Institute for Water
and Energy Sciences
(incl. Climate Change)

**PAN-AFRICAN UNIVERSITY**
**INSTITUTE FOR WATER AND ENERGY SCIENCES**
**(including CLIMATE CHANGE)**

# Master Dissertation

Submitted in partial fulfillment of the requirements for the master's degree in

CLIMATE CHANGE POLICY

Presented by

***Rhodah CHABINGA***

**Evaluating the Influence of Rainfall Patterns and Inadequate Municipal Solid Waste Management on Cholera Outbreaks in Lusaka, Zambia.**

***Defended on …/04/2025 Before the Following Committee:***

| | | | |
|---|---|---|---|
| **Chair** | Tayeb BOULMAIZ | Dr | Affiliation (Institution only) |
| **Supervisor** | Khaldoon MOURAD | Dr | Lund, Sweden |
| **External Examiner** | Bichaye TESFAYE | Dr | Affiliation (Institution only) |
| **Internal Examiner** | Ouhib FETHI | Dr | Affiliation (Institution only) |

# DEDICATION

With profound gratitude, I dedicate this work to my beloved mother, whose unwavering support, sacrifices and constant encouragement have shaped my journey. Her dedication and belief in my abilities have been the foundation of my success.

I also dedicate this research to my supportive family and friends, who never hesitated to remind me that it was achievable. Their encouragement and companionship have been a constant source of strength.

Lastly, to all academicians who relentlessly pursue knowledge and strive to make a difference, this work is a tribute to your perseverance and passion.

## STATEMENT OF THE AUTHOR

I, Rhodah Chabinga, hereby declare that this thesis, titled: "Evaluating the Influence of Rainfall Patterns and Inadequate Municipal Solid Waste Management on Cholera Outbreaks in Lusaka, Zambia," is my own original work and has not been submitted for a degree at any other institution. I have acknowledged all the scholarly material utilized by correctly citing and referencing. All efforts have been made to prevent plagiarism by upholding scholarly ethical guidelines. I am submitting this document in partial fulfilment of the requirements for a master's program in Climate Change Policy at The Pan African University and I accept total responsibility for its content.

Name: Rhodah CHABINGA

Track: Climate Change Policy

Institute: Pan African University Institute for Water and Energy Sciences including Climate Change (PAUWES)

Date: 25th March 2025

Signature:

ACKNOWLEDGEMENTS

This work would not have been possible without the unwavering support of several individuals and institutions, to whom I am deeply grateful.

Firstly, I am grateful to the African Union for the scholarship award to pursue this master's program and contribute to the development of the continent. I am sincerely grateful to all the members of staff and visiting lecturers at the Pan African University Institute for Water and Energy Sciences including Climate Change (PAUWES).

I am profoundly grateful to my thesis supervisor, Professor Khaldoon MOURAD, whose invaluable mentorship, patience and dedication to duty have been instrumental in shaping this research. Your excellence and commitment have inspired me to push beyond my limits.

I am grateful to Lusaka Integrated Solid Waste Management Company for the internship opportunity which helped me understand my research to greater detail. Thank you for your mentorship, insights and knowledge exchange.

To my friends and colleagues at PAUWES Institute, your team spirit, motivation and thoughtfulness have made this journey not only bearable but truly enriching. I am especially grateful to Makhosazana MASUKU and Salifu DUMBUYA for their constant reminders and for standing by me throughout the process.

I also extend my gratitude to my family and friends beyond the academic circle, whose words and unwavering support gave me the drive to successfully complete this research. To all those who contributed in one way or another, I am deeply thankful. This achievement is as much yours as it is mine.

Above all, I give all the glory and honor to God Almighty, whose loving kindness and wisdom have sustained and encouraged me in my times of uncertainty throughout this journey.

## Abbreviations and Acronyms

| | |
|---|---|
| AFOLU | Agriculture, forestry and other land uses |
| ANOVA | Analysis of Variance |
| CBE | Community-based Enterprises |
| CDC | Centers for Disease Control and Prevention |
| CDP | Carbon Disclosure Project |
| COP | Conference of Parties |
| ECDC | European Centre for Disease Prevention and Control |
| EMDAT | Emergency Events Database |
| ENSO | El Niño Southern Oscillation |
| EPA | Environmental Protection Agency |
| EU | European Union |
| EWE | Extreme weather events |
| FEWS | Famine Early Warning Systems Network |
| GHG | Greenhouse gas emissions |
| GRZ | Government of the Republic of Zambia |
| GTFCC | Global Task Force on Cholera Control |
| IPCC | Intergovernmental Panel on Climate Change |
| ITCZ | Inter Tropical Convergence Zone |
| LDC | Least developed countries |
| LISWMC | Lusaka Integrated Solid Waste Management Company |
| MGEE | Ministry of Green Economy and Environment |
| MSW | Municipal solid waste |
| MSWM | Municipal solid waste management |

| | |
|---|---|
| NAP | National Adaptation Plan |
| NDC | Nationally Determined Contribution |
| NGO | Non-governmental Organization |
| NOAA | National Oceanic and Atmospheric Administration |
| NSWMS | National Solid Waste Management Strategy |
| NUTS | Nomenclature of Territorial Units for Statistics |
| OECD | Organization for Economic Cooperation and Development |
| SDGs | Sustainable Development Goals |
| SPSS | Statistical Package for Social Sciences |
| SSA | Sub-Saharan Africa |
| UN | United Nations |
| UNDRR | United Nations Office for Disaster Risk Reduction |
| UNEP | United Nations Environment Program |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNICEF | United Nations International Children Emergency Fund |
| USD | United States Dollar |
| WASH | Water, Sanitation and Hygiene |
| WHO | World Health Organization |
| ZNBC | Zambia National Broadcasting Corporation |

# Table of Contents

## List of Tables

# List of Figures

# Abstract

The cholera crisis remains a recurring public health and socioeconomic concern for several urban and peri-urban communities across the globe, especially in developing countries like Zambia. It has various risk factors including hydroclimatic conditions, poor sanitation and hygiene practices, inadequate water supply and improper waste management practices among several others. In this study, the combined impact of rainfall and poor municipal solid waste disposal on cholera incidence in Lusaka was examined by incorporating both qualitative and quantitative methods particularly household surveys, field assessments and statistical analysis. Lusaka is the capital city of Zambia known to be both an economic hub and cholera hotspot especially during the rainy season due to the many informal settlements existent there. The findings of the study confirmed poor domestic waste disposal practices in the study area which interact with rainwater causing blockages, water stagnation and contamination. Unfortunately, residents were seen exposing themselves to this water when faced with water supply disruptions, thereby creating favorable pathways for cholera bacteria. Spearman's rank correlation assessed the relationship between rainfall and cholera for the duration 1994 to 2024, and a moderate positive correlation was found between the two variables with a correlation coefficient of 0.394 and a p-value of 0.028. However, rainfall alone could not be concluded to cause cholera but its interaction with other risk factors such as domestic waste undeniably creates a conducive environment for the transmission of cholera bacteria. Several challenges for effective municipal solid waste management in Lusaka were highlighted including outdated and unmonitored strategies, and the non-compliance of residents. The study underscores multiple opportunities with the potential to facilitate the implementation of climate-sensitive measures and policy interventions thus should be explored by authorities to prevent cholera. It further emphasizes the need for adequate stakeholder identification and inclusion in the formulation of policies and strategies for guaranteed compliance to sustainable domestic waste practices amid climate change.


**Keywords:** Cholera, Public Health, Rainfall, Municipal Solid Waste, Lusaka.

**RHODAH CHABINGA**

**Evaluating the Influence of Rainfall Patterns and Inadequate Municipal Solid Waste Disposal on Cholera Outbreaks in Lusaka, Zambia.**

# 1. INTRODUCTION

## 1.1 Background

Concerning the global climate, average weather conditions have been continuously shifting over the past decades resulting in changing rainfall patterns, increasing atmospheric and land temperatures, sea level rise, biodiversity loss, species' extinction, and the frequent occurrence of extreme weather events such as floods and droughts among others. The 2023 Intergovernmental Panel on Climate Change (IPCC) Report acknowledged that anthropogenic activities have altered the earth's climate, spreading widely and rapidly to affect millions of people and ecosystems (IPCC, 2023). With high confidence, activities such as Agriculture, Forestry and Other Land Uses (AFOLU); energy generation from fossil fuels; transportation; unsustainable production and consumption patterns; and poor waste management have continued to emit increased concentrations of greenhouse gases (GHG) into the atmosphere. This has resulted in escalating global surface and atmospheric temperatures of about 1.1°C above pre-industrial levels (IPCC, 2023). These changes have further been reported in different layers of the atmosphere and in the oceans too, which serve as the greatest carbon sinks and heat traps thus compromising global environmental and social well-being (United Nations, 2023). Moreover, extreme weather events (EWE) have increased, causing severe losses on livelihoods, ecosystems, and climate-dependent economies. Without any alterations to this current negative trend, the earth will experience some of the most intense and irreversible impacts of the climate crisis. Unfortunately, African countries like Zambia continue to face disproportionate impacts of this crisis despite contributing less than 4% in total to the global GHG emissions (CDP, 2021).

