does your household own land/plot?	1. Yes 2. No
B14	Urugo rwawe rwaba rufite imirima yoguhingamo yanyu? / Does your household own agricultural land?	1. Yes 2. No
B15	Urugo rwawe rwaba rufite amatungo ? / Does your household own farm animals?	1. Yes 2. No → SKIP TO B27 (OBS FLOORING)
B16	How many [cows]? [Inka] zingahe?	
B17	If own a cow, [did you receive for free from government]? Niba uyifite [if you own it], [wayihawe na leta]?	
B18	How many pigs? [Ingurube] zingahe?	
B19	If own a pig, were you given for free from government)	
B20	How many sheep? [Intana zingahe?	
B21	If own a sheep, were you given for free from government?	
B22	How many goats? Ihene zingahe?	
B23	If own a goat, were you given for free from government	
B24	How many chickens? Inkoko zingahe?	
B25	Andi matungo mufite ni angahe? / How many other animals? DESCRIBE. Hint: rabbits, ducks etc.	
B27	OBSERVE: Type of flooring materials Hint: NOTE MOST PREVALENT MATERIAL.	1. Earth/sand 2. Animal Dung 3. Wood/planks

		4. Palm/bamboo 5. Ceramic tiles 6. Cement 7. Bricks 8. Other, specify
B31	OBSERVE: Type of wall materials HINT: NOTE MOST PREVALENT TYPE. IF IN DOUBT, ASK RESPONDENT TO CLARIFY.	[1] NO WALLS [2] Only wood planks [3] Wood planks and mud [4] Mud bricks-NOT covered [5] Mud bricks-covered with mud [6] Mud bricks-covered with cement [7] Real bricks-NOT covered [8] Real bricks-Covered with cement [9] OTHER, specify
B32	Inzu yanyu ifite ibyumba bingahe? / How many rooms are there in your household? Hint: include kitchen and storage rooms. [1-30 ALLOWED]	|__|__|
B33	Ni ibyumba bingahe mu rugo rwawe bikoreshwa mu kuryama? Igihe kinini mu mwaka. / How many rooms in your household are used for sleeping? The majority of the year. [1-30 ALLOWED]	|__|__|

GENERAL INFORMATION AND HOUSEHOLD CHARACTERISTICS COMMENTS

Section T. Toilet Facilities.

T1	Ni ubuhe bwoko bw'umusarane abantu bo mu rugo rwawe bakoresha? Mwambwira uko umeze? / What kind of toilet facility do members of your household usually use? Can you describe it?	1. Pit latrine with slab 2. Pit latrine without slab/open pit 3. Ventilated pit latrine 4. Composting toilet 5. Flush/pour flush 6. No facilities or bush/field 7. Other, specify
T2	Niba ukoresha umusarane w’amazi, uwo musarane wohereza he imyanda? / If you use a flush/pour flush toilet where does it flush to? Relevance: Only if respondent has flush/pour flush.	1. Pit latrine 2. Septic tank 3. Piped sewer system
T3	Ese umusarani/igihuru/icyobo mwitumamo byaba biri mu kibanza? Is the toilet facility/bush/open defecation site on the plot?	1. Yes 2. No

T4	OBSERVE: confirm presence of latrine structure used by household Relevance: Toilet facility not equal to 'no facilities or bush/field'	[1] Yes [2] No [99] Don't know/ can't observe
T5	OBSERVE: Check that answer given for toilet was correct after observing toilet. Checked: Relevance: Toilet facility not equal to 'no facilities or bush/field'	[1] Correct [2] Incorrect: Changed [99] Don't know/can't observe
T6	Waba ufatanya umusarane n'izindi ngo? / Do you share a toilet facility with other households?	1. Yes → # of households 2. No

