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Escherichia coli Exposure Pathways in Some Unplanned Settlements in Lusaka District, Zambia: A case of food safety

A Research Project Report Submitted in Partial Fulfilment for the Master of Science Degree in One Health Food Safety

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Lusaka

DECLARATION

I declare that this research report was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree, diploma or other qualification at this or any other University.

Student: Grace Chiedza Esnart Mwanza

Signature: _____

CERTIFICATE OF APPROVAL

The University of Zambia approves the research report submitted by GRACE CHIEDZA ESNART MWANZA, as fulfilling the partial requirement for the award of the degree of Master of One Health Food Safety Science by the University of Zambia.

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ABSTRACT

Poor sanitation has been characteristic of most peri-urban areas in Zambia resulting in environmental contamination with pathogens such as *Escherichia coli* consequently leading to high morbidity of enteric diseases. Foodborne *E. coli* transmission is recognized as being responsible for a major proportion of these infections. Low sanitation service coverage has downstream effects on food safety and hygiene giving rise to endemic diarrheal disease outbreaks. One of the major organisms used as an indicator of poor sanitation is *E. coli* and it is ubiquitous in nature resulting in a high chance of contracting it. The major pathways responsible for contamination have been identified to be food and water. Studies have been conducted in Accra Ghana indicating that waste water irrigation was a major exposure pathway for fresh crop produce to humans.

A cross sectional study was conducted in 3 residential areas to determine *Escherichia coli* exposure pathways. The nine exposure pathways of *Escherichia coli* were identified in Chawama, Chazanga and George settlements in Lusaka District in a cross-sectional study that involved the collection of two hundred fifty (n=250) environmental samples and various foods. Environmental samples were analysed using the IDEXX kit. Further, behavioural survey data was collected from seven hundred eighty (n=780) participants to assess the relative exposure to *E. coli* contamination.

Through laboratory analysis seventy-two (72) *E. coli* isolates were isolated and of these, twenty-four (24) were presumed invasive on MacConkey-Congo red media and ten (10) were Extended Spectrum Beta-Lactamases producing.

Antibiotic susceptibility of isolated *E. coli* was carried out by disk diffusion method against the commonly used drugs in human and animal medicine. Sulfamethoxazole/Trimethoprim with *E. coli* isolates from seven (7) pathways being 100% resistant and Cefotaxime with *E. coli* isolates from five (5) pathways being 100% resistant showed the highest rate of resistance while Streptomycin showed the least resistance.

The study highlighted the roles that the environment and behaviour play in human exposure to *E. coli* contamination and in turn poor food safety outcomes. Dominant pathways of exposure varied across residential areas and age groups, with dominant pathways for adults including fresh crop produce and drinking water, and dominant pathways for children including stormwater, drainage water, fresh crop produce and surface water. It was recommended that intensive sensitisation be conducted in these areas to highlight the identified exposure pathways.

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DEDICATION

To my husband Kunda, Timothy and Michaela, thank you for being my inspiration and drive. To Esnea, thank you, I would not be if it were not for you being.

ACKNOWLEDGEMENTS

As the old adage goes, with God, nothing is impossible. Thank you, Heavenly Father for making the impossible truly possible. Your grace is indeed sufficient.

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ABBREVIATIONS AND ACRONYMS

CLSI	Clinical Laboratory Standards Institute
DAEC	Diffusely Adhering *Escherichia coli*
EAEC	Enteroaggregative *Escherichia coli*
EAP	United States Environmental Protection Agency
EHEC	Enterohemorrhagic *Escherichia coli*,
EIEC	Enteroinvasive *Escherichia coli*
EPEC	Enteropathogenic *Escherichia coli*
ESBL	Extended Spectrum Beta-Lactamases
ETEC	Enterotoxigenic *Escherichia coli*
MDG	Millennium Development Goals
MPN	Most Probable Number
QMRA	Quantitative Microbial Risk Assessment
STEC	Shiga Toxin–producing *Escherichia coli*
UNICEF	United Nations International Child Education Fund
WASH	Water Sanitation and Hygiene
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 Background

Globally, the trend of increasing numbers of urban centre inhabitants and reducing numbers in rural areas is evident and expected to continue. This is because urban centres are seen to provide new economic opportunities that attract rural workers opting out of agriculture to more remunerative activities, better education and health care (Ravallion, Chen and Sangraula, 2007). It is predicted that in the next 30 years, developing countries will triple their population size resulting in an account for 80% of the world's urban population (Cohen, 2005). Projections for this urbanisation look bleak, with slums to see 60% of all urban population growth and increased poverty. Without a fundamental change, our urbanising world will, in reality, become a vast sprawl of inhuman slums and informal settlements (Uwejamomere, 2008).

An estimated 72% of the urban population of Africa now live in unplanned settlements in cities that do not have the capacity to provide adequate basic services for its inhabitants (Cohen, 2006). This was evident in Eritrea, Malawi, Namibia, Nigeria, Rwanda, Sierra Leone, Zambia and Zimbabwe where the proportion of inhabitants of urban areas with piped water and/or access to safely managed sanitation decreased between 1990 and 2015 (Dodman *et al.*, 2017). Inadequate access to basic services such as safe drinking water, safely managed sanitation, good housing and solid waste management produces extensive hazards for the under-served or un-served. This could lead to the contamination of drinking water, food and food preparation surfaces resulting in diarrhoeal diseases which are the fourth most significant cause of death in sub-Saharan Africa (Fullman, 2010).

The city of Lusaka is no exception with an estimated population of 2,520,102 and growth rate of 4.9% (Central Statistics Office and Ministry of Health, 2016). Overcrowding is linked with a low space per person, high occupancy rates, cohabitation by different families and a high number of single-room units. Many slum dwelling units are overcrowded, with five and more persons sharing a one-room unit used for cooking, sleeping and living (Sclar and Northridge, 2003). Unhealthy living conditions are the result of a lack of basic services, with visible, open sewers, uncontrolled dumping of waste and polluted environments. Houses may be built on hazardous locations or land unsuitable for settlement, such as rocky areas with a high-water table and poor stormwater drainage

as is the case in Kanyama and Chawama residential areas in Lusaka, in proximity to industrial plants with toxic emissions or waste disposal sites, and on areas subject to landslip. The layout of the settlement may be hazardous because of the lack of access and high densities of dilapidated structures a result of the poor economic status of the inhabitants who are unable to complete their structures (Kimani-Murage and Ngindu, 2007).

Poor sanitation results in the presence of *Escherichia coli* in the environment consequently leading to high morbidity due to enteric diseases. *Escherichia coli,* in itself, is a major culprit in enteric disease causation. Being ubiquitous in nature, its presence is not a determination of pathogenicity but maybe an indication of faecal contamination and poor sanitation (Wingender and Flemming, 2011). Humans acquire *Escherichia coli* infections through a number of routes, including eating contaminated food, contact with live animals, and contact with a contaminated environment. Foodborne transmission is recognized as being responsible for a major proportion of these infections, and foodborne diseases may involve many different food sources and commodities (Ayers *et al.,* 2009). This study endeavoured to use *Escherichia coli* as a microbial indicator to determine exposure pathways of faecal contamination and to further determine its pathogenicity and antimicrobial resistance in high population areas. In Zambia, conditions of high population density are found in cities such as Lusaka, where peri-urban areas like Chawama, Chazanga and George settlements lack basic services such as sanitation facilities and safe water sources.

1.2 Statement of the Problem

As a result of rapid urbanisation, the greater city of Lusaka has continued to grapple with sprawling unplanned settlements. These settlements usually referred to as peri-urban areas are an indication of systematic failures in planning and unregulated development. As such, peri-urban areas are not adequately serviced with basic public health support requirements such as water and sanitation. With persistence of low service provision, residents have resorted to the use of unimproved sanitary facilities and shallow wells in order to meet their basic sanitation and water needs respectively (Kulabako *et al.,* 2010). This has given rise to endemic diarrheal disease outbreaks being reported annually and these areas being considered as hot spots (Siziya, 2017).

Poor water and sanitation service provision has had downstream effects on food safety and hygiene such as the contamination of fresh crop produce and water that is used for food preparation and cleaning food preparation utensils such as cutlery and crockery hence the continued endemic state of diarrheal diseases in Lusaka. Currently, faecal exposure pathways have not been determined

scientifically in most settlements in Lusaka. This has resulted in poor intervention outcomes evidenced by recurring outbreaks of diseases that include cholera and dysentery associated conditions. The most recent Cholera outbreak was experienced between October 2017 and May 2018, with a total of 5,414 suspected cases representing 91.7% of all recorded suspected cases in Zambia, were recorded in Lusaka. Furthermore, 98 deaths indicating a Case Fatality Rate of 1.8%, occurred in Lusaka residents (Sinyange et al, 2018). This could be an indication that the actual exposure pathways may have not been determined as most diarrheal disease outbreaks are as a result of sanitation failure. There is therefore need to determine the faecal exposure pathways.

1.3 Rationale of the Study

Peri-urban areas are confronted with poor sanitation as a result of inadequate infrastructure such as unlined pit latrines or dilapidated sewer systems. Due to unavailability of resources to establish the required infrastructure to improve sanitation and the general wellbeing of the populace, there is need for a systematic approach to consider viable intervention options and resource allocation. This can be achieved by determining the most dominant exposure pathways and determining the most efficient high impact interventions to avert exposure from the determined dominant pathways. It is also critical in the case of *Escherichia coli*, being one of the most ubiquitous enteric bacteria in the environment, to determine whether pathogenic strains are present and if the commonly used antimicrobials are effective. This study is intended to determine the most dominant pathways of exposure in order to adequately inform public health interventions by Lusaka City Council with regards faecal exposure and its related enteric diseases such as cholera and typhoid.

1.4 Significance of the Study

This study is intended to scale up the use of a digital exposure pathway assessment tool (Sanipath) provided by the Global Centre for Sanitation at Emory University through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in order to provide a basis upon which it can be applied fully in the Public Health Department of Lusaka City Council. This is in order to improve and encourage risk-based approaches in the provision of interventions. It is also envisioned that the study can provide more information that can be used during health promotion activities with regards faecal exposure pathways and disinfection in relation to food safety. This information is especially critical at household and community levels as both household and community samples will be assessed. Currently, exposure pathways in Chawama, Chazanga and George are unknown as no study has been conducted in these settlements to scientifically determine

these pathways. The information gathered can further be used in other simulation models to predict where the next sanitation related disease outbreak can occur. This is critical for epidemic prevention and preparedness in Lusaka District and for the optimisation of resource use. The study is intended to further influence the optimisation of environmental sampling, the analysis of results and use of Public Health data for decision making by Lusaka City Council and Lusaka District Health Office.

1.5 Research Question

a) What are the most common *Escherichia coli* exposure pathways to residents of highly populated settlements of Lusaka?
b) Are there any pathogenic species of *Escherichia coli* present in the identified exposure pathways?

1.6 Objectives

1.6.1 General Objective

- To determine the main exposure pathways of *Escherichia coli* in highly populated unplanned settlements in Lusaka District.

1.1.1 Specific Objectives

a) To identify probable *Escherichia coli* exposure pathways through isolation of *Escherichia coli* in unplanned settlements of Lusaka District.
b) To determine pathogenicity and the antibiotic susceptibility of *Escherichia coli* isolated in the identified pathways**.**

CHAPTER TWO

LITERATURE REVIEW

2.1 Sanitation and food safety

Globally, 2.3 billion people were estimated to live without access to basic sanitation services (World Health Organization; UN-Water, 2014) with almost 892 million of these people practicing open defecation. Despite significant gains, over 2.2 billion people gained access to improved toilets or latrines since 1990 as sanitation was one of the most off-track Millennium Development Goals (MDGs) globally. Today, only 68% of the world's population has access to basic sanitation, and only 39% of people have access to safely managed sanitation (which includes containment, through safe collection and conveyance, to treatment and end use/disposal). Further, 72% of people in Sub-Saharan Africa and 50% of people in South Asia still lack access to basic sanitation services (an improved toilet/latrine). The world missed the MDG target for sanitation by almost 700 million people (Berendes *et al.*, 2018).

In addition to the challenges of providing many millions of rural households with adequate sanitation, the world continues to urbanize, and cities and small towns will increasingly bear the burden of poor sanitation with an estimated 57% of urban dwellers lacking access to toilets that provide a full sanitation service, 16% of urban dwellers lacking access to basic sanitation services, and almost 100 million urban residents practicing open defecation (Moe, 2006).