Climate change hazards are reportedly aggravating inequality, especially in disadvantaged communities of Africa especially in women and children with higher vulnerability and exposure (African Union, 2023). The impacts of climate change are multi-sectoral and dynamic, affecting even the least discussed sectors like solid waste management and public health. Major impacts of concern in Zambia include rising surface temperatures, changing rainfall patterns, and extreme events such as annual floods, less frequent droughts, and prolonged dry spells (MGEE, 2023). Zambia is characterized under the least developed countries (LDC) in southern Africa according to the United Nations classifications, with an economy majorly supported by mineral mining and rain-fed agriculture (Kapotwe & Tembo, 2021). The country is landlocked by eight countries including Tanzania, Malawi, Mozambique, Zimbabwe, Botswana, Namibia, Angola, and the Democratic Republic of Congo. It covers an area of approximately 752,614 $km^2$, with an estimated population of 21.3 million (Worldometer, 2024). Zambia has ten provinces, namely: Lusaka, Muchinga, Northern, Eastern, Central, Copperbelt, Northwestern, Western, Luapula, and Southern. Lusaka serves as the capital of Zambia, with a population of over 3.3 million, making it the most populous province in the country (World Population Review, 2024).

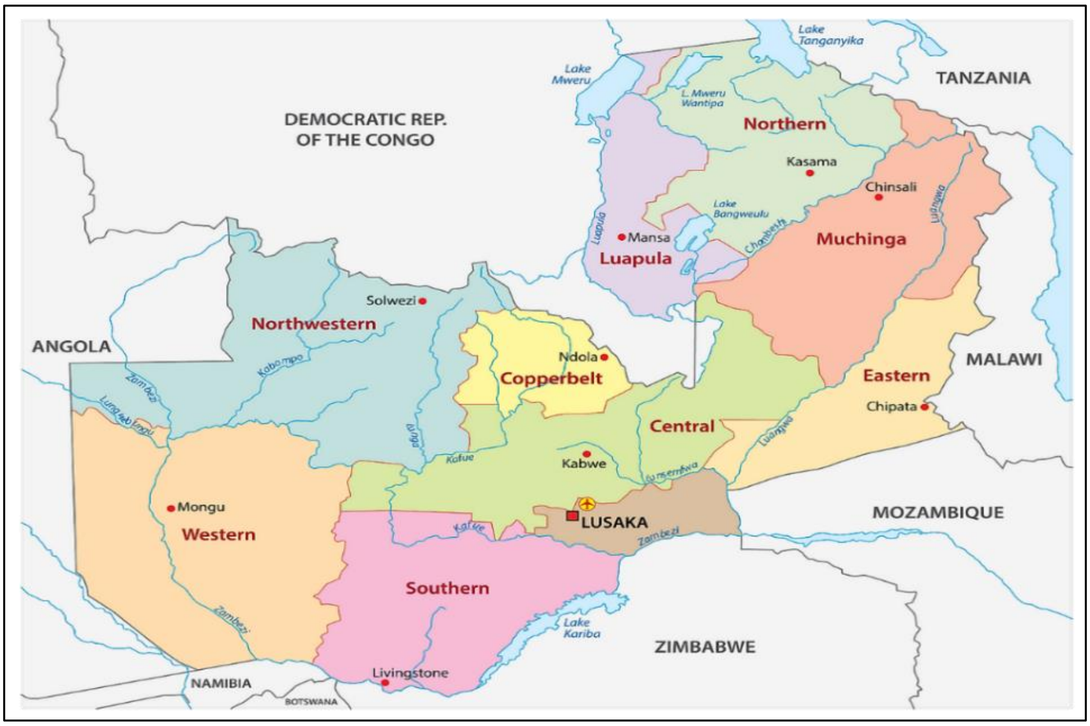


Figure 1.1 Map showing the ten provinces of the Republic Zambia (World Atlas, 2025)

In Zambia, climate change adaptation and mitigation, and the management of municipal solid waste operate through the implementation of various policies, legislation, frameworks and strategies developed locally. At national level, The Ministry of Green Economy and Environment (MGEE) is responsible for activities related to climate change, environment, natural resources, and pollution control. The Ministry of Local Government and Rural Development, through various city councils across the country is responsible for municipal solid waste management (MSWM) or domestic waste management. Some of the policies and legislation established to combat the climate change and solid waste crises in the country include the National Policy on Climate Change of 2016; the Eighth National Development Plan for 2022 to 2026; and the Climate Change and Gender Action Plan of 2018; the Solid Waste Management and Regulation Act of 2018; the Public Health Act of 1978; and the 2004

National Solid Waste Management Strategy among others. Zambia's commitment to climate action stems from its affiliation to international climate frameworks such as the United Nations Framework Convention on Climate Change (UNFCCC), and its various instruments and treaties such as the Paris Agreement of 2015 and the annual Conference of Parties (COP) for climate negotiations.

The aim of local authorities in Zambia regarding municipal waste management is to achieve sustainability through circular economy. Sustainable municipal solid waste management is an intricate system of handling domestic waste in a manner that respects environmental, economic and social principles equally from the point of generation to the recovery or disposal stage at the landfill (Clube & Hazemba, 2024). It requires an effective governance structure as it considers all stages of the waste management process including waste generation amounts, the quality of waste collection and transportation equipment, waste segregation, recycling, composting and treatment, and waste disposal practices. Sustainable MSWM utilizes policy and legislation in enforcement, raising the awareness and education of communities (Banda et al., 2024). In the face of exacerbated impacts of climate change in Zambia, responsible municipal solid waste management needs to be reinforced to prevent public health concerns such as cholera outbreaks. Cholera is a waterborne disease that is caused by the ingestion of water or food that is contaminated by the bacteria *vibrio cholerae* (Koua et al., 2025). According to the European Centre for Disease Prevention and Control, Zambia is currently among the top five countries with the highest cholera cases and deaths in the world (ECDC, 2024). The disease has been occurring since the 1970s, usually breaking out during the rainy season from informal settlements and spreading across the country. Cholera outbreaks often disrupt social wellbeing and hinder economic growth in the country. Overall, the cholera crisis remains a serious concern for the country Zambia and several studies have been conducted to expose various risk factors including hydroclimatic conditions, poor sanitation and hygiene practices, inadequate water supply and improper waste management practices among several others. The capital city Lusaka is considered a cholera hotspot as most cases and deaths are recorded there (Nanzaluka et al., 2020). It has a population of over 3.3 million of which 62% represents the peri-urban population which generates high amounts of domestic waste often indiscriminately disposed of by residents (Chiwele et al., 2022).

Past research on cholera in Zambia has not adequately addressed the synergy of climate change and poor municipal waste disposal as a critical risk factor in cholera prevalence in

Lusaka. Therefore, this study seeks to bridge this gap by assessing the possible relationship between municipal solid waste disposal and cholera prevalence amid climate-induced changes in rainfall patterns in peri-urban Lusaka. The findings of the study will help raise awareness on the need for incorporating climate change in the formulation of policies and strategies related to municipal solid waste management and cholera prevention in the country.

### 1.2 Problem Statement

Municipal solid waste management has proven very challenging for Zambia especially during the rainy season (Banda et al., 2023). This challenge is evident through the recurring vector and waterborne diseases such as malaria and cholera respectively. It is further seen in waste accumulation in unauthorized locations such as drainages and along the roadside. The synergy of climate change and poor MSWM is one of the critical issues impacting public health and the overall socio-economic status of many countries particularly developing countries (Kurniawan et al., 2024). However, in Zambia the major sectors highlighted to be affected by the changing climate according to the National Adaptation Plan of 2023 are Agriculture, Energy, Forestry & Wildlife, Water, Transport, Tourism, Infrastructure, Mining and Health. (MGEE, 2023). The waste management sector has not been specifically highlighted in the climate adaptation plan despite the serious challenges it poses to public health. Additionally, Zambia still relies on the 2004 National Solid Waste Management Strategy thus portraying inadequate climate change considerations as the climate subject has drastically evolved in the past 20 years. Hence, the current state of solid waste management in Zambia is alarming due to major inadequacies such as inadequate adaptation to the climate crisis (Sakanyi & Kooma, 2022). Additionally, accelerated urbanization has resulted in many informal settlements emerging in Zambia's cities, especially in the capital city. This has resulted in an unanticipated increase in indiscriminately disposed waste (Climate Champions, 2022).

As a result, the management of climate change, waste and cholera is not performed in combination as they are often considered as separate challenges. Recurring outbreaks of cholera are recorded across the country, especially during the rainy season with thousands of cases and deaths recorded starting in the overcrowded unplanned settlements of Lusaka (Lusaka Times, 2024). The continuous occurrence of waterborne diseases is globally considered a negative indicator of climate change and sustainable MSWM practices (EPA, 2023). In Zambia, these cholera outbreaks occur almost annually since the 1970s, with many cases and fatalities recorded (Eligon & Moyo, 2024). Most recently, Zambia experienced a cholera outbreak that began in October 2023 and lasted until April 2024, with more than 19,000 cases recorded. Over 15000 of these cases were reported in Lusaka, confirming the city's historical epicenter status in the context of cholera prevalence, thus the reason for its focus in this study. The cholera epidemic poses several socioeconomic effects on the country (UNICEF, 2024). Oftentimes, due to the rapid cholera disease transmission, hospitals become overwhelmed, and makeshift centers are established such as the largest stadium in the country which is turned into a huge cholera center, coupled with multiple requests for medical volunteers due to inadequate staff (ZNBC, 2024).