Section H. Handwashing

H1	Mu masaha 24 ashize, wakarabye mu ntoki incuro zingahe? / In the last 24 hours, how many times did you wash your hands? HINT: Uhereye ejo mugitondo /nimugoroba hashize kugeza uyu munsi mu gitondo/nimugoroba. From yesterday morning/afternoon to this morning/afternoon SKIP → H3 IF RESPONDENT SAYS 0 TIMES	|__|__|__| TIMES
H2	Ni iki cyatumye ukaraba intoki mu masaha 24 ashize? Haba hari ubundi buryo? In which occasions did you wash your hands in the last 24 hours? Any other occasions? HINT: PROBE UNTIL FINISHED. SELECT ALL THAT APPLY NiUhereye ejo mugitondo /nimugoroba hashize kugeza uyu munsi mu gitondo/nimugoroba. From yesterday morning/afternoon to this morning/afternoon	[1] Mbyutse mu gitondo / After waking up in the morning [2] Mbere yo kurya / Before eating [3] Nyuma yo kurya / After eating [4] Mbere yo kugaburira umwana / Before feeding a child [5] uhinguye / After cultivating [6] Nyuma yo gukora imyanda / After handling rubbish [7] Uvuye mu musarane / After defecation [8] Mbere yo guteka / Before cooking [9] Nyuma yo guteka/After cooking [10] Mbere yo gukarabya no guheha umwana/ Before bathing or cleaning a child [11] Nyuma yo gukarabya no guheha umwana/ After bathing or cleaning a child [12] Nyuma yo gukora ku matungo / After touching an animal [13] Other, specify:________________
H3	Ubusanzwe mukoresha iki iyo musukura intoki zanyu? / What do you usually use to wash your hands? HINT: DO NOT PROMPT.	1. Amazi gusa / Water only 2. Amazi & Isabune / Water and soap 3. Ibindi / Other, ______________ 4. Nta na kimwe ,Nothing, doesn't wash hands
H4	Ufite ahantu hihariye ukarabira intoki iyo uvuye mu musarane (kwituma) / Do you have a specific place where you usually wash your hands after defecation (after making a long call)?	1.Yes 2.No⇒SKIP to NEXT SECTION (C1)

H5	[GO TO SPECIFIC HANDWASHING LOCATION. OBSERVE: Is there any water available for handwashing?	[1] Yes [2] No
H6	OBSERVE: Is there any soap, detergent, ash or other cleansing agent? HINT: AT SPECIFIC HANDWASHING LOCATION. Select all that apply.	1. All-purpose bar soap - for hands, dishes and clothes (e.g. Tembo, Mukwano, Savonor, Sulfo, etc.) 2. Body Bar soap - for hands and body only) (e.g. Give, Deto, Duru, etc.) 3. Powder soap (Omo, Nomie, SunLight, etc.) 4. Liquid soap (for dishes only) 5. Liquid soap (for hands) 6. Ash 7. Other, specify
H7	**OBSERVE:** Is there a receptacle such as mug/bucket used for handwashing? HINT: AT SPECIFIC HANDWASHING LOCATION	[1] Yes [2] No

TOILET AND HANDWASHING COMMENTS

Section E: Water Consumption/Treatment

Enumerator reads: In the next set of questions I am going to ask you about water consumption in the household.

E1	Ubusanzwe amazi yo kunywa urayagura cg urayavoma? / Do you usually purchase or collect DRINKING water? HINT: IF USUALLY PAY FOR WATER, SELECT PURCHASE (EVEN IF PAY AND COLLECT)	[1] PURCHASE [2] COLLECT
E2	Amazi yawe yo kunywa uyagura he? / Where do you purchase your drinking water? Relevance: only if respondent purchases water (E1=1)	[1] Public tap [2] Neighbor’s tap [3] EWSA (own tap) [4] Boutique/shop/store [5] Water vendor who comes to household [6] Other water vendor [7] Other, specify________
E3	Mu gihe cy' imvura ni iyihe soko y' ibanze y' amazi yo kunywa umuryango wawe ukoresha? / What is the	1. Piped water into dwelling/yard/plot 2. Public tap/standpipe