Low sanitation service coverage has downstream effects on food safety and hygiene giving rise to endemic diarrheal disease outbreaks (Ayers *et al.*, 2009). Studies have been conducted in Accra Ghana indicating that wastewater irrigation was a major exposure pathway for fresh crop produce to humans (Berendes *et al.*, 2018). This was especially a problem with exotic vegetables such as lettuce, cabbage and spring onion cultivated with wastewater in Accra, Kumasi and Tamale and were likely to be eaten raw posing a food safety risk (Amoah, 2008). Poor microbial and physiochemical water quality, sanitation and hygiene results (WASH) have a downstream effect on food safety. The importance of food safety is not fully appreciated by many public health authorities even though epidemiological surveillance has demonstrated a constant increase in the prevalence of foodborne illnesses (Ka and Abdussalam, 1999). Poor WASH are the main causes of infections like diarrhoea, and inadequate WASH continues to be the leading cause of death of children under the age of five in sub-Saharan Africa.

Ali, (2010) stated that the essential tragedy of the pandemic of diarrhoeal diseases lies in that it is almost entirely preventable. Diarrheal diseases are caused by various bacterial, viral and protozoan pathogens that may be transmitted by contaminated food. The diarrhoeal diseases are communicated via complex and manifold faecal-oral pathways. Pathogens in human and animal excreta are transmitted by soil, surface and groundwater, flies, hands or other vectors where humans ultimately become exposed via the ingestion of contaminated water and food (Medeiros *et al.*, 2001).

2.2 Sanitation in Zambia

Zambia made moderate progress towards reaching its drinking water supply targets under the Millennium Development Goals over the period 1990-2015, according to the WHO-UNICEF Joint Monitoring Programme (UNICEF, 2015). However, during the same period, the country reportedly made 'limited or no progress' towards achieving its sanitation targets.

Poor sanitation results in a 1.3 per cent loss to Zambia's national Gross Domestic Product annually, according to the World Bank (Prüss *et al.*, 2002). Girls and women are particularly affected by poor WASH conditions. The drudgery of hauling water leads to loss of productivity and leisure time and the lack of toilets negatively impacts their dignity (Bartram and Cairncross, 2010).

Access to improved sanitation in the capital city Lusaka has fallen over the last 15 years, and over half of the population currently lack access to even a basic sanitation service (Kappauf *et al.*, 2018). At least 65% of people live in low-income communities, also known as peri-urban areas, which usually lack proper sewerage. This means they need to use on-site sanitation services such as pit latrines and septic tanks instead, which can contaminate nearby water supplies through septage percolation into ground water aquifers (UNICEF, 2015).

2.3 Microbial indicators of faecal contamination

Microbial indicators are employed to assess food safety and sanitation. A food safety indicator should meet certain important criteria. It should be easily and rapidly detectable, be easily distinguishable from other members of the food biota and have a history of constant association with the pathogen whose presence is to indicate (Lahou *et al.*, 2012). The indicator must always be present when the pathogen of concern is present and be an organism whose numbers ideally should

correlate with those of the pathogen of concern possess growth requirements. Its growth rate should equal or exceed that of the pathogen, have a die-off rate that at least parallels that of the pathogen and ideally persists slightly longer than the pathogen of concern and be absent from foods that are free of the pathogen except perhaps at certain minimum numbers (Jay, 2000). Some common hygiene indicators include but are not limited to *Enterobacteriaceae, Escherichia coli*, *Clostridium perfringens* and *Staphylococcus aureus* (Lahou *et al.*, 2012).

2.3.1 *Escherichia coli* as a microbial indicator of faecal contamination

Escherichia coli are the predominant member of the facultative anaerobic portion of the human colonic normal flora (O'Hara and Shanahan, 2006). The bacterium's only natural habitat is the large intestine of warm-blooded animals and since *E. coli*, with some exceptions, generally does not survive well outside of the intestinal tract, its presence in environmental samples, food, or water usually indicates recent faecal contamination or poor sanitation practices in food-processing facilities. The population of *E. coli* in these samples is influenced by the extent of faecal pollution, lack of hygienic practices, and storage conditions. Odonkor and Ampofo, (2013) stated that the mere presence of *E. coli* in food or water does not indicate directly that pathogenic microorganisms are in the sample, but it does indicate that there is a heightened risk of the presence of other faecal-borne bacteria and viruses. These other faecal organisms, belonging to the Enterobacteriaceae family may include *Salmonella spp.* or hepatitis A virus which may be pathogenic. For this reason, *E. coli* is widely used as an indicator organism to identify food and water samples that may contain unacceptable levels of faecal contamination (Odonkor and Ampofo, 2013).

E. coli is considered a more specific indicator of faecal contamination than faecal coliforms since the more general test for faecal coliforms also detects thermotolerant non-faecal coliform bacteria (Jin *et al.*, 1998). The *E. coli* test recommended by the United States Environmental Protection Agency (EPA) confirms presumptive faecal coliforms by testing for the lack of an enzyme which is selective for the *E. coli* organism. This test separates *E. coli* from non-faecal thermotolerant coliforms (Ibid).

2.3.2 *Clostridium perfringens* as a microbial indicator of faecal contamination

Clostridium perfringens is a spore-forming bacterium and a natural inhabitant of soil and the intestinal tract of many warm-blooded animals and humans. The ubiquitous nature of this bacterium and its spores makes it a frequent problem for the food industry and establishments where large amounts of foods are prepared (Brynestad and Granum, 2002). *C. perfringens* is a

relatively large, nonmotile, Gram-positive, anaerobic rod of the family *Bacillaceae*. Most strains sporulate poorly in laboratory media, an important aspect since the presence of the enterotoxin can only be demonstrated in sporulating cultures (Labbe and Juneja, 2017). These properties make it unfavourable for use as a routine indicator of faecal contamination.

2.4 Determination of exposure pathways of *Escherichia coli*

Dominant exposure pathways may be identified through epidemiological studies that examine the effects of intervention(s) on health outcomes. It has been demonstrated that due to nonlinear dose response curves, if diarrheal disease incidence falls sharply after a WASH intervention, the affected route such as contaminated water, food or food preparation material can be considered the primary route of transmission (Wang *et al.*, 2017).

Epidemiological studies of sanitation and health often use incidence of diarrheal disease or anthropometric indicators as an outcome and subsequently seek to characterize exposures. A Cochrane Collaboration, focused on the effect of handwashing with soap on diarrhoea, of water quality improvement and of excreta disposal, respectively (Cairncross *et al.*, 2010) was one such study. Another study examined the impact of several environmental sanitation conditions and hygiene practices on diarrhoea occurrence among children under five years of age living in an urban area (Heller, Colosimo and De Figueiredo Antunes, 2003). Health outcome data on enteric diseases are challenging to collect and interpret. For example, studies typically rely on self-report or clinical records to measure diarrheal disease incidence. Self-reported diarrhoea is subject to biases, and clinical data underestimates the true burden of enteric infection. Diarrhoea surveillance is costly, and without stool samples, enteric infection cannot be confirmed or linked to specific pathogens. Furthermore, even in the absence of symptoms, enteric infection has been shown to be detrimental to child growth and development (Schmidt *et al.*, 2011).

Quantitative Microbial Risk Assessment (QMRA) uses data on pathogen concentrations and human behaviours related to intake or ingestion of faecal contaminated materials to estimate exposure risk. Compared with epidemiological studies, QMRA is better suited to examine low levels of risk and health effects that are difficult to measure. Focusing on exposure recognizes the fundamental concept that health effects are conditional on exposure and without exposure there would be no health effects. However, extrapolating from exposure to health effects may overestimate the risk of health effects because due to differences in immunity, not all who are exposed will develop health effects, some acute health effects will be too mild to be measurable

and other long-term health effects will be delayed in onset, so that they may not be measured during the timeframe of an epidemiological study (Robb *et al.*, 2017a).

Conversely, epidemiological studies that focus on the relation between interventions and population health tend to underestimate risk, because of under- ascertainment and underreporting of health outcomes. The true burden of health effects may be bounded by the QMRA estimates of exposure and epidemiologic estimates of health effects. This gap between risk assessment and epidemiology becomes even more relevant as additional health outcomes associated with faecal exposure such as environmental enteropathy, stunting, and cognitive deficits are being recognized. Robb *et al.*, (2017) suggested that faecal exposure pathways be ranked to provide guidance on where to target WASH interventions, which could lead to reduction of adverse health outcomes.

2.5 Determination of pathogenicity of *Escherichia coli*

Besides the commensal *E. coli*, several pathovars of diarrheagenic strains have been differentiated on the basis of pathogenic features. Thus, Enterohemorrhagic *Escherichia coli* (EHEC), a subcategory of Shiga Toxin–producing *Escherichia coli* (STEC), Enterotoxigenic *Escherichia coli* (ETEC), and Enteroinvasive *Escherichia coli* (EIEC) are obligatory pathogens responsible for severe and acute diarrhoea, because of the production of toxins and/or the invasion of the intestinal epithelium. Enteropathogenic *E. coli* (EPEC), Enteroaggregative *Escherichia coli* EAEC, and Diffusely Adhering *Escherichia coli* (DAEC) are associated with chronic and mild diarrhoea and are characterized by the adherence pattern on epithelial cells (Blanc-Potard *et al.*, 2004).

2.6 Identification of *Escherichia coli*

E. coli is the type species of the genus *Escherichia*, which contains mostly motile gram-negative bacilli within the family *Enterobacteriaceae* and the tribe *Escherichia*. *E. coli* can be recovered easily from clinical specimens on general or selective media at 37°C under aerobic conditions. *E. coli* in stool are most often recovered on MacConkey or Eosin Methylene-Blue (EMB) agar, which selectively grow members of the *Enterobacteriaceae* and permit differentiation of enteric organisms on the basis of carbohydrate utilization (Kaper, 2002).

2.7 Sanitation in Lusaka

In the greater city of Lusaka, water supply service especially in the peri-urban areas is rudimentary, and sanitation service provision almost non-existent. Sanitation provision in the peri-urban areas is generally left to the initiative of the residents who mostly use unlined pit latrines that they dig within their plot boundaries. The pits are covered with soil once they are full. The liquid fraction of the excreta percolates into the ground and ultimately reaches the groundwater. The groundwater table ranges from deep (approx. 30 m) to shallow (approx. 1 m) (Munch and Mayombelo, 2007). Karst features of the geological formations underlying Lusaka make it complicated to predict in which direction and at what velocity groundwater will flow, and makes it difficult to dig new pits. In formal planned areas, predominantly occupied by middle- to high-income residents, sanitation provision consists of the use of the existing conventional sewerage system and on-site septic tanks. Only 10 to 20 per cent of the overall population is served by the sewerage system, however, and the majority relies on on-site systems. This paints a grim picture for food safety as the primary ingredient and principal cleaning agent, water is almost always contaminated (Ibid).

2.8 Knowledge Gap

Currently, there is insufficient information as to the dominant *Escherichia coli* exposure pathways in the greater city of Lusaka. There is need to generate knowledge on the exposure pathways as a way to mitigate and control disease outbreaks in Lusaka.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Design

A cross sectional study of *Escherichia coli* exposure pathways in public domains was conducted. This approach allowed for comparison of risk of exposure to faecal contamination within and across exposure pathways. The relevant exposure pathways were identified using data from the previous pilot fieldwork in Kanyama and were vetted with local key informants. Further, *Escherichia coli* was isolated from the identified pathways and invasiveness was determined. Following *E. coli* isolation, antimicrobial susceptibility was further conducted.

3.2 Study Site

The study was conducted over a period of two months (September to October 2019) in Chawama, Chazanga and George in the Greater City of Lusaka, situated in Lusaka Province of Zambia as shown in Figure 3.1 below. The city's administrative area covers approximately 420Km² with a projected population of 2,520,102 in 2018 as indicated by Central Statistics Office and Ministry of Health, (2016). Lusaka District has the largest share of 79.3 percent of the urban population in Lusaka Province and accounts for 32 percent of the total urban population of the country (Central Statistical Office, 2012). The study areas were chosen because of their history of the recurring water and foodborne diarrhoeal disease outbreaks that were associated with poor sanitation (Siziya, 2017).