The repetitive and destructive cycle of annual cholera cases and deaths has an appearance of a lack of adequate preparedness and understanding of the country's climate and solid waste management system. Therefore, this study highlights the implications of climate-induced changes in rainfall patterns and poor domestic management on cholera incidence in Zambia, particularly in the densely populated Lusaka city, which is both an economic hub and a cholera epicenter. The study offers practical recommendations with the potential to bridge existing gaps and outline preparatory measures for stakeholders especially the community and service providers, to ensure responsible municipal solid waste disposal in Zambia.

### 1.3 Research Objectives

#### 1.3.1 Main Objective

This study aims at evaluating the influence of the interaction of poorly disposed municipal solid waste and rainfall on the occurrence of cholera outbreaks in Lusaka.

#### 1.3.2 Specific Objectives

1. To assess the current municipal solid waste disposal practices by residents of Lusaka and their implications on cholera.

2. To assess community understanding of the implications of this synergy in line with the occurrence of cholera outbreaks.

3. To identify the challenges and opportunities for effective waste management amid the changing rainfall patterns in Lusaka.

4. To propose possible measures and policy interventions for improving MSWM amid increasing rainfall in Zambian communities to effectively manage cholera.

### 1.4 Research Questions

1. What are the current waste management practices by residents of Lusaka and their implications for cholera occurrence?

2. How do rainfall patterns correlate with cholera cases in Lusaka for the duration 1994 to 2024?

3. What are the perceptions of residents of Lusaka regarding the synergy of poor MSWM and rainfall in cholera occurrence?

4. What are the main challenges and opportunities surrounding effective MSWM amid extreme rainfall?

5. What are the most effective policy interventions for addressing the combined cholera risk posed by rainfall and poor MSWM?

### 1.5 Relevance of the study

Thus far, several isolated observations and studies have been conducted to understand the cause of cholera outbreaks in Zambia, but very few address the possible causes in combination. This research is a significant step in highlighting the influence and consequences of climate-triggered changes in rainfall patterns and poor MSWM on public health in Zambia. It is an emerging approach to climate change research in Zambia, as most studies conducted there have not focused on these combined impacts on the occurrence and transmission of cholera in the country. It is important to follow this integrated approach in addressing such an intricate challenge which poses detrimental effects on the country's socioeconomic development. It will provide an integrated understanding of the different determinants of rising cholera cases, while at the same time exposing the diverse perceptions that guide different stakeholders when addressing municipal solid waste and climate action. Additionally, this study is an academic contribution that promotes the following Sustainable Development Goals (SDGs) in Zambia's capital city which is expected to take a leading role in sustainable development in the country:

- SDG 3 on Good Health and Well-being: It addresses public health challenges brought by climate-induced rainfall and poor waste disposal.

- SDG 6 on Clean Water and Sanitation: It highlights how the interaction of rainfall with poorly disposed domestic waste causes stagnant and contaminated water exposure for residents leading to high cholera risks.
- SDG 11 on Sustainable and Resilient Cities: It highlights the dangers of poor waste disposal in peri-urban areas leading to unsustainable cities.
- SDG 13 on Climate Action: It aims at strengthening the climate resilience of the current municipal solid waste management systems to prevent cholera outbreaks.

# 2. LITERATURE REVIEW

## 2.1 Conceptual Framework

In the assessment of the impacts of the synergy between rainfall and poor municipal solid waste management on the occurrence of cholera a waterborne disease, the following concepts are considered: rainfall, municipal solid waste, public health, sanitation, waterborne diseases and cholera outbreaks.

- Rainfall is the liquid form of precipitation that falls when the clouds are saturated with water vapor and is measured in millimeters (mm) or inches (in) using an instrument called a rain gauge. It occurs as a result of the natural water cycle but is influenced by the interaction of various factors such as wind, temperature and pressure, water body proximity, and El-Nino Southern Oscillation (ENSO) (World Meteorological Organization, 2019). Anthropogenic activities that produce greenhouse gas emissions (GHGs) also significantly influence rainfall outcomes from the global to the local level (Chu et al., 2019). In this study, anthropogenically induced rainfall is the focus and is one of the independent variables.
- Municipal Solid Waste (MSW) refers to waste or garbage that is produced especially by residential areas and businesses to be systematically managed by municipalities to prevent harm to the environment and public health (OECD, 2021). It includes waste such as household waste like food waste, commercial waste from packaging and non-hazardous waste from industries and construction works. Depending on waste management practices employed, MSW can be composted, combusted recycled or would commonly end up in landfills. For this study, MSW is limited to household or domestic waste produced by residents and the focus is on the disposal practices of this waste by residents.
- Waterborne diseases are the most common form of water-related diseases that arise from the ingestion of contaminated water or food, examples include cholera which is caused by the bacteria *vibrio cholerae.* These diseases are more prevalent in areas and seasons of high vulnerability risks such as inadequate clean water, unimproved sanitation practices and poor hygiene, where the movements of pathogens such as bacteria, viruses and parasites are promoted. A waterborne disease outbreak occurs when two or more people are linked epidemiologically (based on pattern of the disease) by location of exposure, time and type of illness (CDC, 2023). Globally, waterborne diseases present significant public health concerns, especially in

developing countries where rainfall patterns and waste management practices can exacerbate disease transmission due to socioeconomic capacity limitations. For this study, waterborne disease is used to imply only cholera as the focus of the assessment.

- Public health is a field concerned with the protection and improvement of health for people and the communities they live in mostly through detecting, preventing and responding to diseases (CDC, 2024c). It includes issues of environmental sanitation, health education, hygiene promotion, control of communicable diseases, access to medical care, and social support to ensure an acceptable standard of living for everyone and maintained health and longevity of life. Cholera outbreaks compromise public health thus the two are used synonymously in this study.

This literature review examines the intricate interactions between rainfall and poor municipal solid waste management in the occurrence of waterborne diseases in Zambia, drawing on various studies to highlight key findings and identify gaps in the current understanding of the subject. It assumes rainfall and municipal solid waste as the independent variables, while waterborne disease outbreak is the dependent variable.

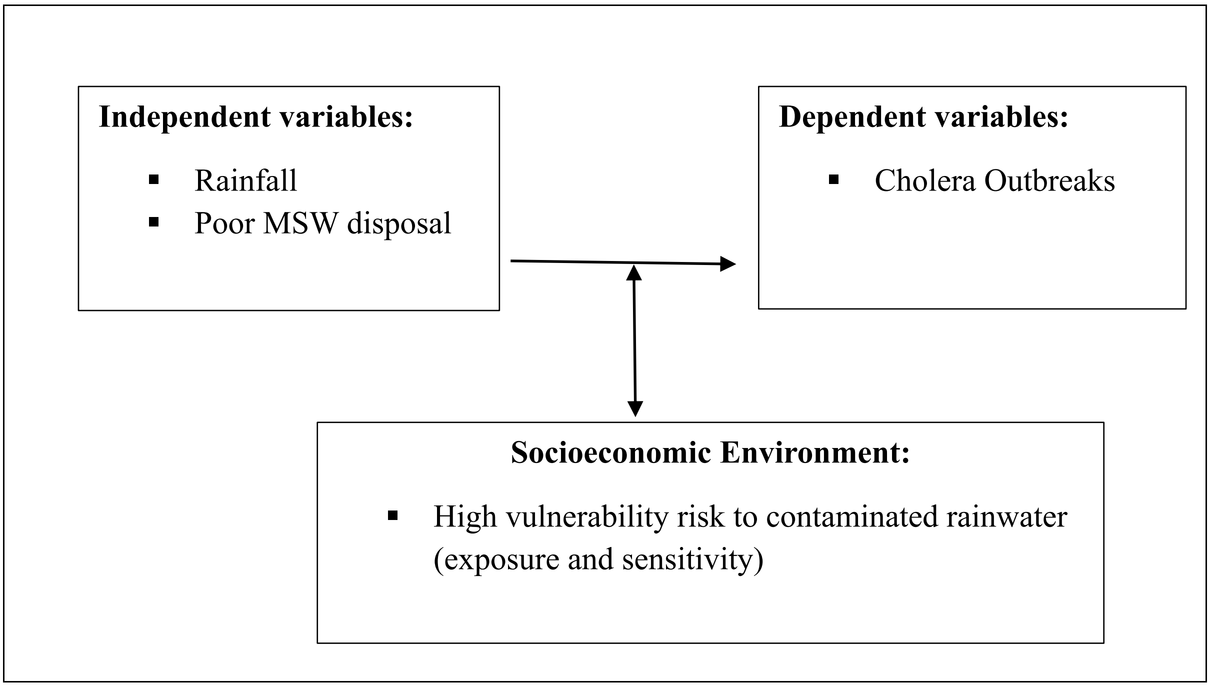


Figure 2.1 Researcher’s summary of the Conceptual Framework for the Occurrence of Cholera Outbreaks

## 2.2 Theoretical Framework

The purpose of this framework is to provide an understanding and illustration of how rainfall patterns and waste management practices influence the prevalence of waterborne diseases such as cholera, using different theories and models. The identified theories all rest on the fecal-oral transmission pathway as the major cause of waterborne disease occurrence, commonly referred to as the “F-diagram” by World Health Organization. The 5-F diagram explains that for waterborne diseases like cholera to be transmitted, one or all five pathways must have successfully transferred the bacteria to a new host, that is through flies, fluids, fingers, fields or food.