	main source of DRINKING water for members of your household during RAINY season?	3. Hand pump 4. Protected dug well /cover well 5. Protected spring 6. Rainwater 7. Bottled water 8. Unprotected dug well 9. Unprotected spring 10. Tanker truck/cart with drum 11. Surface water, specify type (seasonal stream, river, pond, lake, etc) _______________ 12. Other, specify:______________
E4	Ni kure kungana iki wowe cg umuntu wo mu rugo rwanyu mukura AMAZI YO KUNYWA mu gihe cy'IMVURA ugereranyije? / How far do you or someone in your household go to collect DRINKING water during rainy season on average? HINT: ONE-WAY. IN METERS.	Number meters _______
E5	Ugereranije ukoresha igihe kingana iki kujyayo gusa mu gihe cy'imvura? / How long does it take to go there, one-way [during rainy season] on average? HINT: NOT WAIT IN LINE. JUST TO SOURCE IN MINUTES ONE WAY.	Number minutes _______
E6	Ukoresha igihe kingana iki kugenda,kubona amazi no kugaruka uva ku isoko y'aho ukura amazi yo kunywa mu gihe cy'IMVURA ugereranije? / How long does it take to go there, get DRINKING water and come back from the water source you use during RAINY season on average?	Number minutes _______
E7	Ni inshuro zingahe ku munsi wowe cg umuntu wo mu rugo rwanyu mujya ku isoko y'amazi KUVOMA AMAZI YO KUNYWA mu GIHE CY'IMVURA ugereranije? / On average, how many times per day do you or someone in your household go to this water source to collect drinking water during rainy season?	Number_______
E8	Ninde uvoma amazi KENSHI mu rugo rwanyu? / Who usually goes to fetch the water for your household? HINT: SELECT PRIMARY PERSON. SELECT ALL THAT APPLY IF NECESSARY.	1. FEMALE 18 AND OVER 2. MALE 18 AND OVER 3. FEMALE 13-17 4. MALE 13-17 5. FEMALE 9-12 6. MALE 9-12 7. FEMALE 5-8

		8. MALE 5-8 9. FEMALE UNDER 5 10. MALE UNDER 5
E9	Mu gihe cy' izuba ni iyihe soko y' ibanze y' amazi yo kunywa umuryango wawe ukoresha? / What is the main source of DRINKING water for members of your household during DRY season?	[1] Same source as used for drinking during rainy → SKIP to E13 [2] Piped water into dwelling/yard/plot [3] Public tap/standpipe [4] Hand pump [5] Protected dug well /cover well [6] Protected spring [7] Rainwater [8] Bottled water [9] Unprotected dug well [10] Unprotected spring [11] Tanker truck/cart with drum [12] Surface water, specify:_________ [13] Other, specify:________________
E10	Ni kure kungana iki wowe cg umuntu wo mu rugo rwanyu mukura AMAZI YO KUNYWA mu GIHE CY'IZUBA ugereranyije? / How far do you or someone in your household go to collect DRINKING water during DRY season on average? HINT: METERS. ONE-WAY.	Number METERS_______
E11	Ugereranije ukoresha igihe kingana iki kujyayo gusa mu GIHE CY'IZUBA? / How long does it take to go there, one-way [during DRY season] on average? HINT: NOT WAIT IN LINE. JUST TO SOURCE IN MINUTES ONE WAY.	Number MINUTES_______
E12	Ukoresha igihe kingana iki kugenda,kubona amazi no kugaruka uva ku isoko y'aho ukura AMAZI YO KUNYWA mu GIHE CY'IZUBA ugereranije? / How long does it take to go there, get DRINKING water and come back from the water source you use during DRY season on average? HINT: MINUTES	Number MINUTES _______
E13	Ni inshuro zingahe ku munsi wowe cg umuntu wo mu rugo rwanyu mujya ku isoko y'amazi KUVOMA AMAZI YO KUNYWA mu GIHE CY'IZUBA ugereranije? / On average, how many times per day do you or someone in your household go to this water source to collect drinking water during DRY season?	Number of times_______