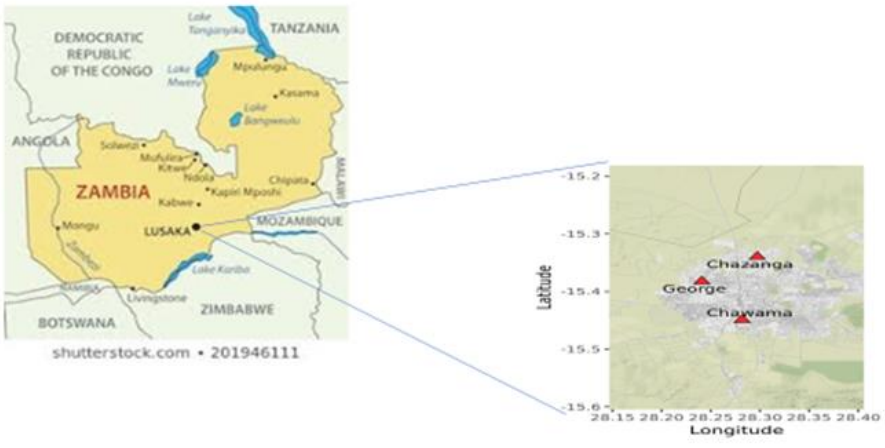

Figure 3-1: Map showing study areas - Chawama, Chazanga and George in Lusaka District

3.3 Study Frame/Population

The study population for the household surveys were households within Chawama, Chazanga and George residential areas in Lusaka with at least one child living in the household between ages 5 and 12. For the community surveys, adults with children under the age of 5 from Chawama, Chazanga and George were selected while children between the ages of 10 and 12 from selected schools within Chawama, Chazanga and George were selected for school surveys.

3.4 Sampling techniques

Global Positioning System coordinates were utilised to mark points to ensure even spatial distribution of sampling units. Stratified random sampling (every 8^{th} household) was used for selecting households for household surveys. On the other hand, Ward Development Committee leaders were requested to recruit community survey participants. Schools for the school surveys were selected through key informant interviews.

3.5 Sample Size

The sample size was based on the minimum required samples of ten (10) per pathway as provided by the SaniPath tool user guide (Center for Global Safe Water, 2014). Tables 3.1 and 3.2 below denote the number of environmental samples and behavioural survey participants respectively.

Table 3.1: Number of samples per pathway in the selected Residential area (environmental samples)

Residential area	Municipal Water	Borehole Water	Shallow Well Water	Open Drain Water	Surface Water	Shared Latrine Swabs	Fresh Crop Produce	Street Food	Soil
Chawama	10	10	10	10	10	10	10	10	10
Chazanga	10	10	10	10	0	10	10	10	10
George	10	10	10	10	0	10	10	10	10
Total	250								

Table 3.2: Number of participants per survey (Behavioural surveys)

	Household Surveys	Community Surveys	School Surveys
Number of Surveys/area	1	4	4
Total Number of Participants/area	100	40	40
Total Number of participants	780 (For all three areas)		

3.6 Sample collection

Environmental samples, one (1) for each pathway were collected and ten (10) household survey participants were randomly selected at each sampling point denoted by a purple mark on the maps in Figures 3.2 (Chawama), 3.3 (George) and 3.4 (Chazanga). The fresh crop produce and street food samples were bought from street vendors.

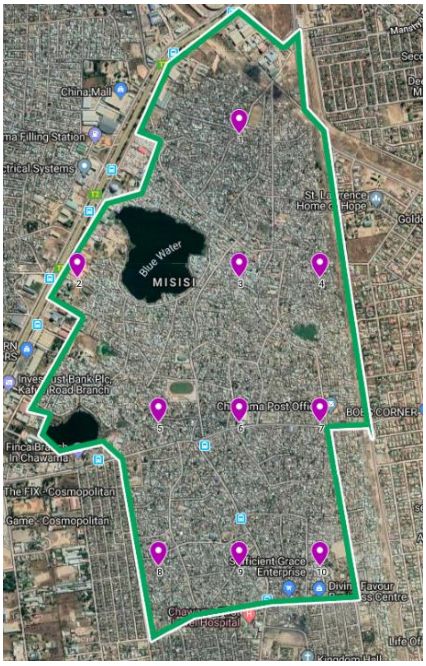

Figure 3.2: Map of Chawama showing sampling points

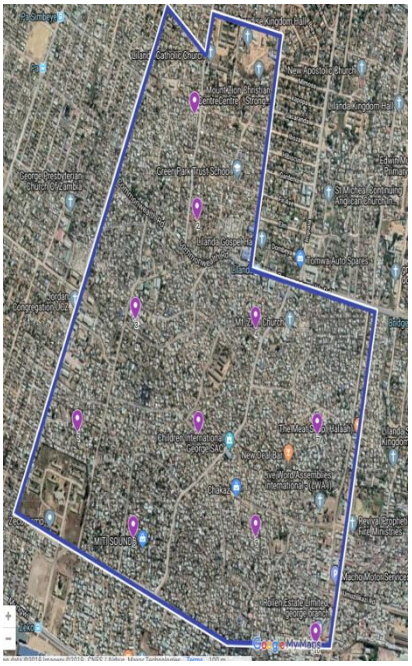

Figure 3.3: Map of George showing samping points

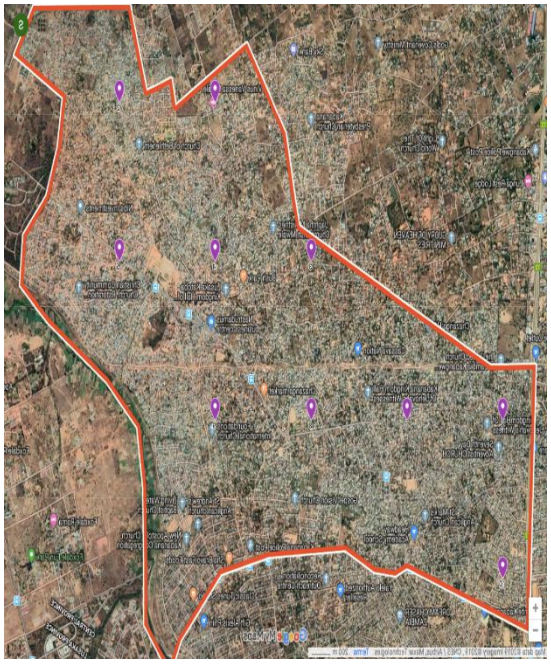

Figure 3.4: Map of Chazanga showing sampling points

3.7 Environmental analysis of samples

All the environmental samples were collected from public areas in target communities (Center for Global Safe Water, 2014). The public areas included communal water collection points of varying sources, open stormwater drainages, open grounds where children played, shared latrines and open informal markets. The environmental samples were analysed for *Escherichia coli* to provide information on presence of faecal indicator contamination. The quantification of the level of bacterial contamination was conducted using the IDEXX kit were a 100 mL sample was divided into 51 wells on a Quanti-tray with colilert then the standard methods' Most Probable Number (MPN) approach was used to determine the number of bacteria in the original sample. Two to three serial dilutions were used for each sample type, optimized to capture *E. coli* within the countable range (0 - 2419.6 MPN). A negative control was processed every day alongside sample analyses.

3.7.1 Culture, isolation and identification of *Escherichia coli* species

Samples that were positive for *E. coli* on IDEXX were selected and inoculated on MacConkey agar and incubated for 24 h at 37°C. Lactose fermentation-positive colonies were picked and confirmed by the triple sugar iron and indole, methyl red, voges-Proskauer, citrate and hydrogen sulphide tests (IMViC tests). Any isolate appearing as fermenting lactose with gas production within 48 hours, hydrogen sulphide negative and demonstrating an IMViC pattern of positive-positive-negative-negative was considered to be *E. coli*.

For the identification of pathogenic *Escherichia coli*, Congo red agar was used. It comprised Trypticase soy agar supplemented with 0.03% of Congo red dye and 0.15% bile salts. After inoculation, an incubation period of 24 hours at 37^{o}C was observed and the plates were left at room temperature for an additional 2 days. Congo-red-positive *E. coli* isolates (pathogenic) were identified by the appearance of red colonies. Congo- red-negative *E. coli* colonies did not bind the dye (white colonies) (Vinal, 1986).

3.8 Antimicrobial susceptibility tests

The antimicrobial susceptibility test was carried out using a Kirby-Bauer agar disk diffusion method. Clinical Laboratory Standards Institute (CLSI) guidelines were followed for inoculum standardization, medium and incubation conditions, and internal quality control organisms (CLSI, 2015). The following commercially available antimicrobial discs (Oxoid, Basingstoke, UK) were employed: Ceftazidime (CAZ 30), Ampicillin (AMP10), Streptomycin (S300), Chloramphenicol (C 30), Ciprofloxacin (CIP 5), Amoxicillin/Clavulanic acid (AMC 30), Gentamicin (CN10), Sulfamethoxazole/Trimethoprim (SXT 25), Tetracycline (TE 30) and Cefotaxime (CTX 30). ESBL-producing strains were confirmed by the combination disk method using cefotaxime (30 μg) or ceftazidime (30 μg) alone or in combination with clavulanic acid (10 μg). An increase in zone diameter of ≥ 5 mm for either cefotaxime or ceftazidime in combination with clavulanic acid indicated ESBL production. *E. coli* ATCC 25922 were used as quality control organisms.

Each pure bacterial isolate was emulsified in 5 ml sterile physiological saline (0.85% NaCl) to make a bacterial suspension compared with a barium chloride standard (0.5 McFarland). Prior to bacterial inoculation, the surfaces of Muller-Hinton agar plates were dried at 37^{o}C. This was followed by dipping a sterile swab into the bacterial suspension, removed excess fluid by pressing the swab against the wall of the test tube and applied the swab contents evenly on to the surface of the agar. Test culture plates were incubated at 37^{o}C for 24 hours and followed by determination of susceptibility or resistance profiles according to the breakpoints as described in the guidelines of the Clinical and Laboratory Standards Institute (CLSI, 2015).

3.9 Behaviour survey approach

To assess the frequency at which adults and children interacted with different pathways, behavioural surveys in communities, households, and schools were conducted. All households in the residential areas were asked to participate in the voluntary survey. The household member who

managed the water supply in the home was interviewed. Survey participants in households and community meetings were asked about their frequency of contact with the selected environmental pathways. They were further requested to estimate the frequency at which their children came into contact with same pathways. In school surveys, children were asked about their frequency of contact with the selected environmental pathways and were also requested to estimate the frequency of contact at which their parents or guardians came into contact with the same pathways.

3.10 Data/Statistical Analysis

Exposure assessment data was analysed using SaniPath Digital faecal Exposure Pathway analysis tool which was developed by Emory University (Center for Global Safe Water, 2014) and based on the generated laboratory results. The behaviour surveys provided information on the frequency of behaviour associated with exposure to selected exposure pathways namely municipal water, borehole water, shallow well water, open storm water drain water, surface water, shared latrine swabs, fresh crop produce (tomatoes and cucumber), street food (fritters and scones) and soil and the concentration of faecal contamination in each pathway. The environmental samples were analysed for *E. coli* as an indicator of faecal contamination. This data was then combined with frequency data from behavioural surveys and additional information from the literature that included intake values and duration of exposure, and analysed using Bayesian methods. All pathways were analysed with regard to ingestion of faecal contamination, either direct or indirect. A Monte Carlo simulation was then used to generate risk profiles of exposure to faecal contamination. This was done using the Sanipath tool.

3.11 Ethics Considerations

This study was undertaken in accordance with the ethical recommendations of ERES, Reference No 2018-Jan-004.

CHAPTER FOUR

RESULTS

4.1 Samples collected

A total of seven hundred and eighty (780) participants took part in the household, community and school surveys as indicated in table 4.1 below.

Table 4.1: Number of participants in behavioural surveys in selected residential areas

	Household Surveys		Community Surveys		School Surveys		Total No. Of Participants
Township	No. of Surveys	No. of Participants	No. of Surveys	No. of Participants	No. of Surveys	No. of Participants	
Chawama	100	100	4	80	4	80	260
Chazanga	100	100	4	80	4	80	260
George	100	100	4	80	4	80	260
Total No. of Participants		300		240		240	**780**

A total of two hundred fifty (n=250) environmental samples from municipal communal taps, borehole communal taps, shallow wells, open storm water drainages, surface water (dams), shared latrine surfaces, fresh crop produce (tomatoes and cucumbers), street food and soil were collected from the three study areas as shown in table 4.2 below.

Table 4.2: Number of environmental samples per pathway in selected residential areas

Township	No. of Samples per Exposure Pathway									
	Municipal Water	Borehole Water	Shallow Well Water	Open storm water Drain Water	*Surface water	Shared Latrine Swabs	Fresh crop Produce (tomatoes and cucumber)	Street Food (Fritters and scones)	Soil	Total No. Of Samples
Chawama	10	10	10	10	10	10	10	10	10	90
Chazanga	10	10	10	10	0	10	10	10	10	80
George	10	10	10	10	0	10	10	10	10	80
Total No. Of Samples	30	30	30	30	10	30	30	30	30	**250**

*The surface water samples were only collected in Chawama as there was no surface water in other areas.