The following are some of the theories believed to hold true for waterborne diseases to occur hydrological theory, environmental health theory, vulnerability theory and the disease ecology theory. The hydroclimatic cycle theory links waterborne outbreaks to the changes in the water cycle such as an increase or decrease in rainfall due to climate change. The water cycle is the continuous circulation of water molecules between the earth and the atmosphere through evaporation, condensation, infiltration and precipitation (NOAA, 2019). During excess rainfall, flooding and runoff increases thus facilitating the breeding and transmission of pathogens that cause waterborne diseases as the rainwater sweeps across multiple sources of contamination such as exposed sewage. This theory emphasizes that excess but contaminated water is the major cause of disease outbreaks as it fulfils one of the fecal-oral pathways (Bertuzzo & Mari, 2017). The environmental health theory considers how public health is affected by environmental factors such as poor waste disposal. It links health outcomes directly or indirectly to environmental factors and explains how controlling these factors can promote health and wellbeing by preventing disease outbreaks. Environmental factors can be controlled by providing efficient municipal waste management services, raising awareness on the dangers of indiscriminate disposal and providing basic sanitary resources like safe and adequate water, thereby preventing the breeding and transmission of harmful pathogens (StudyCorgi, 2022).

The vulnerability theory shows how various factors exacerbate the population’s susceptibility to waterborne disease outbreaks, that is, their exposure, sensitivity and adaptive capacity. Exposure is the extent of contact with contaminated sources, sensitivity is the degree to which the affected population is affected by the exposure, and adaptive capacity is the ability of a population to respond and recover from the adverse effects caused by exposure. Reducing exposure and sensitivity and building adaptive capacity can reduce the vulnerability of that population to waterborne disease outbreaks. According to the United Nations Office for Disaster Risk Reduction (UNDRR), vulnerability conditions are determined based on the physical, environmental and socioeconomic factors that surround a population such as proximity to contaminated source, rainfall patterns, drainage system, economic stability, government support among others (UNDRR, 2023).

Finally, the disease ecology model considers all the highlighted theories as factors influencing waterborne disease occurrence. It exposes the various dynamics that govern the disease outbreaks such as hydroclimatic factors (precipitation patterns, water sources); environmental factors (modes of pathogen transmission, sanitation and hygiene, waste disposal) and vulnerability factors (such as the characteristics of possible hosts such as immune system or age; location of hosts, and available public health infrastructure, urbanization). This model holistically combines perspectives from environmental, ecological, social and biological factors and proposes that waterborne disease outbreaks worsen when these variables occur in combination (Perkins & Rohr, 2020).

### 2.3 Climate Trends in Zambia

Zambia lies between latitude 8º and latitude 18º South of the Equator in Sub-Saharan Africa (SSA), falling in the tropical climatic zone. The country has three distinct seasons; that is, the rainy season, hot dry season and a cool dry season distributed differently in the ten provinces: Lusaka, Southern, Copperbelt, Northern, North-Western, Western, Muchinga, Eastern, Central and Luapula (World Bank Group, 2021). Generally, temperature and rainfall patterns vary significantly across the different provinces. Rainfall is expected to be lower in the Southern part of Zambia: Southern, Lusaka, and part of Western, Eastern and Central Provinces (at a 700mm average) and higher in the Northern region, that is: Northern, Luapula, Muchinga and part of North-Western Province (1400mm average).

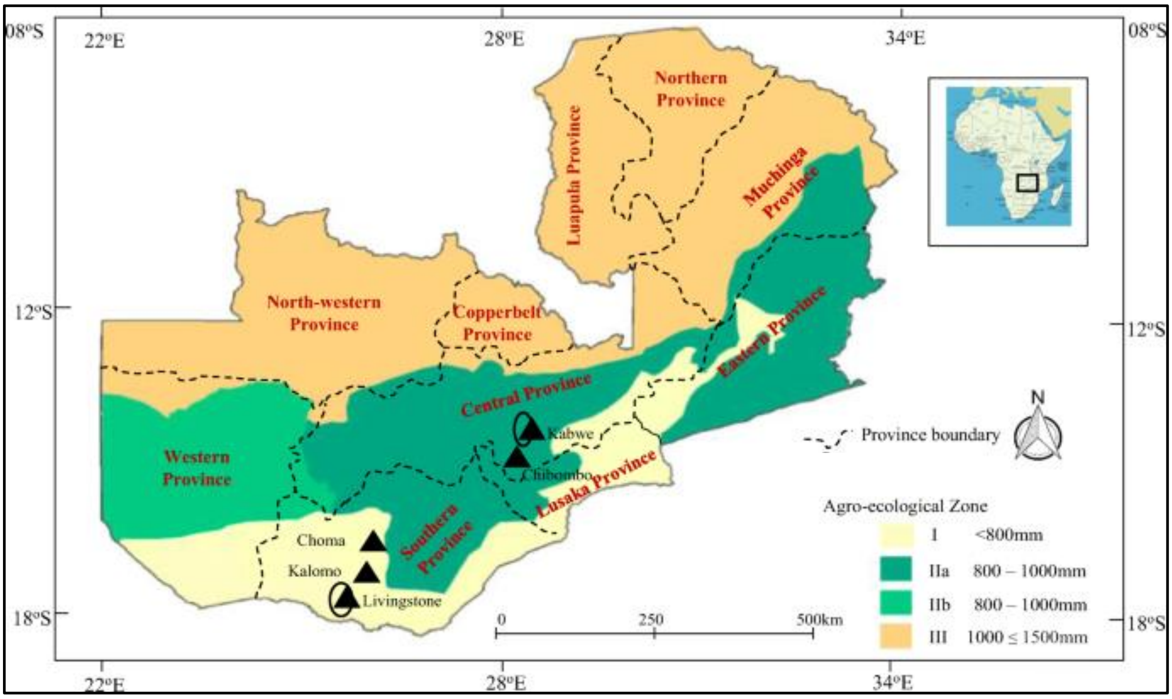


Figure 2.2 Rainfall patterns in Zambia according to the different agro-ecological zones (Makondo & Thomas, 2020)

Historically, the rainy season in Zambia starts around late October, but intensifies around December or January, and finally ends around April. It is followed by a cool dry season from May to August characterized by constant windy conditions especially towards the end. Late August to October is the hot dry season characterized by significantly high average atmospheric temperatures. Temperatures may range from around 19-25$^{0}$c on average, with the warmest being recorded during the hot season as demonstrated in figure 2.2. However, minimal fluctuations may be observed regarding the precise commencement or ending of a season.

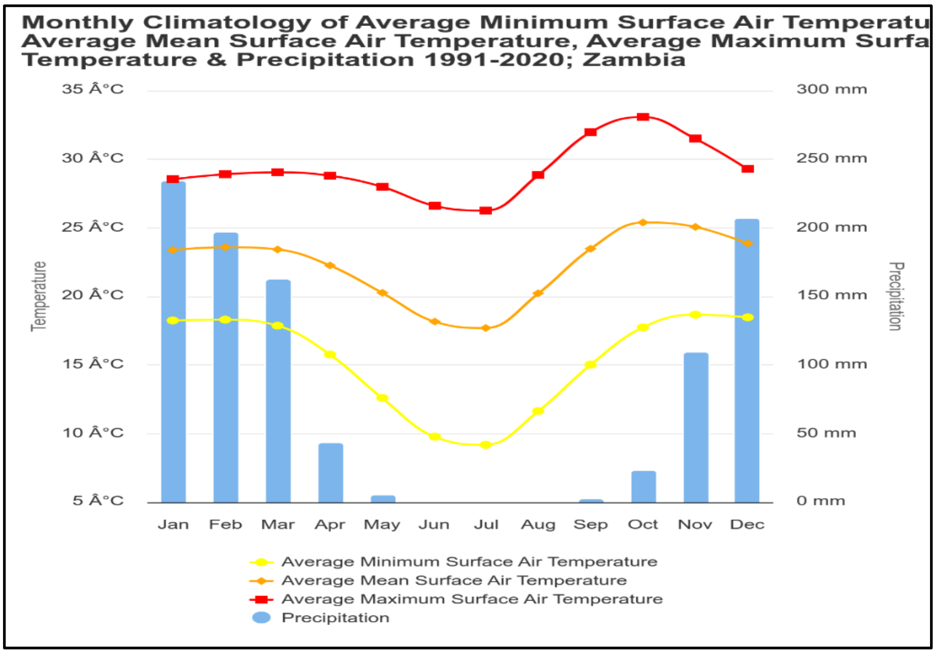


Figure 2.3 The seasonal variation patterns in Zambia between 1991-2020 as obtained from (World bank group, 2020)

However, the current increase in global greenhouse gas concentrations in the atmosphere has resulted in the much-discussed climate change crisis which has brought about significant seasonal changes. Despite Zambia being one of the lowest emitters of GHG in the world contributing about 0.02%, it has not been spared from the adverse impacts of climate change (Ritchie & Roser, 2020). In Zambia, the average temperatures have continued to increase, while the rainfall amounts show erratic fluctuations, resulting in either flooding or droughts or simply prolonged dry spells (MGEE, 2023). Climate variability has also been observed where the duration and intensity of the seasons are not constant. For instance, the duration of the rainy season has generally reduced, while the intensity of the rain tends to increase only in a particular period. This leads to highly destructive flash floods, whose impacts are felt across a wider area but more frequently in Lusaka. Infrastructure such as dams, bridges and roads are observed to constantly collapse or overflow due to their inability to withstand the extremely high amounts of rain and flood water. Droughts are also prevalent in periods of low rainfall, affecting sectors such as rainfed agriculture and overall Water, Sanitation and Hygiene (WASH) practices. For instance, in 2023, flash floods were recorded between January and March, affecting close to 400 000 people especially small-scale farmers whose crops were swept away (Schneider, 2023). A clearer case of climate variability occurred in February 2024, when Zambia declared a drought emergency during a season that would initially be considered rainy. However, by April the same year, the drought was suppressed by flooding which was experienced in some parts of the country and predictions suggested further fluctuations in the rainfall patterns throughout the year (FEWS, 2024). After this, drought conditions became more persistent in the country, affecting mostly maize production and hydroelectricity generation on which the country mostly depends for its close to 85% of energy (Ministry of Energy, 2024).