E14	Ni iyihe soko y' ibanze umuryango wawe uvomaho AMAZI YO GUKORESHA IBINDI BINTU nko guteka no gufura mu gihe cy' imvura? / What is the main source of water used by your household for OTHER purposes such as cooking and hand washing during RAINY season?	[1] Same source used for drinking during rainy → SKIP TO E18 [2] Same source used for drinking during dry → SKIP TO E18 [3] Piped water into dwelling/yard/plot [4] Public tap/standpipe [5] Hand pump [6] Protected dug well /cover well [7] Protected spring [8] Rainwater [9] Bottled water [10] Unprotected dug well [11] Unprotected spring [12] Tanker truck/cart with drum [13] Surface water, specify:_________ [14] Other, specify:_____________
E15	Ni kure kungana iki wowe cg umuntu wo mu rugo rwanyu mukura AMAZI YO GUKORESHA IBINDI BINTU mu GIHE CY'IMVURA ugereranyije? / How far do you or someone in your household go to collect water for OTHER PURPOSES during rainy season on average? HINT: ONE WAY. METERS.	Number meters_______
E16	Ugereranije ukoresha igihe kingana iki kujyayo gusa mu GIHE CY'IMVURA? / How long does it take to go there, one-way [during RAINY season] on average? HINT: NOT WAIT IN LINE. JUST TO SOURCE IN MINUTES ONE WAY.	Number minutes ________
E17	Ukoresha igihe kingana iki kugenda,kubona amazi no kugaruka uva ku isoko y'aho ukura AMAZI YO GUKORESHA IBINDI BINTU mu GIHE CY'IMVURA ugereranije? / How long does it take to go there, collect water FOR OTHER PURPOSES, AND come back from the water source you use during RAINY season on average? HINT: MINUTES.	Number minutes _______
E18.	Ni inshuro zingahe ku munsi wowe cg umuntu wo mu rugo rwanyu mujya ku isoko kuvoma amazi YO GUKORESHA IBINDI BINTU mu GIHE CY'IMVURA ugereranije? / On average, how many times per day do you or someone in your household go to this	_________

	water source to collect water FOR OTHER PURPOSES during RAINY season?	
E19	Ni iyihe soko y' ibanze umuryango wawe uvomaho AMAZI YO GUKORESHA IBINDI BINTU nko guteka no gufura mu GIHE CY'IZUBA? / What is the main source of water used by your household for OTHER purposes such as cooking and hand washing during DRY season?	[1] Same source as used for drinking during rainy → SKIP TO E.23 [2] Same source as used for drinking during dry → SKIP TO E.23 [3] Same source as used for other purposes during rainy → SKIP TO E.23? [4] Piped water into dwelling/yard/plot [5] Public tap/standpipe [6] Hand pump [7] Protected dug well /cover well [8] Protected spring [9] Rainwater [10] Bottled water [11] Unprotected dug well [12] Unprotected spring [13] Tanker truck/cart with drum [14] Surface water, specify:________ [15] Other, specify:______________
E20	Ni kure kungana iki wowe cg umuntu wo mu rugo rwanyu mukura AMAZI YO GUKORESHA IBINDI BINTU mu GIHE CY'IZUBA ugereranyije? / How far do you go to collect water for other purposes on average during dry season? HINT: ONE WAY. METERS.	Number meters_______
E21	Ugereranije ukoresha igihe kingana iki kujyayo gusa mu GIHE CY'IZUBA? / How long does it take to go there, one-way [during DRY season] on average? HINT: NOT WAIT IN LINE. JUST TO SOURCE IN MINUTES ONE WAY.	Number minutes _______
E22	Ukoresha igihe kingana iki kugenda,kubona amazi no kugaruka uva ku isoko y'aho ukura AMAZI YO GUKORESHA IBINDI BINTU mu GIHE CY'IZUBA ugereranije? / How long does it take to go there, get water FOR OTHER PURPOSES, and come back during dry season? HINT: MINUTES.	Number minutes _______
E23	Ni inshuro zingahe ku munsi wowe cg umuntu wo mu rugo rwanyu mujya ku isoko kuvoma amazi YO GUKORESHA IBINDI BINTU mu GIHE CY'IZUBA ugereranije? / How many times per day do you go to	