4.1 Exposure pathway risk profiles

Out of the 780 respondents, 17% indicated using shallow well water, 52% borehole water and 86% municipal water. On the other hand, 31%, 39% and 100% of the respondents came into contact with surface water, open drain water and soil, respectively. A further 71% had consumed fresh crop produce (tomatoes and cucumbers) and 66% had consumed street food (fritters and scones) while 89% of the respondents had used shared latrines (Table 4.3).

Table 4.3: Number of respondents (adults and children) exposed to various pathways

	Chawama		George		Chazanga		Total-780 (260 for surface water) [%]	
Exposure Pathway	Adult-180	Children-80	Adult-180	Children-80	Adult-180	Children-80		
Shallow well water	24	14	24	8	6	54	131	[17]
Surface water	58	23	-	-	-	-	-	[31]
Open drain water	77	51	48	47	47	31	300	[39]
Borehole water	59	29	79	35	144	64	409	[52]
Soil	180	80	180	80	180	80	779	[100]
Shared latrine surfaces	159	74	164	77	148	70	692	[89]
Fresh crop produce	119	56	141	62	119	59	556	[71]
Street food	138	67	135	69	105	4	518	[66]
Municipal water	175	79	176	77	116	48	670	[86]

The average *Escherichia coli* concentrations in Log10/month that respondents (both adults and children) were exposed to were calculated for each pathway in each study area. The highest concentration *Escherichia coli* exposure in children was from tomatoes and cucumbers at 6.2 Log10/month in George while the lowest was from shared latrine surfaces in Chazanga at 0.2 Log10/month. In adults, the lowest exposure was 0.3 Log10/month from shared latrine surfaces in Chazanga and the highest was 5.7 Log10/month from borehole water (Table 4.4).

Table 4.4: The average concentration (Log 10 MPN) of *Escherichia coli* in selected residential areas in Lusaka

Exposure Pathways	Log10 MPN/Month *Escherichia coli*					
	Chawama		George		Chazanga	
	Adult	Children	Adult	Children	Adult	Children
Shallow well water	5.4	4.9	5.5	4.5	3.4	3.2
Surface water	4.9	5.6	-	-	-	-
Open drain water	3.9	5.1	4	5.4	2.8	4.1
Borehole water	5.7	4.9	3.7	3.6	2.6	2.3
Soil	2.5	3.7	2.7	2.7	0.8	1
Shared latrine surfaces	1.6	1.7	0.4	0.3	0.3	0.2
Fresh crop produce	3.9	3.6	5.4	6.2	4.8	5.4
Street food	3	2.6	2.5	2.2	2	2.7
Municipal water	2.4	2.8	5.2	4.3	2.6	2.5

Through the use of exposure data in Table 4.3 from the behaviour surveys and determined concentration values in Table 4.4, risk profiles for all exposure pathways were generated in the form of people plots for Chawama, Chazanga and George residential areas. The number of people per 100 were indicated by the people's icons shaded while the concentration of *E. coli* they were exposed to in Log10/month was indicated by the intensity of the red colour. The risk profiles in the form of people plots for various pathways in the study areas are indicated in figure 4.

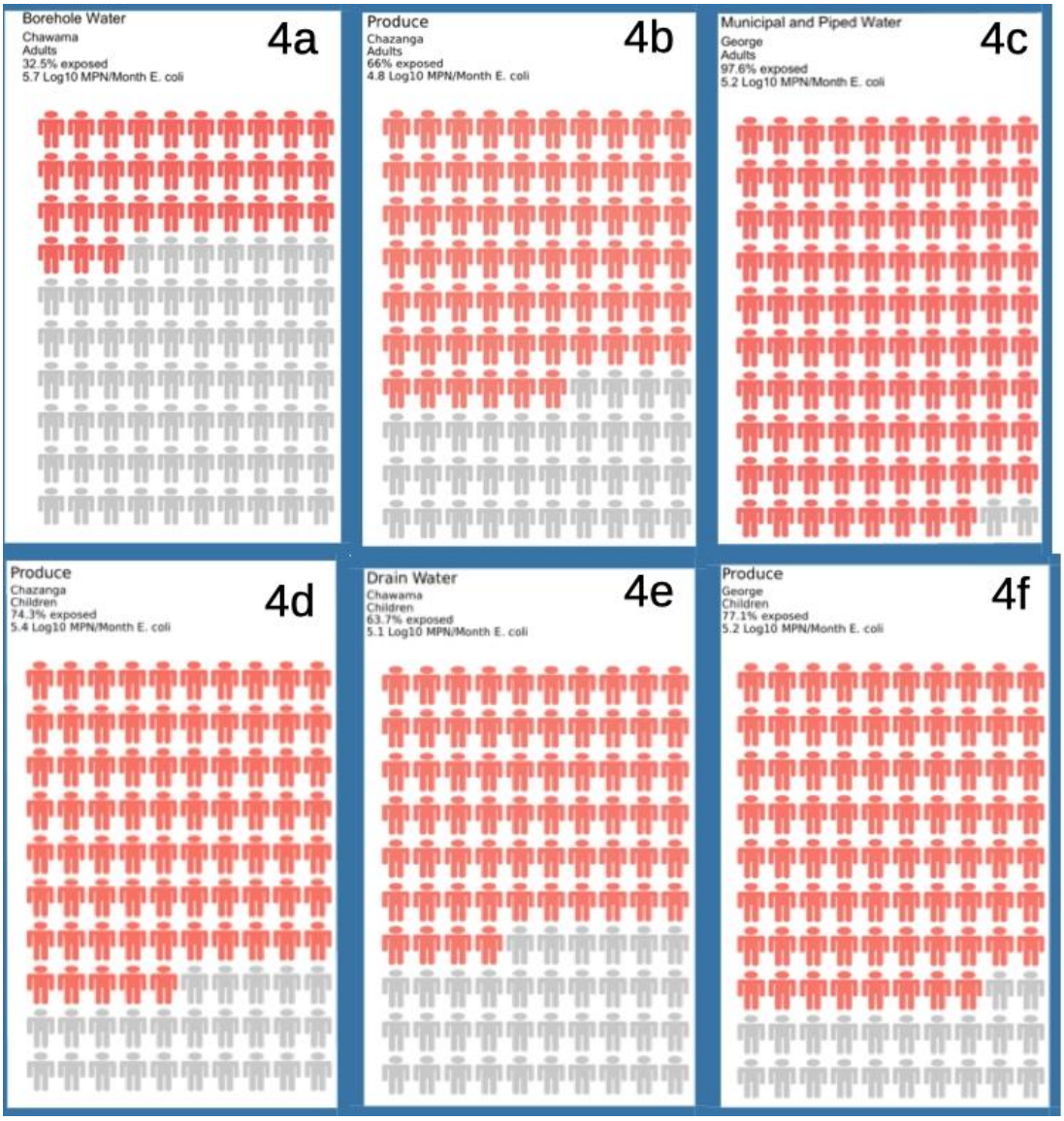

Figure 4: People plot (Risk Profile). People plot Figure 4a: shows that 33/100 adults were exposed to 5.7 Log10/month *Escherichia coli* in Chawama through borehole water while Figure 4b: indicates that 66/100 adults were exposed to 4.8 Log10/month *Escherichia coli* through tomatoes and cucumbers in Chazanga and Figure 4c: shows that 98/100 adults were exposed to 5.2 Log10/month *Escherichia coli* through municipal water in George. Figure 4d: indicates that 75/100 children were exposed to 5.4 Log10/month *Escherichia coli* in tomatoes and cucumbers in Chazanga while Figure 4e: shows 64/100 children were exposed to 5.1 Log10/month *Escherichia coli* in drain water from Chawama and Figure 4f: shows that 78/100 children were exposed to 5.2 Log10/month *Escherichia coli* in tomatoes and cucumbers in George.

Denotes exposed Denotes unexposed

Through an algorithm in the SaniPath tool, dominant *E. coli* exposure pathways were identified as indicated in Table 4.5. The algorithm was based upon the proportion of the population exposed to those pathways and the corresponding magnitude of exposure to *E. coli* contamination.

Table 4.5: Dominant exposure pathways by residential area

Residential area	Adults	Children
Chawama	Surface Water	Surface Water and Stormwater drainage water
Chazanga	Fresh Crop Produce (tomato and cucumber)	Fresh Crop Produce (tomato and cucumber)
George	Fresh Crop Produce (tomato and cucumber) and Municipal water	Storm water drainage water, Produce (tomato and cucumber) and Municipal

4. 2 Isolation and presumptive identification of *Escherichia coli*

The isolation of *E. coli* was done on MacConkey agar while the presumptive identification of invasive and Extended Spectrum Beta – Lactamases producing *E. coli* was done using MacConkey agar with Congo red dye and MacConkey agar with cefotaxime, respectively as indicated in Table 4.6. A total of seventy-two (72) *Escherichia coli* isolates were isolated. Of these, twenty-four (24) were presumed invasive on MacConkey agar supplemented with the Congo red and ten (10) were identified as Extended Spectrum Beta – Lactamases producing based on their growth on MacConkey agar with cefotaxime (Table 4.6).

Table 4.6: Isolated and presumptively identified *Escherichia coli*

			Chawama			Chazanga			George		
Exposure Pathways		*Collected samples (n)	Samples with *E. coli*	Pathogenic *E. coli* on Congo red	ESBL *E. coli*	Samples with *E. coli*	Pathogenic *E. coli* on Congo red	ESBL *E. coli*	Samples with *E. coli*	Pathogenic *E. coli* on Congo red	ESBL *E. coli*
Shallow well		30	5	3	0	2	2	0	6	4	0
Surface water		10**	5	3	1	-	-	-	-	-	-
Open drain		30	5	0	0	4	0	1	2	1	0
Borehole		30	4	2	2	3	1	1	1	0	0
Soil		30	1	1	0	2	0	0	0	0	0
Shared latrine		30	5	1	0	4	1	1	1	1	0
Fresh crop produce		30	4	0	1	3	1	1	1	0	0
Street food		30	3	0	0	2	0	1	4	1	0
Municipal water		30	2	0	0	1	1	1	2	1	0

*30 samples were collected in total for each pathway unless stated, with 10 samples coming from each study site.

**The surface water samples were only collected in Chawama as there was no surface water in other areas.

4. 3 Antimicrobial susceptibility

Antibiotic susceptibility tests of isolated *E. coli* were carried out using the disk diffusion method against the commonly used drugs in human and veterinary medicine. The isolates were tested for susceptibility against Ceftazidime, Ampicillin, Streptomycin, Chloramphenicol, Ciprofloxacin, Amoxicillin/Clavulanic acid, Gentamicin, Sulfamethoxazole/Trimethoprim, Tetracycline and Cefotaxime as shown in Table 4.7 below. Sulfamethoxazole/Trimethoprim was observed not to be effective on *E. coli* isolates with all nine (9) pathways showing 100% resistance and Cefotaxime with *E. coli* isolates from five (5) pathways being 100% resistant. Sulfamethoxazole/Trimethoprim and Cefotaxime showed the highest rate of resistance while Streptomycin showed the least resistance. Most of the remaining antibiotics showed over 50% resistance.

Table 4.7: Percentage of Antimicrobial Resistant *Escherichia coli* (n=72)

Exposure Pathway	Ampicillin	Amoxycillin-clavulanic acid	Chloramphenicol	Streptomycin	Sulfamethoxazole	tetracycline	Gentamicin	Ceftazidime	Ciprofloxacin	Cefotaxime
Shallow well	50	50	80	0	100	60	50	60	70	70
Surface water	40	60	20	0	100	80	20	80	80	100
Open drain	100	100	100	0	100	100	100	100	100	100
Borehole	80	100	80	0	100	60	40	80	100	80
Shared latrine	60	60	30	0	100	60	30	60	60	60
Municipal Water	100	100	100	0	100	100	0	0	0	100
Fresh Crop Produce	0	0	0	0	100	80	0	50	100	100
Street food	0	50	40	0	100	70	50	0	100	80
Soil	0	100	100	0	100	100	0	100	0	100

CHAPTER FIVE

DISCUSSION

Escherichia coli is an indicator bacterium in sanitation as well as food safety. Its presence in food demonstrates the possible faecal contamination (Newell *et al.*, 2010). As a result, in this study the focus was on the detection of *E. coli* in the possible focal points of contamination or entry of *E. coli* in the survival pathways of communities. There could be multiple pathways that may contribute to faecal-oral transmission of diseases, making it not feasible to empirically test all possible interventions using epidemiological methods. Therefore, it is a challenge for decision-makers in countries with poor water, sanitation, and hygiene to identify where the greatest public health risks lie and to prioritize interventions based on the most urgent needs. This exposure assessment study provided an independent probabilistic approach, to support causal analysis of the relations between interventions and health effects and guide food hygiene intervention decisions in a complex environment with multiple *E. coli* transmission pathways. The results of this comprehensive study allow for the prediction and comparison of exposures and the identification of important exposure pathways.