In addition, although rainfall is historically expected to be higher in the northern part of the country and lower in the southern part where Lusaka, the capital city is located, the inverse has been occurring more often in recent times. For instance, towards the end of the 2022/23 rainy season when rainfall was normally expected to have reduced in preparation for transition to the next cold dry season, significantly heavy and continuous rainfall was recorded in the southern region particularly in Lusaka. These rains led to extreme flood events and overflow of waterbodies in the region, which damaged infrastructure (roads, bridges, houses) and crops, and led to some fatalities and waterborne diseases specifically cholera. More than 300 000 people were affected, displacing over 7000 of these (Worlds Aid, 2023).

Other notable contributions to this climate variability and change in Zambia are the El Niño Southern Oscillation (ENSO) and Inter-Tropical Convergence Zone (ITCZ) (World Bank Group, 2021). ENSO has two phases called the El-Niño (warming of the sea) and La-Niño (cooling of the sea) occurring in the eastern and central Pacific Ocean. The ITCZ is a band of clouds that is characterized by showers and occasional thunderstorms which circle the globe near the equator, due to the convergence of the moving trade winds from the east. The position of the ITCZ varies seasonally since it follows the sun, resulting in wet and dry seasons in the tropics like Zambia, whether they are located near or much further from the equator. The storms in the tropics are usually small-scale and short lived but can produce intense rainfall. Away from the equator, the climate results in one wet season and one dry season. For example, the wet season occurs from around May to July in the Northern Hemisphere, and from around November to February in the Southern Hemisphere, thus coinciding with the rainy season in Zambia which is further south of the equator (NOAA, 2023). Despite both the ENSO and ITCZ being naturally occurring, their interaction with a significantly warming atmosphere caused by high GHG concentrations exacerbates the average weather extremes across some locations like Zambia, causing climate variability and change (Qiaohong et al., 2023).

## 2.4 Relationship between Rainfall Patterns and Waterborne Diseases

Climate change has resulted in alterations in global precipitation patterns, making some areas receive excess rainfall which causes floods, while little or no rainfall is recorded in other areas (IPCC, 2023). The IPCC confirms that climate change will have catastrophic effects if left uncontrolled, and that the cost of inaction is significantly higher than the costs of action. Currently, climate change is contributing significantly to humanitarian crises especially when climate hazards interact with high socioeconomic vulnerabilities (IPCC, 2023). Subsequently, changes in climatic conditions can make a direct or indirect contribution to the transmission of pathogens particularly when they interact with other risk factors such as indiscriminately disposed waste. This is observed through water-related diseases such as cholera and malaria which are globally acknowledged as indicators of climate change vulnerability and compromised public health.

In Zambia, frequent and severe cholera outbreaks occur almost annually since the 1970s, with many cases and fatalities recorded especially during the rainy season (Eligon & Moyo, 2024). Most recently, Zambia experienced a cholera outbreak that began in October 2023 and lasted until early 2024 with more than 19 000 cases recorded (UNICEF, 2024). This is because floods are recorded almost annually in Zambia, while droughts are less frequent, with the former being a major driver of these outbreaks. These factors threaten the country's agricultural productivity, food security and overall economic growth projected at 5 billion USD economic loss by 2030, and resulting in an increase in poverty, malnutrition, displacement, and the earlier highlighted water and vector-borne diseases (World Bank, 2023). Waterborne diseases affect both developed and developing countries in many ways, such as: economically due to increased costs of healthcare due to hospitalization and treatment; socially by disrupting the quality of life; and environmentally as ecological imbalances may occur. A study in the United States of America showed that waterborne diseases affect over 7 million people every year, costing their health system over USD 3 billion (CDC, 2024a). For Zambia, cases of waterborne diseases specifically cholera often overwhelm the designated cholera centers, and to cater for the growing demand, infrastructure meant for other uses is turned into cholera centers. For instance, the largest stadium in the country, National Hero's Stadium, is usually turned into a major cholera health center for cholera victims (Lusaka Times, 2024). Victims of such waterborne diseases are cared for at the expense of the government of Zambia and other supporting international funding bodies. This forces the country to divert funds, resources, infrastructure use and expertise meant for other developmental projects. Apart from these significant direct expenses, cholera has indirect costs in other sectors due to loss of human capital and decrease in trade and tourism caused by rampant hospitalizations, deaths and overall social restrictions. Ultimately, these challenges strain the country's budget, slowing down economic growth and increasing its debts in a bid to cater for emerging costs.

### 2.4.1 Excess Rainfall and Waterborne Diseases

Excess rainfall is the major driver of waterborne diseases as the contaminated rain and flood water promotes the breeding and transmission of pathogens that cause diseases such as cholera, typhoid fever, and dysentery (Semenza & Ko, 2023). These rains usually result in floods and surface water runoff which encounter other public health challenges such as poorly disposed domestic waste and blocked sewers especially in developing countries, thereby endangering community and environmental health. The sixth IPCC report noted with very high confidence that extremely high rainfall increases the occurrence of vector-borne, food-borne, and water-borne diseases especially in areas exposed to poor sanitation and waste disposal practices (IPCC, 2023). Developing countries, especially in Africa and Asia, record the highest annual cases and deaths from water and vector borne diseases especially when their irregular and inadequate waste management services interact with extreme climate impacts like excess rainfall and floods (Robertine et al., 2021). Although many factors contribute to disease outbreaks, the contact of municipal solid waste with extreme climate events cannot be marginalized. Different epidemiological studies on the impacts of heavy rainfall and flooding further reveal that excess rainwater leads to uncontrollable and intensified surface run-off which may propagate waterborne disease pathogens thus triggering their exposure to unsuspecting humans in several ways. When the surface runoff flows rapidly, it may mix with poorly disposed household waste, leading to pathogenic contamination of storm water and its outlets. Evidence of the relationship between heavy rainfall and increased risk of waterborne diseases among different age groups in different continents has been unearthed, more specifically the increase in hospitalization of young children, days immediately after heavy rainfall (Lai et al., 2020). Over the last thirty years, diarrheal-related diseases have remained the third leading cause of the disease burden among children under the age of 10 years, but improved access to WASH (water, sanitation, and hygiene), access to care, vaccination, and improved nutrition have reduced the occurrence by 68% between 1990 and 2019 (Semenza & Ko, 2023). The World Health Organization also acknowledges children as particularly at risk from water-related diseases. Other groups identified as vulnerable to waterborne diseases include low-income communities with lower adaptive capacity and poor WASH infrastructure and services (WHO, 2023).

According to the WHO, sub-Saharan Africa (SSA) is reported to record the most cholera cases since 1996. A statistical modelling of the seasonality of cholera outbreaks in SSA was conducted in 2022 by Perez-Saez et al. and the following were the findings. Cholera cases were obtained from the Global Task Force on Cholera Control (GTFCC), a global database for cholera, for 34 countries in SSA. The researchers developed a Bayesian statistical model to infer the monthly risk of cholera at the first and second administrative levels. First administrative level being the national level and second being subnational entities such as region, provinces, or states. This study focused on the association between seasonality estimates (the distinct seasonal patterns) and hydroclimatic variables including cumulative monthly precipitation, mean monthly fraction of area flooded and mean monthly air temperature. Out of the 34 countries in SSA, 24 showed a seasonal pattern of excess cholera risk between 1970 and 2021 based on statistical evidence. Regional patterns revealed that West Africa had a higher excess risk of cholera occurring between July and October, especially inland countries across the Sahel, with an exclusion of Mali. For southern Africa where Zambia lies, the peak of excess cholera risk was between December and April which is usually a rainy season. East African seasonal cholera patterns were not uniform, some peaking in the second half of the year, and others peaking around December, May or August. It was concluded that excess cholera risk was consistently associated with rainfall, showing a generally strong positive correlation across SSA, and among the countries with a large positive correlation were Zambia, Malawi, Mozambique, Niger, Nigeria, northern Cameroon, Chad, Sudan, and eastern Ethiopia (Perez-Saez et al., 2022).

An analysis by the United Nations International Children's Emergency Fund (UNICEF) on ten African countries (Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria, and Somalia), revealed that 190 million children in these countries are at the highest risk from a convergence of three water-related threats: waterborne disease, climatic hazards, and inadequate water, sanitation, and hygiene (WASH) services (UNICEF, 2023). In developed countries, most of the waterborne disease challenges are not as pronounced as in developing countries. This is because they have advanced water treatment and distribution systems, and effective waste disposal measures; and their governments are in constant consultation with updated regulations of The World Health Organization despite the occurrence of climate variation and change. For instance, in Europe cholera is not considered a common and regular problem due to high standards of hygiene regardless of the season, hence has a low risk of spreading even from the few imported cases recorded (ECDC, 2024).