	this water source to collect water for other purposes during the dry season?	
E24	Uvomesha ijerikani ingana gute? / What size jerry can(s) does your household use to COLLECT water? HINT: SELECT ALL THAT APPLY.	[1] 1 LITER [2] 2 LITER [3] 3 LITER [4] 4 LITER [5] 5 LITER [6] 10 LITER [7] 15 LITER [8] 20 LITER [9] 30 LITER [10] OTHER, SPECIFY:_____________
E25	Ni amajerekani angahe y'amazi mukoresha mu GUTEKA ku munsi? /How many JERRY CANS of water are used for COOKING per day? HINT: ASK ABOUT QUANTITY AND SIZE OF JERRY CANS USED FOR COOKING	|__|__| JERRY CANS
E26	CALCULATE NUMBER OF LITERS USED TO COOK PER DAY HINT: LITERS.	|__|__|__| LITERS
E27	Ni amajerekani angahe Y'AMAZI YO KUNYWA mukoresha ku munsi? / How many JERRY CANS of water are used for DRINKING per day? HINT: ASK ABOUT QUANTITY AND SIZE OF JERRY CANS USED FOR DRINKING	|__|__| JERRY CANS
E28	CALCULATE NUMBER OF LITERS USED FOR DRINKING PER DAY HINT: LITERS	|__|__|__| LITERS
E29	Ni amajerekani angahe y'amazi mukoresha mu ISUKU ku munsi? / How many JERRY CANS of water are used for HYGIENE per day? ASK ABOUT QUANTITY AND SIZE OF JERRY CANS USED FOR HYGIENE	|__|__| JERRY CANS
E30	CALCULATE NUMBER OF LITERS USED FOR DRINKING PER DAY HINT: LITERS.	|__|__|__| LITERS
E31	Umwana ashatse kunywa amazi nonaha wayakurahe? Wanyereka? Niba nta mwana uri munsi y'imyaka itanu uhari,wowe wayakurahe uyashatse? / If a child under 5 wants a drink of water right now, where would you take it from? Can you show me? If no child under 5, where would you take it from if you want a drink of water?	1.Yes 2.No/refused → SKIP TO E43 (USUALLY TREAT WATER?) 3.No water in house → SKIP TO E43 (USUALLY TREAT WATER?)
E32	OBSERVE: Does household store water in the home? HINT: Do not ask, just observe and note.	1Yes 2.No, use directly from tap → SKIP TO E35 (how is drinking water served)

		3.No, asks water from neighbor → SKIP TO E35 (how is drinking water served)
E33	OBSERVE: What type of containers do they use for storing drinking water? *<u>Narrow neck</u> = the neck is small enough to prevent a child's hand to enter*	1.Narrow mouth 2.Wide mouth
E34	OBSERVE: Is the storage container covered?	1.Yes 2.No
E35	Ni gute mutanga amazi yo kunywa? Wanyereka? How is the drinking water served? Can you show me?	1. Use tap 2. Pour water 3. Dip cup/container into the water 4. Use a ladle 5. Drink directly from container
E36	Nafataho amazi yo gupima? May I take a water sample? CONFIRM WATER SAMPLE TAKEN	1.Yes 2.No
E37	Aya mazi mwayavomye ryari ku isoko? / When was this water collected from the water source?	[1] HOURS AGO, SPECIFY_____ [2] DAYS AGO, SPECIFY _________
E38	Ni irihe zina ry'isoko mwavomyeho aya mazi? / What is the name of the water source from which this water was collected? HINT: WRITE ALL KNOWN NAMES.	
	WATER SOURCE ID HINT: RECORD FROM WATER SOURCE ID SHEET IF MATCHES. ELSE CALL TEAM LEADER FOR ID. FIRST THREE DIGITS ARE VILLAGE ID.	WS |__|__|__|__|__|
E39	Ni ubuhe bwoko bw'isoko mwavomyeho aya mazi? / What type of source was this water collected from?	[1] Same source as used for drinking during rainy [2] Same source as used for drinking during dry [3] Same source as used for other purposes during rainy [4] Same source as used for other purposes during dry [5] Piped water into dwelling/yard/plot [6] Public tap/standpipe [7] Hand pump [8] Protected dug well /cover well [9] Protected spring [10] Rainwater [11] Bottled water [12] Unprotected dug well [13] Unprotected spring [14] Tanker truck/cart with drum