The detection of *E. coli* in these environmental samples suggests the potential presence of pathogenic organisms and the potential risk of enteric disease among the residents of Chawama, Chazanga and George, who are frequently exposed to these contaminated environments, drink contaminated municipal water, and/or consume raw or undercooked fresh crop produce. The widespread *E. coli* contamination in these residential areas may be due to unsafe faecal sludge and poor sewerage system management and consequent movement and distribution of faecal contamination in the environment through poor drainage systems, and/or unsafe dumping of sludge and sewage. This was observed by Berendes and others (2018) in Accra, Ghana. It was noted that, *E. coli* concentrations in drain samples collected near household with poor sanitation were significantly higher than in and around clusters of high coverage sanitation facilities. This correlates with the findings in George residential area for example where municipal water supply was contaminated as a result of dilapidated sewerage systems.

Furthermore, this study reveals that any identified *Escherichia coli* exposure pathway with a high frequency of exposure as a result of behaviour and high dose of *Escherichia coli* contamination

renders it a high-risk pathway that should be a priority for intervention. In Chawama, 32.5% of the adults were exposed to 5.7 Log10/month *Escherichia coli* through borehole water while in Chazanga 66% of adults were exposed to 4.8 Log10/month *Escherichia coli* through consumption of tomatoes and cucumber as indicated by the behaviour surveys. On the other hand, 98% of adults in George were exposed to 5.2 Log10/month *Escherichia coli* through municipal water. Stormwater drainage water exposed 64% of children to 5.1 Log10/month *Escherichia coli* in Chawama. In Chazanga and George 74.3% of children were exposed to 5.4 Log10/month and 77.2% of children were exposed to 5.2 Log10/month of *Escherichia coli*, respectively through the consumption of tomatoes and cucumbers. Other studies conducted in Lusaka have revealed that the bacterial contamination of underground and municipal water is high thereby making these sources unsuitable for human consumption. Nakaonga et al., (2017) reported 30% of the borehole water from Libala south contaminated with *E. coli*. In another study in Lusaka where water was sampled from various sources from the seven (7) constituencies namely, Kanyama, Chawama, Kabwata, Lusaka Central, Munali, Mandevu and Matero. It was reported that overall, 52.5% of all water sources were contaminated with faecal coliforms across these constituencies. The water sources included municipal water, shallow wells and borehole and the percentage of unsatisfactory water quality was 51%, 100% and 52%, respectively (Silavwe et al., 2018). Unlike these studies conducted in Lusaka, the present study besides determining the rates of microbial contamination in water sources, also determined the frequency of exposure, therefore making it possible to determine the risk. Contamination of municipal water can occur either in the distribution system due to frequent pipe breaks and illegal connections, low or negative water pressure due to intermittent service, and/or because of poor domestic water storage structures and maintenance. It is important to note that it is this water that is frequently utilised for all food preparation activities hence resulting in this water becoming a food contaminant.

High concentrations of *E. coli* contamination were reported on tomatoes and cucumbers in Chazanga and George. The tomatoes and cucumbers serve as a vehicle for *E. coli* contamination to move across the residential areas and households and can pose a major health risk to populations. This is because the products are usually sold by mobile hawkers moving from one residential area to another and tomatoes and cucumbers are usually consumed raw in the form of salads.

The microbiological data generated in this study makes a significant contribution to the limited evidence base regarding *E. coli* contamination of peri-urban townships in Lusaka districts. The

intent of the microbiological analyses was not to make high resolution comparisons between different types of samples or contamination in the three residential areas, but rather to provide information on the order of magnitude of *E. coli* contamination and the frequency of exposure in relation to food safety. The highest concentration *Escherichia coli* exposure to children was from tomatoes and cucumbers at 6.2 Log10/month in George while the lowest was from shared latrine surfaces in Chazanga at 0.2 Log10/month. In adults, the lowest exposure was 0.3 Log10/month from shared latrine surfaces in Chazanga and the highest was 5.7 Log10/month from borehole water. In this study, the monthly dose per pathway ranged from 0.2 Log10 MPN to 6.2 Log10 MPN and in a study by Kothary and Babu, (2001) it was observed that for the different strains of pathogenic *E. coli,* the infective dose ranged from 6 Log10 MPN to 16 Log10 MPN. As such, in this study, fresh crop produce in George presented the highest ingestible dose for children and was also at the lower range of the infective dose at 6.2 Log10 MPN as indicated in Table 4.4, in relation to Kothary and Babu's, (2001) infective dose range. However, the isolate for fresh crop produce from George was non-invasive. This could explain the absence of an active outbreak during the study period.

Total *E. coli* and Extended Spectrum Beta-Lactamases (ESBL) producing abundance varied across environmental samples. Each sample positive for *E. coli* at IDEXX detection was cultured, isolated and screened for total ESBL and antimicrobial resistance to estimate levels in sampled bacteria. From this study, 72 *E. coli* isolates were isolated from the environmental samples; 24 were presumed as the invasive strain while 10 were Extended Spectrum Beta-Lactamases producing isolates. Antimicrobial resistance has been recognized as an emerging worldwide public health problem in human and veterinary medicine, both in developed and developing countries (Ferri *et al.*, 2017). A variety of foods and environmental sources harbour bacteria that are resistant to one or more antimicrobial drugs. From the present study the isolates were tested for susceptibility against ceftazidime, ampicillin, streptomycin, chloramphenicol, ciprofloxacin, amoxicillin/clavulanic acid, gentamicin, sulfamethoxazole/trimethoprim, tetracycline and cefotaxime. All the *Escherichia coli* isolates from the nine (9) exposure pathways namely municipal water, borehole water, shallow well water, open storm water drain water, surface water, shared latrine swabs, fresh crop produce (tomatoes and cucumber), street food (fritters and scones) and soil were 100% resistant to Sulfamethoxazole/Trimethoprim while cefotaxime was 100% resistant in isolates. All of the nine pathways could serve as a transmission route of this Sulfamethoxazole/Trimethoprim resistant strain through either direct ingestion of municipal water,

borehole water, shallow well water, fresh crop produce (tomatoes and cucumber) and street food (fritters and scones). On the other hand, open storm water drain water, surface water, shared latrine swabs and soil could serve as a source of contamination through food handling and poor hygienic practices by food handlers resulting in the contamination of food during preparation and/or consumption. Furthermore, 5 pathways namely surface water, open storm water drain water, municipal water, fresh crop produce (tomatoes and cucumber) and soil contained Cefotaxime resistant strains. Streptomycin showed the least resistance in all the exposure pathways. This is a wakeup call to the frontline staff involved in the prevention of Antimicrobial resistance.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The study highlighted the role the environment plays in human exposure to *E. coli* contamination and in turn poor food safety. From this study the following conclusions were drawn:

1. *Escherichia coli* exposure pathways were identified through isolation of *Escherichia coli* in unplanned settlements of Lusaka District.
2. The pathogenicity of *Escherichia coli* isolated in the identified pathways was determined with 24 samples being deemed invasive on Congo red media and 10 were Extended Spectrum Beta-Lactamases producing**.**
3. Antibiotic resistance was also observed with the majority of the antibiograms used showing over 50% resistance and isolates from 7 exposure pathways exhibiting 100% resistant to sulfamethoxazole/trimethoprim and 100% cefotaxime resistance in isolates from 5 pathways, with Streptomycin showing the least resistance in all the exposure pathways.

6.2 Recommendations

Recommendations can be made for potential interventions to reduce exposure to *E. coli* contamination and improve food safety based on behaviour and environmental contamination levels. These include:

1. Improve regulations on water quality and improve treatment and distribution mechanisms.
2. Improve access to clean drinking water in densely populated residential areas and curb illegal connections.
3. Promote point-of-use water treatment and alternative sources of clean drinking water.
4. Provide education for shopkeepers, marketeers, vendors and consumers on proper food and handling hygiene practices.
5. Improve faecal sludge management in communities and reduce open defecation practices.
6. Provide education about the risk associated with coming into contact with contaminated surface water.

7. Strength the Water, Sanitation and Hygiene (WASH) clubs in schools so as to use them as point of contact with children in the various communities to teach about personal hygiene, food safety and sanitation.
8. An all-encompassing City-wide strategy on WASH and Food safety taking a One Health approach is required for the Greater City of Lusaka.

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Appendices

Consent form

University of Zambia
School of Veterinary Medicine
Consent to be a Research Subject in a Community/Household Survey/ School Survey

Title: *Escherichia coli* Exposure Pathways in Some Unplanned Settlements in Lusaka District, Zambia: A case of food safety

Principal Investigator:
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Funding Source:

ACEIDHA
Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)

Introduction

You are invited to participate in a research study about sanitation needs and practices in relation to food safety. **It is entirely your choice. If you decide to take part, you can change your mind later on and withdraw from the research study. If there are any questions you do not wish to answer, you may leave the room. You are free to stop answering questions at any time without having to give a reason.**

Before making your decision:

- Please carefully read this form or have it read to you
- Please ask questions about anything that is not clear

You can take a copy of this consent form, to keep. Feel free to take your time thinking about whether you would like to participate. By signing this form, you will not give up any legal rights.

Study Overview

The goal of the study is to understand *Escherichia coli* exposure pathways in your community that may lead to food safety compromise.

Procedures

Household Survey: If you choose to participate in the study, you will be asked questions about your residential area, your daily activities, your household, and how you dispose of waste. You will also be asked about the activities of other people who live here. This will take no more than 30 minutes of your time.

Risks and Discomforts

Participating in the study will not cause you any risks or discomfort, aside from possibly being a little bit embarrassed when you are asked some questions about your toilet specifically. This is necessary because we are trying to understand the cleanliness of this residential area and toilets can be a big problem.

Benefits

By participating in this study, you will help policy makers learn about the problems in your residential area and decide how to help.

Compensation

You will not be offered payment for being in this study.

Confidentiality

All information is confidential and your name will not be recorded on any documents. All of your information will be kept securely on a password-protected computer and only those working on the study will have access to your information.

We will be providing results to members of community organizations. We will write reports about things we learn from this survey. The reports will not contain any names or any other information that would make it possible to identify you.

Voluntary Participation and Withdrawal from the Study

You have the right to leave a study at any time without penalty. You may refuse to answer any questions that you do not wish to answer.

Contact Information

- [insert contact]
- if you have any questions about this study or your part in it,
- if you feel you have had a research-related injury, or
- if you have questions, concerns or complaints about the research

Consent

Please, print your name and sign below if you agree to be in this study. By signing this consent form, you will not give up any of your legal rights. We will give you a copy of the signed consent, to keep.