A study by Lopez-Velez and Presotto (2021) on Cholera in travelers of Europe exposed that cholera is usually of low incidence in Europe and is mostly expected in travelers who visit areas prone to endemic or epidemic cholera. Endemic refers to repeated outbreaks of at least three times in five years, while epidemic refers to occurrence of at least one confirmed case with evidence of local transmission. This kind of cholera recorded in Europe is commonly referred to as "Imported cholera". In 2018, 26 cases of cholera were reported to the WHO in five European Union (EU) countries and 22 were associated with travel, that is: eight of these victims were infected while in India, seven in Pakistan, three in Thailand, two in Bangladesh, one in Myanmar and one in Tunisia, all developing countries associated with high cholera risk especially in the rainy season (López-Vélez & Presotto, 2021).

### 2.4.1 Inadequate Rainfall and Waterborne Diseases

Although limited studies have been conducted on the impacts of inadequate rainfall and droughts on the occurrence of waterborne diseases, there is emerging evidence on what the potential impacts could be. This comes from first understanding the purpose of rainfall in replenishing both underground and surface water bodies from which water distribution networks and boreholes/wells source their water. Through the rain cycle, water is naturally replenished in rivers, lakes and oceans, therefore inadequate rainfall implies a low water supply. A narrative review on drought-related cholera outbreaks in Africa revealed that Africa experiences extreme droughts across the continent, with some regions affected more severely than others and among the many socioeconomic consequences resulting from this are waterborne disease outbreaks such as cholera (Charnley et al., 2022).

Charnley et al. (2021) explored the relationship between drought and epidemic cholera in Africa between 1970 and 2019 using generalized linear models and projected the following. Overall, outbreaks of cholera are closely related to changes in environmental and climatic conditions particularly temperature and precipitation which act as dispersal mechanisms. Droughts limit the availability of adequate safe water thereby disturbing water, sanitation and hygiene (WASH) practices. They also increase the concentrations of infectious bacteria in the limited water resources. The study developed three scenarios: S1 (best case), S2 (intermediate) and S3 (worst case) for the duration 2020–2070 in alignment with achieving climate change targets and sustainable development goals (SDGs), and cholera projections for the same duration. Three different types of droughts were targeted to understand which one is mostly associated with cholera incidences, that is: meteorological drought, agricultural drought and hydrological drought. Meteorological drought is caused by abnormally low precipitation over a specific time and region and was measured using the Palmer Drought Severity Index. Hydrological drought arises when there is a significant reduction in the amount of water in waterbodies such as rivers and lakes, while agricultural drought occurs when the soil has insufficient moisture to meet the required demands for crops to grow. According to the parameter values for each of the three scenarios, cholera cases were predicted showing several changes and heterogeneity among countries. Using S1 and S2, most countries showed a decrease in cholera outbreaks with few outliers like Tunisia in north Africa. However, some countries had the highest cholera levels throughout such as Nigeria and Democratic Republic of Congo. S3 showed a small increase in cholera for the entire projected period. Of all the droughts simulated, meteorological drought and high temperatures had a significant potential to result in cholera outbreaks, thereby confirming drought contribution to waterborne diseases like cholera. In Zanzibar, 1 °C increase in temperature was associated with a twofold increase in cholera cases. However, the overall continental results suggested that significant progress in attaining the SDGs may help reduce cholera risk in the future (Charnley et al., 2021). Therefore, in addition to floods, droughts should be considered as periods of increased risk of cholera outbreaks across the globe.

### 2.5 Municipal Solid Waste Management Trends

The annual global waste generation rates stand at around 2 billion tons of municipal solid waste and more than 50% of this is from developing countries (World Bank Group, 2019). Generally, municipal solid waste management practices in the global north differ significantly from practices in the global south because the former have a greater capacity to implement more advanced, sustainable and effective management initiatives. Developed countries have harnessed various advanced technologies to sort, process and treat solid waste, with the aim of reducing the amount and exposure to climatic extremes. Technologies include recycling, composting, incineration, bio-drying, and bio-stabilization, all in the aim of protecting both the environment and public health. Therefore, in most waste management studies in the global north, water and vector borne diseases are not prevalent due to the advanced and sustainable technologies in place. However, MSWM systems in developing countries face challenges due to uncontrolled urbanization and population growth; weak institutional capacity to incentivize waste management or engage in recycling initiatives; inadequate technologies, information and infrastructure; inadequate community capacity to subscribe to formal waste collection services and limited finances for effective and regular waste management (Peach, 2024). As a result, there is inadequate waste collection and treatment leading to further challenges that manifest in socioeconomic indicators such as water and vector-borne disease outbreaks. For Africa, interventions to curb this problem have been initiated by many global and regional frameworks including the African Union which has set an ambitious target for all African countries to be engage in the recycling, reusing and recovery of at least 50% of the generated waste by 2030. Unfortunately, many countries including Zambia, that have not achieved this yet. Globally, waste management follows a particular hierarchy in terms of preference for improved environmental and public health, including prevention, reduction, re-use, recycling, recovery and disposal. Prevention is the most preferred and advocated method while disposal is the last resort in promoting a healthy environment and community.

### 2.5.1 The Role of Municipal Solid Waste Management in Public Health

The general MSWM process follows the steps: generation, temporal storage, collection, transport/processing and final disposal or landfilling. These steps, when effectively followed, play a crucial role in maintaining public health as they minimize pollution and reduce greenhouse gas emissions, and subsequently promote more sustainable environments and community well-being. However, in most developing countries, 93% of waste disposal is openly dumped either in formal dumpsites or informal locations established by communities. Ultimately, this waste ends up in public ecosystems or is burned in the open affecting human health and the environment (Fernando & Zutshi, 2023).

For the protection of human and environmental health, sustainable municipal solid waste management must be employed as it further promotes efficient resource use to minimize waste generation. Sustainable MSWM can be best achieved by obeying the waste management hierarchy highlighted earlier for both individual and commercial uses. It remains the responsibility of household waste generators who then determine its successful implementation, the MSWM authorities such as governments which creates policies and legislation, and the adopted MSWM stream, processes and infrastructure which determine what happens to all the generated waste (Adipah & Kwame, 2019). Successful and proactive waste handling, storage, collection, transfer and transport or treatment before disposal at the designated dumpsite or land fill is an effective way of preventing public health emergencies such as cholera outbreaks.

### 2.5.2 Municipal Solid Waste Management in Developed Countries

Generally, MSWM in developed countries is more effective than in developing countries because different strategies are used in waste management that incorporate the treatment or processing of the waste before disposal. Examples include waste segregation and recycling, incineration, landfilling, smart waste solutions, and waste-to-energy recovery among others. Several European countries can be commended for the tremendous progress made in their municipal solid waste management practices such as Germany, Sweden, France, Switzerland, Netherlands which have adopted incineration and recycling as part of their traditional waste management practices (Adipah & Kwame, 2019).

A regional analysis of sustainable solid waste management was conducted in the European Union (EU) by Chioatto et al. (2023) and the following were the findings. The main regulatory action created by the EU involves the shifting of waste management systems from traditional waste management to sustainable waste management across the region such as circular economy. This is because traditional methods were leading to resource exploitation, the accumulation of material into landfills, and production of high amounts of GHG emissions. The study examined the implementation of EU legislation from the 2008 Waste Framework Directive at regional level. It utilized Data Envelopment Analysis for the analysis of 75 NUTS-2 regions (subnational regions) from Italy, France, Germany and the Netherlands between 2008 and 2013. The EU aims to reduce resource extraction by half thereby preserving economic growth and competitiveness. The results showed that the Netherlands and Germany have significantly moved from landfilling and now embrace recycling practices. However, France and Italy are still lower in performance but with commendable progress has been observed. In the entire region studied, Netherlands was the best performer followed by Germany, France and Italy (Chioatto et al., 2023).

### 2.5.3 Municipal Solid Waste Management in Developing Countries

For developing countries, MSWM systems are often characterized by ineffective planning, lack of technical expertise, limited infrastructure, irregular collection times and inadequate research and funding. The locals are also often uncompliant with the existing policies and regulations, some are seen scavenging through disposal sites for remnants of valuable items and metals thereby directly exposing themselves to public health risks. Despite these overall differences, some developing countries are still doing better than others. Generally, developing countries are lagging severely in comparison to the developed countries. While the latter are now shifting from engineered landfills and exploring recycling, re-use and recovery, developing countries are still struggling to set up fully functional engineered landfills. They often use non-engineered landfills or approved open dumpsites, making it challenging to turn waste resources into commercialized products as done in the western world. In the case of Zambia, the whole country only has one landfill which is not even fully functional (Milimo et al., 2023). An analysis of the status of landfill classification systems was done in 13 developing countries in SSA between 2000 and 2018 and the following was discovered. Thirty-one (31) landfill sites were selected and classified as 0, 1, 2, 3 or 4 to respectively represent uncontrolled dumping, semi controlled facility, medium controlled facility, medium/high-engineered facility or high state-of-the-art facility. Uncontrolled dumping lacks significant control functions thus waste is burned in an uncontrolled manner and leachate infiltration into the ground is common. Semi-controlled facilities have basic control and some site equipment such as vehicles with no un-authorized site access. Medium controlled has satisfactory control with some emission control measures. Medium or high engineered facilities have compliance control and thus cover the waste daily with some material to prevent emissions. High state-of-the-art facilities refer to fully functional and well-designed landfill sites that have means of containing leachate and capturing GHG emission to comply with the global standards. Based on this study, about 80% of the assessed landfills in SSA were classified as 0 or 1 as many landfills had limited or no linings leading to leaking leachate that threatens groundwater quality and a source of high GHG emissions. Additionally, many sites often operated unmonitored during the study duration leading to uncontrolled dumping of waste. South Africa was labelled outstanding of all the countries studies as it was the only one with a Waste Information Centre Initiative that provides an inventory of all its landfill sites, recycling centers, storage and treatment facilities. The other countries were encouraged to start their landfill rehabilitation journey taking South Africa’s example (Idowu et al., 2019).