		[15] Surface water, specify:________ [16] Other, specify:_______________
E40	Waba warasukuye aya mazi ngo abe meza yo kunyobwa? / Did you treat this water to make it safer to drink?	1.Yes 2.No → SKIP TO E43 (usually treat?) 99. Don't know → SKIP TO E43 (usually treat?)
E41	Aya mazi wayasukuye ute? / How did you treat this water? HINT: SELECT ALL THAT APPLY.	1. Boiling 2. Sur Eau 3. Filter 4. Purchase water 5. PUR 6. Other (please specify) _________
E42	Aya mazi wayasukuye ryari? /When did you treat this water?	HOURS AGO, specify_______ DAYS AGO, specify ________
E43	Ubusanzwe hari uburyo ubwo ari bwo bwose usukura amazi yawe ngo uyagire meza yo kunyobwa? / Do you usually treat your water in any way to make it safer to drink?	1. Yes 2. No → SKIP TO E48 (why not treat)
E44	Uyasukura ute? / How do you usually treat your water? HINT: SELECT ALL THAT APPLY	1. Boiling 2. Sur Eau 3. Filter 4. Purchase water (from store/boutique/shop) 5. PUR 6. Other (please specify) _________
E45	OBSERVE FOR EACH PRODUCT LISTED ABOVE (E44): Does household have product in the house?	1.Yes 2.No 99. Don't know/can't observe
E46	Ni incuro zingahe usukura amazi yanyu yo kunywa? / How often do you treat your drinking water?	1.Daily 2.Once per week 3.2-3 per week 4.Other, specify
E47	Mu cyumweru musukura litiro zingahe z'amazi? / How many liters of water do you treat each week HINT: LITERS.	Amount liters _________
E48	Ni ukubera iyihe mpamvu udasukura amazi yanyu? / Why do you not treat your water? Relevance: If respondent does not usually treat water (E43 = NO)	1. Expensive 2. Takes too much time 3. No firewood 4. The water looks clean/doesn't need to be treated 5. Don't know if water needs to be treated 6. Don't know about any methods 7. No Storage 8. Don't like the taste 9. Other (please specify) _________
E49	Waba hari ubundi buryo uzi mu gusukura amazi? / Are you aware of other methods of treating water?	1. Yes 2. No → SKIP TO E.52 (FUEL USED FOR BOILING)

E50	Ubwo buryo ni ubuhe? / What methods? HINT: SELECT ALL THAT APPLY	1. Boiling 2. Sur Eau 3. Filter 4. Purchase water 5. PUR 6. Other (please specify) _________
E51	Wigiye he ubwo buryo? / Where did you learn about this method? HINT: SELECT ALL THAT APPLY.	[1] School [2] From neighbor, family, or other people [3] Community health workers [4] Hospital [5] Government policy [6] Organization (please specify) _________ [7] Other (please specify) _________
E52	Wifashisha ibihe bicanwa mu guteka amazi? / What type of fuel do you use for boiling? HINT: SELECT ALL THAT APPLY. Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	1. Wood 2. Charcoal 3. LPG/Natural Gas/Biogas 4. Electricity 5. Kerosene 6. Straw/shrubs/grass 7. Agricultural crop 8. Animal dung 9. Other (please specify) _________
E53	Ni ubuhe bwoko bw'amashyiga ukoresha mu guteka amazi? / what type of stove is used for boiling? HINT: SELECT ALL THAT APPLY. Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	1. 3-stone 2. Rondereza 3. Imbabura/charcoal stove 4. Mud woodstove 5. Ceramic woodstove 6. Metal woodstove 7. Improved charcoal stove 8. Gasifier stove 9. Biogas stove 10. LPG 11. Kerosene 12. Electric 13. Other (please specify) _________
E54	Ukoresha igihe kingana iki utetse amazi? / How long does it take to boil water? HINT: MINUTES Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	Number minutes ________
E55	Ni gute umenya ko amazi ahiye neza?/ how do you know when the water is well-boiled?	

	Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	
E56	Ubusanzwe iyo utetse amazi urapfundikira? / Do you usually use a lid to cover the pot? Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	1. Yes 2. No
E57	Ni incuro zingahe muteka amazi yo kunywa? / How often do you boil your drinking water? Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	1.Daily 2.Once per week 3.2-3 per week 4.Other, specify
E58	Mu cyumweru muteka litiro zingahe z'amazi? / How many liters of water do you boil each week? HINT: LITERS. Relevance: Only if respondent mentioned boiling water (E44=BOILING) OR this water boiled (E41=BOILING)	Amount liters_______
E59	Hari ubundi buryo wumva bugushimishije bwo gusukura amazi? / Are you interested in other methods of treating your water?	1. Yes 2. No → SKIP TO E60A
E60	Ni ubuhe buryo? / Which methods	1. Boiling 2. Sur Eau 3. Filter 4. Purchase water 5. PUR 6. Don't know any methods 7. Other (please specify) ________
E60A	Uramutse ufite ubushobozi bwose ku gihe n'amafaranga,? / If you had all the needed resources of time and money what water treatment method would you choose?	1. Boiling 2. Sur Eau 3. Filter 4. Purchase water 5. PUR 6. Don't know any methods 7. Other (please specify) ________
E61	Wahitamo kwishyura ku kwezi cg kwishyurira rimwe? / Would you prefer to pay per month or one-time cost? HINT: IF SELECTED BOILING, HOW MUCH WILLING TO PAY FOR MATERIALS.	[1] PER MONTH [2] ONE TIME COST
E.62	Ubwo buryo wabwishyura amafaranga angahe? / How much would you pay for it? HINT: RWF. IF SELECTED BOILING, HOW MUCH WILLING TO PAY FOR MATERIALS.	

E63	Ese mwaba mufite igikatsi/umutobe byo kunywa? Does your household have banana water/juice available to drink?	[1] YES [2] NO → SKIP TO WATER PRACTICES COMMENTS
E64	Nafataho igipimo? May I please collect a sample? HINT: WRITE BW + HOUSEHOLD ID ON BAG	[1] YES [2] NO
E65	Waba warasukuye iki gikatsi/uyu mutobe ngo bibe byiza byo kunyobwa? / Did you treat this banana water/juice to make it safer to drink?	1.Yes 2.No → SKIP TO WATER PRACTICES COMMENTS 99. Don't know → SKIP TO WATER PRACTICES COMMENTS
E66	iki gikatsi/uyu mutobe wabisukuye ute? / How did you treat this banana water/juice? HINT: SELECT ALL THAT APPLY.	1. Boiling 2. Sur Eau 3. Filter 4. Purchase water 5. PUR 6. Other (please specify) ________
E67	iki gikatsi/uyu mutobe wabisukuye ryari? /When did you treat this banana water/juice?	HOURS AGO, specify_______ DAYS AGO, specify ________

WATER PRACTICES COMMENTS

Season Identification

Y.1	Ni iminsi ingahe mu cyumweru gishize(uhereye umunsi nk'uyu mu cyumweru gishize)imvura yaguye? / On how many DAYS in the last week (since this day last week) did it rain? HINT: WRITE 99 IF DON'T KNOW	|__| DAYS
Y.2	Uko ubibona ubona turi mu gihe cy'imvura cg cy'izuba? / In your opinion, do you think we are in rainy or dry season?	[1] YES [2] NO [99] DON'T KNOW

CONCLUSION

Z.1	SURVEY END TIME	|__|__|:|__|__|

	FORMAT: HH:MM	
Z.2	RECORD HOUSEHOLD GPS POINT	
Z.3	WAS SOMEONE ABLE TO ACCOMPANY YOU TO WATER SOURCE?	[1] YES – PERSON FROM HOUSEHOLD WHO USUALLY COLLECTS WATER [2] YES – OTHER PERSON FROM HOUSEHOLD [3] YES – OTHER PERSON (E.G., NEIGHBOR) [4] NO ONE [88] N/A – WATER SOURCE ON PREMISES/PURCHASES WATER

GENERAL SURVEY COMMENTS:

***Give the person the business card with the contact information

If you have questions related to the study please contact Jean Ntazinda of the Del Agua Health and Development Program at 0788481439.

If you have any questions related to your right as a participant, contact Dr. Justine Wane, the chairperson of Rwanda Ethics Committee at 0788500499 or the secretary of RNEC Dr. Emmanuel; NKERAMIHIGO at 0788557273.

Time Interview Ended: _____________ Surveyed by: ________________________________

PLEASE RECORD ANY USEFUL OBSERVATIONS OR COMMENTS BY RESPONDENTS