_____

Name of Subject

_____ _____

Signature of Subject Date Time

_____ _____

Signature of Person Conducting Informed Consent Discussion Date Time

_____ _____

Signature of Legally Authorized Representative Date Time

Authority of Legally Authorized Representative or Relationship to Subject Date Time

Household Survey Form

Demographic Data	
Household ID	
Date of Survey	__ __ / __ __ / __ __ MONTH DAY
Time at Start of Survey	__ __ : __ __ ___ HOUR MINUTE
Residential area	☐ George ☐ Chawama ☐ Chazanga
Observe the type of home the respondent is living in.	☐ Single family home ☐ Compound
Did it rain in the past week?	☐ Yes ☐ No
Ask the respondent: How many people live in your household?	
Ask the respondent: Do you have children between the ages of 5-12?	☐ Yes ☐ No

Open Drains
If open drains apply to this household, answer the following questions. *If not, skip to the floodwater section.*

1.	Think about whether you ever go into open drains in your residential area, including to pick up something that fell in there, accidentally falling in, to go through the drain to cross the street, or to defecate. How many times in the past month did you go into the drains? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past month ☐ 6 to 10 times in the past month ☐ 5 times or less in the past month ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____
2.	Now think about whether your children ever go into open drains, including to pick up something that fell in there, to play, accidentally falling in, to go through the drain to cross the street, or to defecate. How many times in the past month did your children go into the drains? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past month ☐ 6 to 10 times in the past month ☐ 5 times or less in the past month ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____

Floodwater		
If floodwater applies to this household, answer the following questions. *If not, skip to the drinking water section.*		
3.	Think about whether you ever come into contact with floodwater during the last rainy season, including to pick up something that fell into floodwater, to walk through floodwater in the street, or to clean your house after it floods. How many times total every week did you come into contact with floodwater during the last rainy season? *If not applicable/unable to collect information, explain.*	☐ More than 10 times total every week during the rainy season ☐ 6 to 10 times total every week during the rainy season ☐ 5 times or less total every week during the rainy season ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____

4. Now think about whether your children ever come into contact with floodwater during the last rainy season, including to pick up something that fell into floodwater, to play in the floodwater, to walk through floodwater in the street, or to clean your house after it floods. How many times total every week did your children come into contact with floodwater during the last rainy season? *If not applicable/unable to collect information, explain.*	☐ More than 10 times total every week during the rainy season ☐ 6 to 10 times total every week during the rainy season ☐ 5 times or less total every week during the rainy season ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____

Drinking Water	
If drinking water applies to this household, answer the following questions.	
5. Think about whether you drink municipal water. How many days within the past week did you drink municipal water? *If not applicable/unable to collect information, explain.*	☐ Every day in the past week ☐ 4 to 6 days in the past week ☐ 3 or less days in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____
6. Now think about whether your children drink municipal water. How many days within the past week did your children drink municipal water? *If not applicable/unable to collect information, explain.*	☐ Every day in the past week ☐ 4 to 6 days in the past week ☐ 3 or less days in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
7. Think about whether your borehole water. How many days within the past week did you drink borehole water? *If not applicable/unable to collect information, explain.*	☐ Every day in the past week ☐ 4 to 6 days in the past week ☐ 3 or less days in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____

8. Now think about whether your children drink borehole water. How many days within the past week did your children drink borehole water? *If not applicable/unable to collect information, explain.*	☐ Every day in the past week ☐ 4 to 6 days in the past week ☐ 3 or less days in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____
9. Think about whether you drink shallow well water. How many days within the past week did you drink shallow well water? *If not applicable/unable to collect information, explain.*	☐ Every day in the past week ☐ 4 to 6 days in the past week ☐ 3 or less days in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
10. Now think about whether your children drink shallow well water. How many days within the past week did your children drink shallow well water? *If not applicable/unable to collect information, explain.*	☐ Every day in the past week ☐ 4 to 6 days in the past week ☐ 3 or less days in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information: _____
Water Treatment	
11. Think about whether your household regularly treats your household's drinking water by boiling it, adding chlorine, or using a filter to make it less cloudy or safer to drink. Does your household regularly treat your household's water?	☐ Yes ☐ No ☐ Do not know ☐ Not applicable/unable to collect information: _____

Bathing Water	
If bathing water applies to this household, answer the following questions. If not, skip to the raw produce section.	
12. Think about how often you bathe. How many times in the past week did you bathe? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 1 to 5 times in the past week ☐ 0 times in the past week ☐ Do not know ☐ Not applicable/unable to collect information:_____
13. Think about how often your children bathe. How many times in the past week did they bathe? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 1 to 5 times in the past week ☐ 0 times in the past week ☐ Do not know ☐ Not applicable/unable to collect information:_____
14. Think about the water that your household uses to bathe. What is the main source of bathing water in your household? *If not applicable/unable to collect information, explain.*	☐ Municipal Water ☐ Borehole Water ☐ Shallow Well Water ☐ Other:_____ ☐ Do not know ☐ Not applicable/unable to collect information:_____

Raw Produce	
If raw produce applies to this household, answer the following questions. *If not, skip to the street food section.*	
15. Think about whether you eat produce that is raw (uncooked). For this question, we are referring to any produce that does not grow on a tree, and that does not have a peel or shell. Think both about the produce you eat whole and produce you prepare but eat raw, such cucumber or apples. How many times within the past week did you eat raw produce? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 1 to 5 times in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
16. Think about whether your children eat produce that is raw (uncooked). For this question, we are referring to any produce that does not grow on a tree, and that does not have a peel or shell. Think both about the produce you eat whole and produce you prepare but eat raw, such as cucumber or apples. How many times within the past week did your children eat raw produce? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 1 to 5 times in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
17. Think about whether anyone in your household washes the produce that your household eats raw before eating it. Does anyone in your household wash the produce that you eat before eating it? *If not applicable/unable to collect information, explain.*	☐ Yes ☐ No ☐ Do not know ☐ Not applicable/unable to collect information:_____

Street Food	
If street food applies to this household, answer the following questions. *If not, skip to the Public/shared latrines section.*	
18. Think about whether you eat food that is prepared and sold on the street, such as roasted maize, roasted or boiled cassava, or fritters. How many times in the past week did you eat street food? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 1 to 5 times in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
19. Think about whether your children eat food that is prepared and sold on the street, such as such as roasted maize, roasted or boiled cassava, or fritters. How many times in the past week did your children eat street food? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 1 to 5 times in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____

Public/Shared Latrines	
If Public/shared latrines apply to this household, answer the following questions. If not, skip to the private latrines section.	
20. Think about whether you use public latrines in your residential area. These include latrines shared by people who do not live in your household, like those at markets, schools, churches, or bars. How many times within the past week did you use public latrines in your residential area? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 5 times or less in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____

21. Now think about whether your children use public latrines in your residential area. These include latrines shared by people who do not live in your household, like those at markets, schools, churches, or bars. How many times within the past week did your children use Public latrines in your residential area? *If not applicable/ unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 5 times or less in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
22. Think about whether you use shared latrines in your residential area. These include latrines shared by people who do not live in your household, like your neighbours living in your compound. How many times within the past week did you use shared latrines in your residential area? *If not applicable/unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 5 times or less in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____
23. Think about whether your children use shared latrines in your residential area. These include latrines shared by people who do not live in your household, like your neighbours living in your compound. How many times within the past week did your children use shared latrines in your residential area? *If not applicable/ unable to collect information, explain.*	☐ More than 10 times in the past week ☐ 6 to 10 times in the past week ☐ 5 times or less in the past week ☐ Never ☐ Do not know ☐ Not applicable/unable to collect information:_____

Private Latrines	
If private latrines apply to this household, answer the following questions. *If not, skip to the closing questions section.*	
24. Think about whether you have a latrine in your household. Do you have any latrines in your household? *If not applicable/unable to collect information, explain.*	☐ Yes ☐ No ☐ Do not know ☐ Not applicable/unable to collect information:_____
25. Think about whether you use the latrine in your household. Do you use the latrine in your household? *If not applicable/ unable to collect information, explain.*	☐ Yes ☐ No ☐ Do not know ☐ Not applicable/unable to collect information:_____
26. Think about whether you flush the latrine in your household with water. Do you flush the latrine with water? *If not applicable/ unable to collect information, explain.*	☐ Yes ☐ No ☐ Do not know ☐ Not applicable/unable to collect information:_____
27. Think about whether the latrine in your household ever floods. Does the latrine in your household ever flood? *If not applicable/ unable to collect information, explain.*	☐ Yes ☐ No ☐ Do not know ☐ Not applicable/unable to collect information:_____

Closing Questions	
Please write the names of all enumerators involved in this survey	
Additional Comments	

Community Survey Form

Demographic Data	
Group Name	
Date of Survey	__ __ / __ __ / __ __ MONTH DAY
Time at Start of Survey	__ __ : __ __ ___ HOUR MINUTE
Residential area	☐ George ☐ Chawama ☐ Chazanga
Did it rain the past week?	☐ Yes ☐ No
Observe the total number of participants.	
Observe the group's gender composition.	☐ All male ☐ All female ☐ A combination of male and female
If a combination	Observe # female: Observe # male:

Question 1 (Only ask if it is a combination of male/female)	
Answer the following questions to ensure the participants understand the process.	
Vote if you are a woman.	
Vote if you are a man.	
Question 2	
Vote if you live in this residential area.	
Vote if you live in another residential area.	
Question 3	

Vote if you have children between the ages of 5-12.	
Vote if you do not have children between the ages of 5-12.	

Question 4: Surface Water – Adults

If open drains apply to this residential area, answer the following questions.
If not, skip to the floodwater section.

Think about whether you go into rivers, ponds, or lakes in your residential area to wade, swim, splash around, fish, do laundry, or to defecate. How many times within the past month did you go into rivers, ponds, or lakes for any of these reasons?

28. Vote if you went into surface water more than 10 times in the past month.	
29. Vote if you went into surface water 6 to 10 times in the past month.	
30. Vote if you went into surface water 5 times or less in the past month.	
31. Vote if you never went into surface water in the past month.	
32. Vote if you do not know how often you went into surface water in the past month.	

Question 5: Open Drains – Adults

If open drains apply to this residential area, answer the following questions.
If not, skip to the floodwater section.

Think about whether you ever go into open drains in your residential area, including to pick up something that fell in there, accidentally falling in, to go through the drain to cross the street, or to defecate. How many times within the past month did you go into the drains?

33.	Vote if you went into open drains more than 10 times in the past month.	
34.	Vote if you went into open drains 6 to 10 times in the past month.	
35.	Vote if you went into open drains 5 times or less in the past month.	
36.	Vote if you never went into open drains in the past month.	
37.	Vote if you do not know how often you went into open drains in the past month.	

Question 6: Floodwater – Adults

If floodwater applies to this residential area, answer the following questions.
If not, skip to the drinking water section.

Think about whether you ever come into contact with floodwater during the rainy season, including to pick up something that fell into floodwater, to walk through floodwater in the street, or to clean your house after it floods. How many times total every week did you come into contact with floodwater during the rainy season?

38. Vote if you come into contact with floodwater more than 10 times total every week during the rainy season.	
39. Vote if you come into contact with floodwater 6 to 10 times total every week during the rainy season.	
40. Vote if you come into contact with floodwater 5 times or less total every week during the rainy season.	
41. Vote if you never come into contact with floodwater during the rainy season.	
42. Vote if you do not know how often you come into contact with floodwater during the rainy season.	

Question 7: Drinking Water – Adults

If drinking water applies to this residential area, answer the following questions.

Think about whether you drink municipal water. How many days within the past week did you drink municipal water?

43.	Vote if you drank municipal water every day.	
44.	Vote if you drank municipal water 4 to 6 days within the past week.	
45.	Vote if you drank municipal water 3 days or less within the past week.	
46.	Vote if you never drank municipal water within the past week.	
47.	Vote if you do not know how often you drank municipal water within the past week.	

Question 8: Drinking Water: Borehole – Adults

Think about whether you drink borehole water. How many days within the past week did you drink borehole water?

48.	Vote if you drank borehole water every day.	
49.	Vote if you drank borehole water 4 to 6 days within the past week.	
50.	Vote if you drank borehole water 3 days or less within the past week.	
51.	Vote if you never drank borehole water within the past week.	
52.	Vote if you do not know how often you drank borehole water within the past week.	

Question 9: Drinking Water: Shallow Well – Adults

Think about whether you drink shallow well water. How many days within the past week did you drink shallow well water?

53.	Vote if you drank shallow well water every day.	
54.	Vote if you drank shallow well water 4 to 6 days within the past week.	
55.	Vote if you drank shallow well water 3 days or less within the past week.	
56.	Vote if you never drank shallow well water within the past week.	
57.	Vote if you do not know how often you drank shallow well water within the past week.	

Question 10: Water Treatment

If drinking water applies to this residential area, answer the following questions.

Think about whether your household regularly treats your household's drinking water by boiling it, adding chlorine, or using a filter to make it less cloudy or safer to drink. Does your household regularly treat your household's drinking water?

21.	Vote if your household regularly treats your household's drinking water.	
22.	Vote if your household does not regularly treat your household's drinking water.	
23.	Vote if you do not know whether your household regularly treats your households drinking water.	

Question 11: Bathing Water – Adults

If bathing water applies to this residential area, answer the following questions.
If not, skip to the raw produce section.

Think about how often you bathe. How many times within the past week did you bathe?

29.	Vote if you bathed more than 10 times within the past week.	
30.	Vote if you bathed 6 to 10 times within the past week.	
31.	Vote if you bathed 1 to 5 times within the past week.	
32.	Vote if you bathed 0 times in the past week.	
33.	Vote if you do not know how often you bathed in the past week.	

Question 12: Bathing Water Source

Think about the water that your household uses to bathe. What is the main source of bathing water in your household?

58.	Raise your hand if Municipal Water is your main source of bathing water.	
59.	Raise your hand if Borehole Water is your main source of bathing water.	
60.	Raise your hand if Shallow Well Water is your main source of bathing water.	
61.	Raise your hand if another source is your main source of bathing water or you do not know.	