An assessment of the contribution of MSWM to the 2022 cholera epidemic in Kathmandu, the capital and most densely populated city in Nepal, had these findings. When the only landfill in Kathmandu could not be accessed due to protests for over a month, several cases of cholera were reported in the region. This study aimed at unearthing the contribution of municipal solid waste management to the occurrences of waterborne disease outbreaks particularly cholera in developing countries like Nepal. The Kathmandu valley has the highest number and quality of policies and infrastructure in the country, yet urbanization has strained these resources leading to cholera disease outbreaks almost annually. The

Kathmandu valley was estimated to produce 1,200 metric tons of waste every day which is managed by first being stored at the Teku Transfer Station and then carried to the landfill using 150 garbage trucks every day. When the locals had a protest, the transportation of waste to the landfill was terribly disrupted leaving waste to be improperly dumped in different parts of the valley for months. The open dumping of waste exposed the public to *vibrio cholerae* bacteria resulting in a cholera outbreak. These cases were further worsened by the interaction of waste with stormwater since the open dumping was met by the monsoon season. The waste further clogged drainage systems intended to transport excess water from residential areas, resulting in flooding and further public health risks (Khadka et al., 2022).

Furthermore, in understanding reasons behind recurring cholera outbreaks in Nigeria, Olajide-Mariam et al. (2022) outlined several factors as contributors to the outbreaks among them being poor environmental sanitation, poor WASH services and poor living conditions. The study then emphasized the need for adequate regulations to control the illegal waste disposal by providing sanitation facilities in strategic locations around the country and raising awareness on the importance of environmental sanitation in schools (Olajide Mariam et al., 2022).

### 2.5.4 Municipal Solid Waste Management in Zambia

In Zambia, the Ministry of Green Economy and Environment (MGEE) is responsible for the coordination of activities related to climate change, environment, natural resources, and pollution control at national level. To ensure compliance with environmental management regulations and laws in the country, the Zambia Environmental Management Agency coordinates respective governmental bodies and local municipalities. The Ministry of Local Government and Rural Development then operates at the sub-national level through the City or Municipal Councils to regulate solid waste management. The different City Councils then plan for and provide solid waste management services through the Department of Public Health and the Department of Planning. However, for Lusaka city, the Lusaka Integrated Solid Waste Management Company (LISWMC) has been extracted from the Lusaka City Council, to operate independently in the management of waste across the city. LISWMC collects waste directly from the central business district of Lusaka and provides supervision to private contractors licensed to collect waste in residential areas of Lusaka. Private entities are involved in providing waste management services either as franchise contractors or Community Based Enterprises (CBEs) (ACEN Foundation, 2023). The franchise contractors collect municipal solid waste from the formal settlements which have been divided into zones, while the CBEs collect from the informal settlements at a lower subscription fee. Overall, MSWM in Zambia is based on a Management Framework comprising of both legal and regulatory components for effective management and improved public health. This framework incorporates various stakeholders such as the public sector, private sector, NGOs, academia and general residents (Banda et al., 2024). Despite the many policies, frameworks and strategies, municipal solid waste management has proven very challenging for local authorities in Zambia especially during the rainy season. Non-subscription to waste collection services and uncollected waste are common in urban and peri urban areas (informal settlements) as it is in other developing countries. From observation, illegal waste collectors also hinder service delivery by LISWMC as they collect waste at a small fee from residents but end up dumping the collected waste in undesignated places instead of the landfill which is a distance away. Overall, such poor management practices when in contact with climate change impacts cause the increased spread of water and vector borne diseases such as cholera and malaria respectively. Zambia follows the traditional waste management practices and has not yet incorporated advanced management option. In the whole of Zambia, only one landfill exists called Chunga landfill which is also operating under stressful conditions as it is overwhelmed. Its drainage system is severely uncontrolled thus leachate leaks into groundwater and sometimes is exposed to the environment. Landfill fires occur resulting in pollutant plumes into the atmosphere. The ground has also significantly steepened with unstable waste-tips, making the landfill a source of great danger to public health and the environment. Beyond this national limitation, local communities are not compliant with proper waste disposal practices as they opt to dump their waste in undesignated places to avoid subscribing to official collection services. An assessment of MSWM practices in high population density areas in Lusaka the capital of Zambia by Chisanga et al. (2024) using both qualitative and quantitative methods revealed the dominance of open dumping and burning even with available door-to-door waste collection services by the local government and contractors at relatively affordable amounts (Chisanga et al., 2024).

### 2.6 Interactions Between Rainfall, Waste Management, and Waterborne Diseases

Evidence thus far confirms that the contribution of rainfall and poor municipal solid waste management to the occurrence of waterborne diseases cannot be overlooked. Each of the variables have been separately studied and understood to significantly result in waterborne disease outbreaks especially in developing countries. However, a combination of these two is often severely disastrous to public health.

A study by Ormsby et al. (2024) on how *vibrio cholerae* bacteria can cycle between environmental plastic waste and floodwater had the following revelations. The increase in plastic pollution, especially in developing countries, has brought about serious challenges, especially for the environment and water bodies. However, this does not just end up being an environmental nuisance. Plastic surfaces provide a suitable habitat for communities of microbial biofilms and pathogens. The study determined whether *vibrio cholerae* is one of the bacteria that can survive on the surface of plastics following a heavy downpour. The results showed that bacteria could survive for a minimum of 14 days at concentrations capable of causing infection in humans before it transfers to available floodwater where it can further persist in causing more cholera infections in living hosts. Though persistent for at least 14 days, the transfer to water occurred after only 24 hours of contact. This study simulated a typical cholera outbreak scenario in SSA and South Asia using specific pathogenic strains of *vibrio cholerae* serotyped (identification and differentiation) using MASTring slide according to manufacturer's instructions to confirm exact identity. The conclusion was that major serogroups of *vibrio cholerae* are significantly capable of inhabiting the surfaces of plastic waste and persisting for longer when exposed to floodwater to cause infections, hence plastic pollution must be prevented. When in brackish flood water, the bacteria may thrive even longer because it can tolerate such conditions unlike other pathogens (Ormsby et al., 2024). Additionally, in the 2022 Kathmandu case study earlier highlighted, multiple more cases of cholera were recorded as soon as the monsoon season set with significantly heavy rainfall (Khadka et al., 2022). These studies further clarify the correlation between MSW and rainfall in causing waterborne disease outbreaks especially in developing countries like Zambia.

## 2.7 Challenges and Gaps in Literature

Most of the reviewed literature discussed the separate impacts of poor municipal solid waste and climate-induced rainfall on the occurrence of waterborne diseases, while few studies have addressed their combined impacts on disease outbreaks. It must be noted that a vicious cycle exists between climate change and poor solid waste management, and their interactions must be examined especially their combined impacts on critical sectors such as public health. There is limited scientific research concerning the contribution of poor municipal solid waste management to disease outbreaks in developing countries even though they are majorly affected by consequences of poor management practices from individual to national level. Additionally, studies expose several significant socioeconomic impacts of poor practices, yet the proactive measures and practical recommendations remain woefully inadequate. Therefore, this study assesses the synergy between climate-induced rainfall, and poor MSWM on public health outcomes, as an area of emerging concern especially in the prevention of the excessive spread of waterborne diseases particularly in developing countries like Zambia. It proposes actionable policy interventions that would be presented to relevant stakeholders for assessment and implementation in a bid to bridge the knowledge gap.

It is argued that effective municipal solid waste management depends on local institutional characteristics, which vary with institutional capacity, and cultural, climatic, and socioeconomic factors. However, most studies do not recognize outdated policies, inadequate research and stakeholder engagement to be contributing to unsustainable practices as they mostly focus on financial challenges in the sector. Some countries, Zambia included, have not updated their MSWM policy frameworks to integrate the growing climate change crisis and recurring waterborne disease outbreaks, thereby leaving room for challenges that could be prevented with a clear roadmap. In addition, this study recognizes the need for updated policies and recommends measures which when strategically and timely implemented have the potential to effectively protect ecosystems, boost the economy and support people's general well-being by promoting preparedness for any climate-related cholera outbreak.

# 3. METHODS

## 3.1 Description of Study Area

The study area is Lusaka district, the capital city of Zambia ($15^0 23'15''$S, $28^0 19'22''$E) located in the south-central region of the country. As of 2024, the human population of Lusaka stood at approximately 3,324,000 (Macrotrends, 2024). The district stands as the economic and political hub of Zambia, with over 62% of its population living in informal settlements (Chiwele et al., 2022). These settlements and residential expansions pose significant challenges such as improper waste management, resulting in serious public health issues such as cholera outbreaks.