Question 13: Raw Produce – Adults

If raw produce applies to this residential area, answer the following questions.
If not, skip to the street food section.

Think about whether you eat produce that is raw (uncooked). For this question, we are referring to any produce that does not have a peel or shell. Think both about the produce you eat whole and produce you prepare but eat raw, such as cucumbers or apples. How many times within the past week did you eat raw produce?

34.	Vote if you ate raw produce more than 10 times within the past week.	
35.	Vote if you ate raw produce 6 to 10 times within the past week.	
36.	Vote if you ate raw produce 1 to 5 times within the past week.	
37.	Vote if you never eat raw produce within the past week.	
38.	Vote if you do not know how often you ate raw produce within the past week.	

Question 14: Raw Produce – Washing

Think about whether anyone in your household washes the produce that your household eats raw before eating it.

39.	Vote if anyone in your household washes the produce that your household eats raw before eating it.	
40.	Vote if nobody in your household washes the produce that your household eats raw before eating it.	
41.	Vote if you do not know if anybody in your household washes the produce that your household eats raw before eating it.	

Question 15: Street Food – Adults

If street food applies to this residential area, answer the following questions.
If not, skip to the communal/shared latrines section.

Think about whether you eat food that is prepared and sold on the street, such as roasted maize, roasted or boiled cassava, or fritters. How many times within the past week did you eat street food?

62.	Vote if you ate street food more than 10 times within the past week.	
63.	Vote if you ate street food 6 to 10 times within the past week.	
64.	Vote if you ate street food 1 to 5 times within the past week.	
65.	Vote if you never ate street food within the past week.	
66.	Vote if you do not know how often you ate street food within the past week.	

Question 16: Public/Shared Latrines – Adults

If communal/shared latrines apply to this residential area, answer the following questions. If not, skip to the private latrines section.

Think about whether you use Public/Shared latrines in your residential area. These include latrines shared by people who do not live in your household, like those at markets, schools, churches, or bars. How many times within the past week did you use Public/Shared latrines in your residential area?

42.	Vote if you used a Public/Shared latrine in your residential area more than 10 times within the past week.	
43.	Vote if you used a Public/Shared latrine in your residential area 6 to 10 times within the past week.	
44.	Vote if you used a Public/Shared latrine in your residential area 5 times or less in the past week.	
45.	Vote if you never used a Public/Shared latrine in your residential area in the past week.	
46.	Vote if you do not know how often you used a Public/Shared latrine in your residential area in the past week.	

Question 18: Private Latrines – Adults

If private latrines apply to this residential area, answer the following questions. If not, skip to the children section.

Think about whether you have a latrine in your household. Do you have any latrines in your household?

47.	Vote if you do have a latrine in your household.	
48.	Vote if you do not have a latrine in your household.	
49.	Vote if you do not know if you have a latrine in your household.	

Question 19: Private Latrines – Adults

Think about whether you use the latrine in your household. Do you use the latrine in your household?

50.	Vote if you do use the latrine in your household.	
51.	Vote if you do not use the latrine in your household.	
52.	Vote if you do not know if you use the latrine in your household.	
53.	Vote if you do not have a latrine in your household.	

Question 20: Private Latrines – Adults

Think about whether you flush the latrine in your household with water. Do you flush the latrine with water?

54.	Vote if you do flush the latrine in your household with water.	
55.	Vote if you do not flush the latrine in your household with water.	
56.	Vote if you do not know if you flush the latrine in your household with water.	
57.	Vote if you do not have a latrine in your household.	

Question 21: Private Latrines – Adults

Think about whether the latrine in your household ever floods. Does the latrine in your household ever flood?

58.	Vote if the latrine in your household does flood.	
59.	Vote if the latrine in your household does not flood.	

60.	Vote if you do not know if the latrine in your household floods.	
61.	Vote if you do not have a latrine in your household.	

Question 22: Surface Water – Adults

If open drains apply to this residential area, answer the following questions.
If not, skip to the floodwater section.

Think about whether your children go into rivers, ponds, or lakes in your residential area to wade, swim, splash around, fish, do laundry, or to defecate. How many times within the past month did your children go into rivers, ponds, or lakes for any of these reasons?

67.	Vote if you went into surface water more than 10 times in the past month.	
68.	Vote if you went into surface water 6 to 10 times in the past month.	
69.	Vote if you went into surface water 5 times or less in the past month.	
70.	Vote if you never went into surface water in the past month.	
71.	Vote if you do not know how often you went into surface water in the past month.	

Question 23: Open Drains – Children

If open drains apply to this residential area, answer the following questions.
If not, skip to the floodwater section.

Now think about whether your children ever go into open drains, including to pick up something that fell in there, to play, accidentally falling in, to go through the drain to cross the street, or to defecate. How many times within the past month did your children go into the drains?

67.	Vote if your children went into open drains more than 10 times in the past month.	
68.	Vote if your children went into open drains 6 to 10 times in the past month.	

69.	Vote if your children went into open drains 5 times or less in the past month.	
70.	Vote if your children never went into open drains in the past month.	
71.	Vote if you do not know how often your children went into open drains in the past month.	

Question 24: Floodwater – Children

If floodwater applies to this residential area, answer the following questions.
If not, skip to the drinking water section.

Now think about whether your children ever come into contact with floodwater during the rainy season, including to pick up something that fell into floodwater, to play in the floodwater, to walk through floodwater in the street, or to clean your house after it floods. How many times total every week did your children come into contact with floodwater during the rainy season?

72.	Vote if your children come into contact with floodwater during the rainy season more than 10 times total every week during the rainy season.	
73.	Vote if your children come into contact with floodwater 6 to 10 times total every week during the rainy season.	
74.	Vote if your children come into contact with floodwater 5 times or less total every week during the rainy season.	
75.	Vote if your children never come into contact with floodwater during the rainy season.	
76.	Vote if you do not know how often your children come into contact with floodwater during the rainy season.	

Question 25: Drinking Water – Children

If drinking water applies to this residential area, answer the following questions.

Now think about whether your children drink municipal water. How many days in the past week did your children drink municipal water?

77.	Vote if your children drank municipal water every day in the past week.	
78.	Vote if your children drank municipal water 4 to 6 days in the past week.	
79.	Vote if your children drank municipal water 3 days or less in the past week.	
80.	Vote if your children never drank municipal water in the past week.	
81.	Vote if you do not know how often your children drank municipal water in the past week.	

Question 26: Drinking Water: Borehole – Children

Now think about whether your children drink borehole water. How many days in the past week did your children drink borehole water?

77.	Vote if your children drank borehole water every day in the past week.	
78.	Vote if your children drank borehole water 4 to 6 days in the past week.	
79.	Vote if your children drank borehole water 3 days or less in the past week.	
80.	Vote if your children never drank borehole water in the past week.	
81.	Vote if you do not know how often your children drank borehole water in the past week.	

Question 27: Drinking Water: Shallow Well – Children

Now think about whether your children drink shallow well water. How many days in the past week did your children drink shallow well water?

77.	Vote if your children drank shallow well water every day in the past week.	
78.	Vote if your children drank shallow well water 4 to 6 days in the past week.	
79.	Vote if your children drank shallow well water 3 days or less in the past week.	

80.	Vote if your children never drank shallow well water in the past week.	
81.	Vote if you do not know how often your children drank shallow well water in the past week.	

Question 28: Bathing Water – Children

If bathing water applies to this residential area, answer the following questions.
If not, skip to the raw produce section.

Think about how often your children bathe. How many times within the past week did your children bathe?

87.	Vote if your children bathed more than 10 times within the past week.	
88.	Vote if your children bathed 6 to 10 times within the past week.	
89.	Vote if your children bathed 1 to 5 times within the past week.	
90.	Vote if your children bathed 0 times within the past week.	
91.	Vote if you do not know how often your children bathe.	

Question 29: Raw Produce – Children

If raw produce applies to this residential area, answer the following questions.
If not, skip to the street food section.

Think about whether your children eat produce that is raw (uncooked). For this question, we are referring to any produce that does not have a peel or shell. Think both about the produce you eat whole and produce you prepare but eat raw, such as cucumber or apples. How many times within the past week did your children eat raw produce?

92.	Vote if your children ate raw produce more than 10 times within the past week.	
93.	Vote if your children ate raw produce 6 to 10 times within the past week.	
94.	Vote if your children ate raw produce 1 to 5 times within the past week.	

95.	Vote if your children never ate raw produce within the past week.	
96.	Vote if you do not know how often your children ate raw produce within the past week.	

Question 30: Street Food – Children

If street food applies to this residential area, answer the following questions. If not, skip to the communal/shared latrines section.

Think about whether your children eat food that is prepared and sold on the street, such as roasted maize, roasted or boiled cassava, or fritters. How many times within the past week did your children eat street food?

72.	Vote if your children ate street food more than 10 times within the past week.	
73.	Vote if your children ate street food 6 to 10 times within the past week.	
74.	Vote if your children ate street food 1 to 5 times within the past week.	
75.	Vote if your children never ate street food within the past week.	
76.	Vote if you do not know how often your children ate street food within the past week.	

Question 31: Public/Shared Latrines – Children

If communal/shared latrines apply to this residential area, answer the following questions. If not, skip to the closing questions section.

Think about whether your children use Public/Shared latrines in your residential area. These include latrines shared by people who do not live in your household, like those at markets, schools, churches, or bars. How many times within the past week did your children use Public/Shared latrines in your residential area?

97.	Vote if your children used Public/Shared latrines in your residential area more than 10 times within the past week.	
98.	Vote if your children used Public/Shared latrines in your residential area 6 to 10 times within the past week.	

99.	Vote if your children used Public/Shared latrines in your residential area 5 times or less within the past week.	
100.	Vote if your children never used Public/Shared latrines in your residential area within the past week.	
101.	Vote if you do not know how often your children used Public/Shared latrines in your residential area within the past week.	

Closing Questions	
Observe number of female participants.	
Observe number of male participants.	
Question 33: Closing Questions	
Vote if you are a woman.	
Vote if you are a man.	
Question 34: Closing Questions	
Vote if you live in this residential area.	
Vote if you live in another residential area.	

Closing Information	
Please write the names of all enumerators involved in this survey	
Additional Comments	

School Survey Form

Demographic Data	
School Name	
Date of Survey Time at Start of Survey	__ __ / __ __ / __ __ MONTH DAY __ __ : __ __ ____ HOUR MINUTE
Residential area	☐ George ☐ Chawama ☐ Chazanga
Did it rain the past week?	☐ Yes ☐ No
Observe the total number of participants.	
Observe the group's gender composition.	☐ All male ☐ All female ☐ A combination of male and female

Practice Questions	
Answer the following questions to ensure the participants understand the process.	
Observe number of female participants.	
Observe number of male participants.	
Raise your hand if you are a girl.	
Raise your hand if you are a boy.	
Raise your hand if you live in this residential area.	
Raise your hand if you live in another residential area.	

Surface Water

If Surface Water applies to this residential area, answer the following questions.
If not, skip to the open drains section.

Think about whether you go into rivers, ponds, or lakes in your residential area to wade, swim, splash around, fish, do laundry, or to defecate. How many times within the past month did you go into rivers, ponds, or lakes for any of these reasons?

77.	Raise your hand if you went into open drains more than 10 times in the past month.	
78.	Raise your hand if you went into open drains 6 to 10 times in the past month.	
79.	Raise your hand if you went into open drains 5 times or less in the past month.	
80.	Raise your hand if you never went into open drains in the past month.	
81.	Raise your hand if you do not know how often you went into open drains in the past month.	

Think about whether the adults in your household go into rivers, ponds, or lakes in your neighborhood to wade, swim, splash around, fish, do laundry, or to defecate. How many times within the past month did the adults go into rivers, ponds, or lakes for any of these reasons?

82.	Raise your hand if the adults went into open drains more than 10 times in the past month.	
83.	Raise your hand if the adults went into open drains 6 to 10 times in the past month.	
84.	Raise your hand if the adults went into open drains 5 times or less in the past month.	
85.	Raise your hand if the adults never went into open drains in the past month.	
86.	Raise your hand if you do not know how often the adults went into open drains in the past month.	

Open Drains

If open drains applies to this residential area, answer the following questions.
If not, skip to the floodwater section.

Think about whether you ever go into open drains in your residential area, including to pick up something that fell in there, to play, accidentally falling in, to go through the drain to cross the street, or to defecate. How many times within the past month did you go into the drains?

87.	Raise your hand if you went into open drains more than 10 times in the past month.	
88.	Raise your hand if you went into open drains 6 to 10 times in the past month.	
89.	Raise your hand if you went into open drains 5 times or less in the past month.	
90.	Raise your hand if you never went into open drains in the past month.	
91.	Raise your hand if you do not know how often you went into open drains in the past month.	

Now think about whether the adults living in your household ever go into open drains, including to pick up something that fell in there, accidentally falling in, to go through the drain to cross the street, or to defecate. How many times within the past month do the adults go into the drains?

92.	Raise your hand if the adults went into open drains more than 10 times in the past month.	
93.	Raise your hand if the adults went into open drains 6 to 10 times in the past month.	
94.	Raise your hand if the adults went into open drains 5 times or less in the past month.	
95.	Raise your hand if the adults never went into open drains in the past month.	
96.	Raise your hand if you do not know how often the adults went into open drains in the past month.	

Floodwater

If floodwater applies to this residential area, answer the following questions.
If not, skip to the drinking water section.

Think about whether you ever come into contact with floodwater during the rainy season, including to pick up something that fell into floodwater, to play in the floodwater, to walk through floodwater in the street, or to help clean your house after it floods. How many times total every week do you come into contact with floodwater during the rainy season?

97. Raise your hand if you come into contact with floodwater more than 10 times total every week during the rainy season.	
98. Raise your hand if you come into contact with floodwater 6 to 10 times total every week during the rainy season.	
99. Raise your hand if you come into contact with floodwater 5 times or less total every week during the rainy season.	
10(Raise your hand if you never come into contact with floodwater during the rainy season.	
10: Raise your hand if you do not know how often you come into contact with floodwater during the rainy season.	

Now think about whether the adults living in your household ever come into contact with floodwater during the rainy season, including to pick up something that fell into floodwater, to walk through floodwater in the street, or to help clean your house after it floods. How many times total every week do the adults come into contact with floodwater during the rainy season?

10: Raise your hand if the adults come into contact with floodwater more than 10 times total every week during the rainy season.	
10: Raise your hand if the adults come into contact with floodwater 6 to 10 times total every week during the rainy season.	
10- Raise your hand if the adults come into contact with floodwater 5 times or less total every week during the rainy season.	
10: Raise your hand if the adults never come into contact with floodwater during the rainy season.	
10(Raise your hand if you don't know how often the adults come into contact with floodwater during the rainy season.	

Drinking Water

If drinking water applies to this neighborhood, answer the following questions.

Think about whether you drink municipal water. How many days within the past week did you drink municipal water?

10	Raise your hand if you drank municipal water every day.	
10	Raise your hand if you drank municipal water 4 to 6 days in the past week.	
10	Raise your hand if you drank municipal water 3 days or less in the past week.	
11	Raise your hand if you never drank municipal water in the past week	
11	Raise your hand if you do not know how often you drank municipal water in the past week.	
Now think about whether the adults living in your household drink municipal water. How many days in the past week did the adults drink municipal water?		
11	Raise your hand if the adults drank municipal water every day.	
11	Raise your hand if the adults drank municipal water 4 to 6 days in the past week.	
114	Raise your hand if the adults drank municipal water 3 days or less in the past week.	
11	Raise your hand if the adults never drank municipal water in the past week.	
11	Raise your hand if you do not know how often the adults drank municipal water in the past week.	
Think about whether you drink borehole water. How many days within the past week did you drink borehole water?		
11	Raise your hand if you drank borehole water every day.	
11	Raise your hand if you drank borehole water 4 to 6 days in the past week.	
11	Raise your hand if you drank borehole water 3 days or less in the past week.	
12	Raise your hand if you never drank borehole water in the past week	
12	Raise your hand if you do not know how often you drank borehole water in the past week.	

Now think about whether the adults living in your household drink borehole water. How many days in the past week did the adults drink borehole water?		
12	Raise your hand if the adults drank borehole water every day.	
12	Raise your hand if the adults drank borehole water 4 to 6 days in the past week.	
124	Raise your hand if the adults drank borehole water 3 days or less in the past week.	
12	Raise your hand if the adults never drank borehole water in the past week.	
12	Raise your hand if you do not know how often the adults drank borehole water in the past week.	
Think about whether you drink shallow well water. How many days within the past week did you drink shallow well water?		
12	Raise your hand if you drank shallow well water every day.	
12	Raise your hand if you drank shallow well water 4 to 6 days in the past week.	
12	Raise your hand if you drank shallow well water 3 days or less in the past week.	
13	Raise your hand if you never drank shallow well water in the past week	
13	Raise your hand if you do not know how often you drank shallow well water in the past week.	
Now think about whether the adults living in your household drink shallow well water. How many days in the past week did the adults drink shallow well water?		
13	Raise your hand if the adults drank shallow well water every day.	
13	Raise your hand if the adults drank shallow well water 4 to 6 days in the past week.	
134	Raise your hand if the adults drank shallow well water 3 days or less in the past week.	
13	Raise your hand if the adults never drank shallow well water in the past week.	

13(	Raise your hand if you do not know how often the adults drank shallow well water in the past week.	

Water Treatment

If drinking water applies to this neighborhood, answer the following questions.

Think about whether your household regularly treats your household's drinking water by boiling it, adding chlorine, or using a filter to make it less cloudy or safer to drink. Does your household regularly treat your household's drinking water?

13'	Raise your hand if your household regularly treats your household's drinking water.	
138	Raise your hand if your family does not regularly treat your household's drinking water.	
13!	Raise your hand if you do not know whether your family regularly treats your household's drinking water.	

Bathing Water

If bathing water applies to this residential area, answer the following questions.
If not, skip to the raw produce section.

Think about how often you bathe. How many times within the past week did you bathe?

14(	Raise your hand if you bathed more than 10 times in the past week.	
14	Raise your hand if you bathed 6 to 10 times in the past week.	
14	Raise your hand if you bathed 1 to 5 times in the past week.	
14	Raise your hand if you bathed 0 times in the past week.	
14	Raise your hand if you do not know how often you bathed in the past week.	

Think about how often the adults in your household bathe. How many times within the past week did they bathe?

14!	Raise your hand if the adults bathed more than 10 times in the past week.	

14	Raise your hand if the adults bathed 6 to 10 times in the past week.	
14	Raise your hand if the adults bathed 5 times or less in the past week.	
14	Raise your hand if the adults never bathed in the past week.	
14	Raise your hand if you do not know how often the adults bathed in the past week.	

Think about the water that your household uses to bathe. What is the main source of bathing water in your household?

15	Raise your hand if Municipal Water is your main source of bathing water.	
15	Raise your hand if Borehole Water is your main source of bathing water.	
15	Raise your hand if Shallow Well Water is your main source of bathing water.	
15	Raise your hand if another source is your main source of bathing water or you do not know.	

Raw Produce

If raw produce applies to this residential area, answer the following questions.
If not, skip to the street food section.

Think about whether you eat produce that is raw (uncooked). For this question, we are referring to any produce that does not grow on a tree, and that does not have a peel or shell. Think both about the produce you eat whole and produce you prepare but eat raw, such as cucumber or tomatoes. How many times within the past week did you eat raw produce?

15	Raise your hand if you ate raw produce more than 10 times in the past week.	
15	Raise your hand if you ate raw produce 6 to 10 times in the past week.	
15	Raise your hand if you ate raw produce 1 to 5 times in the past week.	
15	Raise your hand if you never ate raw produce in the past week.	

15	Raise your hand if you do not know how often you ate raw produce in the past week.	

Think about whether the adults living in your household eat produce that is raw (uncooked). For this question, we are referring to any produce that does not grow on a tree, and that does not have a peel or shell. Think both about the produce you eat whole and produce you prepare but eat raw, such cucumber or tomatoes. How many times within the past week did the adults eat raw produce?

15	Raise your hand if the adults ate raw produce more than 10 times in the past week.	
16	Raise your hand if the adults ate raw produce 6 to 10 times in the past week.	
16	Raise your hand if the adults ate raw produce 1 to 5 times in the past week.	
16	Raise your hand if the adults never ate raw produce in the past week.	
16	Raise your hand if you do not know how often the adults ate raw produce in the past week.	

Think about whether anyone in your household washes the produce that your household eats raw before eating it.

16	Raise your hand if anyone in your household washes the produce that your household eats raw before eating it.	
16	Raise your hand if nobody in your household washes the produce that your household eats raw before eating it.	
16	Raise your hand if you do not know if anybody in your household washes the produce that your household eats raw before eating it.	

Street Food

If street food applies to this residential area, answer the following questions.
If not, skip to the communal/shared latrines section.

Think about whether you eat food that is prepared and sold on the street, such as roasted maize, roasted or boiled cassava, or fritters. How many times within the past week did you eat street food?

16	Raise your hand if you ate street food more than 10 times in the past week.	
16	Raise your hand if you ate street food 6 to 10 times in the past week.	
16	Raise your hand if you ate street food 1 to 5 times in the past week.	
17	Raise your hand if you never ate street food in the past week.	
17	Raise your hand if you do not know how often you ate street food in the past week.	

Think about whether the adults living in your household eat food that is prepared and sold on the street, such as roasted maize, roasted or boiled cassava, or fritters. How many times within the past week did the adults eat street food?

17	Raise your hand if the adults ate street food more than 10 times in the past week.	
17	Raise your hand if the adults ate street food 6 to 10 time in the past week.	
17	Raise your hand if the adults ate street food more than 1 to 5 times in the past week.	
17	Raise your hand if the adults never ate street food in the past week.	
17	Raise your hand if you do not know how often the adults ate street food in the past week.	

Public/Shared Latrines

If communal/shared latrines apply to this residential area, answer the following questions. If not, skip to the private latrines section.

Think about whether you use public latrines in your residential area. These include latrines shared by people who do not live in your household, like those at markets, schools, churches, or bars. How many times within the past week did you use public latrines in your residential area?

177.	Raise your hand if you used a public latrine in your residential area more than 10 times in the past week.	
178.	Raise your hand if you used a public latrine in your residential area 6 to 10 times in the past week.	
179.	Raise your hand if you used a public latrine in your residential area 5 times or less in the past week.	
180.	Raise your hand if you never used a public latrine in your residential area in the past week.	
181.	Raise your hand if you do not know how often you used a public latrine in your residential area in the past week.	

Now think about whether the adults living in your household use public latrines in your residential area. These include latrines shared by people who do not live in your household, like those at markets, schools, churches, or bars. How many times within the past week did adults in your household use public latrines in your residential area?

182.	Raise your hand if the adults used a public latrine in your residential area more than 10 times in the past week.	
183.	Raise your hand if the adults used a public latrine in your residential area 6 to 10 times in the past week.	
184.	Raise your hand if the adults used a public latrine in your residential area 5 times or less in the past week.	
185.	Raise your hand if the adults never used a public latrine in your residential area in the past week.	
186.	Raise your hand if you don't know how often the adults used a public latrine in the past week.	

Private Latrines

If private latrines apply to this residential area, answer the following questions. If not, skip to the closing questions section.

Think about whether you have a latrine in your household. Do you have any latrines in your household?		
187.	Raise your hand if you do have a latrine in your household.	
188.	Raise your hand if you do not have a latrine in your household.	
189.	Raise your hand if you do not know if you have a latrine in your household.	
Think about whether you use the latrine in your household. Do you use the latrine in your household?		
190.	Raise your hand if you do use the latrine in your household.	
191.	Raise your hand if you do not use the latrine in your household.	
192.	Raise your hand if you do not know if you use the latrine in your household.	
193.	Raise your hand if you do not have a latrine in your household.	
Think about whether you flush the latrine in your household with water. Do you flush the latrine with water?		
194.	Raise your hand if you do flush the latrine in your household with water.	
195.	Raise your hand if you do not flush the latrine in your household with water.	
196.	Raise your hand if you do not know if you flush the latrine in your household with water.	
197.	Raise your hand if you do not have a latrine in your household.	

Think about whether the latrine in your household ever floods. Does the latrine in your household ever flood?

198.	Raise your hand if the latrine in your household does flood.	
199.	Raise your hand if the latrine in your household does not flood.	
200.	Raise your hand if you do not know if the latrine in your household floods.	
201.	Raise your hand if you do not have a latrine in your household.	

Closing Questions

If there is a combination of male and females in the group, answer the following questions. If the group is all male or all female, skip to the residential area vote.

Observe number of female participants.	
Observe number of male participants.	
Raise your hand if you are a girl.	
Raise your hand if you are a boy.	
Raise your hand if you live in this residential area.	
Raise your hand if you live in another residential area.	
Please write the names of all enumerators involved in this survey	

Additional Comments	