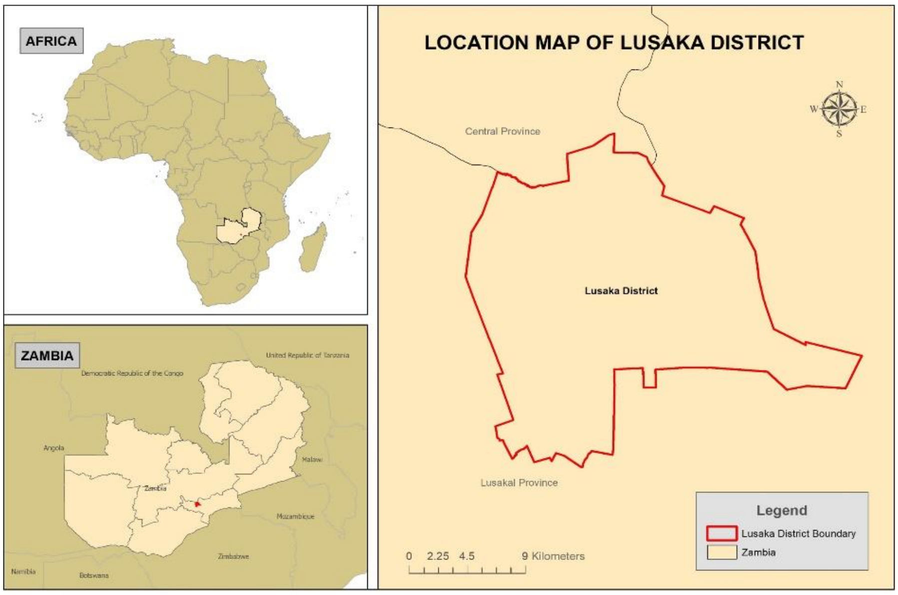


Figure 3.1 Location map of Lusaka created using Geographical Information Systems.

## 3.2 Research Design

This research takes the form of a descriptive ecological study formulated to establish the relationship between the occurrence of cholera and environmental factors particularly rainfall and poor municipal solid waste disposal in Lusaka, Zambia. It is a mixed study comprising majorly of household surveys and field observations to understand existing solid waste management practices amid climate-induced rainfall and possible cholera risks of this synergy in the study area. This was done between December 2024 and March 2025 during the country's rainy season. For the household survey, questionnaires were administered to household representatives, then for the field assessment, observations and random interviews were made to stakeholders encountered there. Lastly, Spearman's correlation analysis was performed using IBM SPSS Statistics 27 between rainfall and cholera for a 31 year-duration from1994 to 2024 gain an understanding of the existing relationship between the two variables.

**3.3 Study Population**

The target population were households in peri-urban Mutendere compound found in the eastern region of Lusaka city. Mutendere compound, formerly known as Chinama Hills, is an informal settlement of high-density population, with several unapproved residential and commercial expansions. Regarding the distance to Chunga landfill, Mutendere is located approximately 15-20km away from the landfill which is in the northern region of Lusaka. The compound mostly records cholera cases due to illegal waste dumping which interacts with rainwater and compromises public health. Major economic activities in the area are informal small and medium enterprises such as charcoal selling, liquor stores, and unconventional food sales such as open table markets for meat and vegetables.

**3.4 Sample Size and Method**

312 participants were targeted for the household survey and were sampled using stratified random sampling to cover the two different regions of the study population, that is the old and new Mutendere. The sample size was estimated using the standard Cochran's formular:

$$\boldsymbol{n = \frac{Z^2 \times p \times (1-p)}{e^2}} \quad \text{.........................................} \ (1)$$

Where: $n$ is the sample size; $p$ is the population proportion; $Z$ is the z-score for 95% confidence level set at 1.96 and $e$ is the margin of error set at 5% (0.05).

**3.5 Data Collection Methods**

- **Desktop approach:** Previous studies, local policies and regulations were reviewed on the impacts of the synergy of rainfall and waste management to establish gaps, opportunities and propose recommendations. Local policies were reviewed to understand the national and global stance, initiatives, and challenges in addressing poor MSWM amid climate change.
- **Household Surveys:** To gather information on practices and perceptions of residents in the study area, structured questionnaires were utilized focusing on waste disposal methods, sources of drinking water, and their understanding of the synergy between climate-induced rainfall and waste disposal in relation to cholera outbreaks.

- **Field Observations**: Field assessments of the waste management practices in Mutendere community were conducted randomly to fully understand the waste disposal practices especially after a heavy downpour and possible impacts on public health. Relevant stakeholders encountered during this assessment were randomly interviewed to understand possible challenges and opportunities in the area regarding cholera, solid waste management and rainfall.

Figure 3.2 Researcher conducting a field assessment in the study area after distributing questionnaires on 10th January 2025


Figure 3.3 Researcher interviewing Lusaka City Council Health Inspectors on waste management challenges and opportunities on 20th February 2025.

- **Statistical analysis:** Rainfall data was obtained from the Zambia Meteorological Department for a 31-year duration from 1994-2024 to correlate with cholera incidence data for the same duration obtained from Lusaka District Health Office. This was done to help establish the strength and direction of the relationship between the two variables.

### 3.6 Data Analysis

Data was analyzed using IBM SPSS Statistics 27 and Microsoft excel. The analysis plan included Descriptive Statistics which summarized the demographic characteristics, solid waste practices, community understanding of climate change and possible health outcomes. It also included Statistical Analysis to examine the relationships between rainfall and the incidence of cholera for the duration 1994-2024.

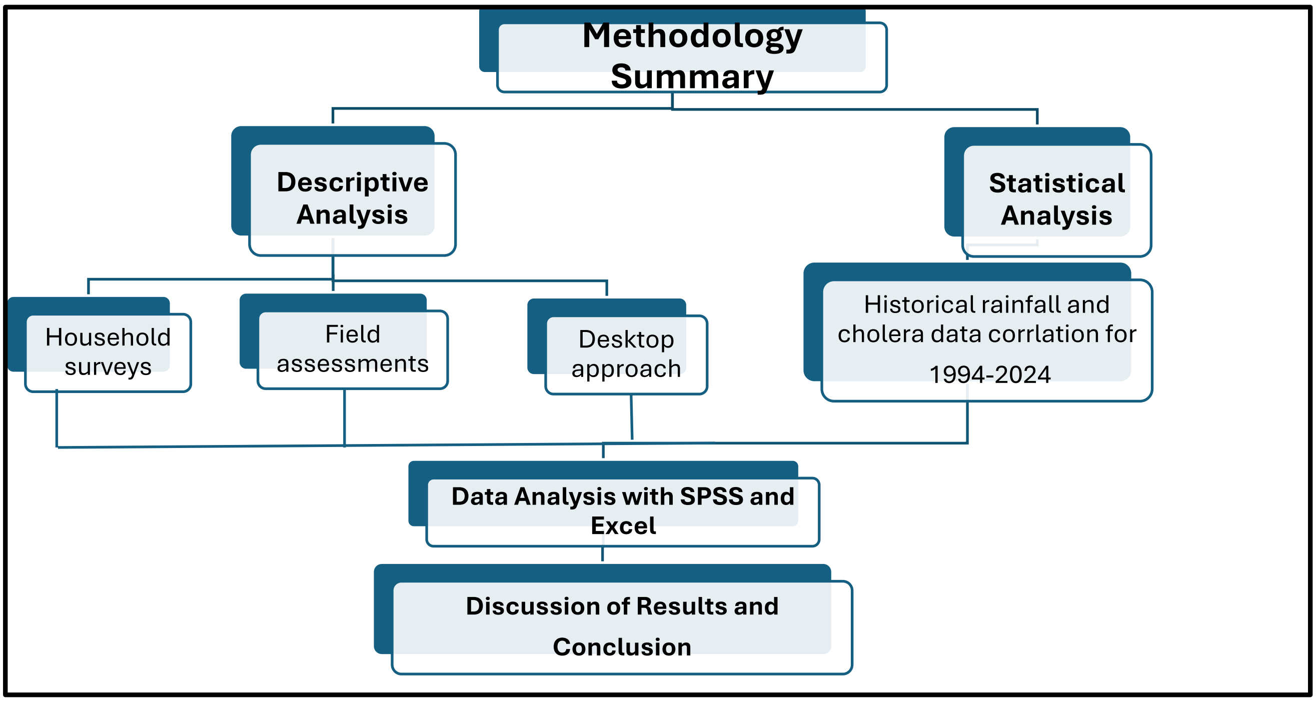


Figure 3.4 The researcher's summary of the methodologies to be used in the study

### 3.7 Expected Outcomes

This methodology provides a framework for investigating the impacts of rainfall and poor municipal solid waste management on cholera disease outbreaks in Zambia, particularly in peri-urban areas of the capital city Lusaka. By employing the above data collection and analysis methods, the study contributes valuable insights into public health challenges faced by peri-urban populations across the globe. It has obtained comprehensive information on current perspectives and waste practices from relevant stakeholders including the local community of Mutendere. It further identified challenges and opportunities in achieving sustainable municipal solid waste management in Lusaka and has provided actionable recommendations with the potential to reduce public health vulnerabilities based on the obtained findings.

### 3.8 Ethical Considerations

The researcher obtained ethical clearance from the National Health Research Authority in Zambia through ERES Converge IRB (Ref: 2024-Dec-028) prior to data collection to ensure participant confidentiality and welfare. This was done as a legal requirement by the Republic of Zambia for all health research requiring human participation to protect human rights and ensure international and national ethical principles are upheld throughout the research. Under the ethical clearance, the following ethical issues were addressed:

- Informed consent from participants: The study adhered to necessary ethical standards by obtaining informed consent from all participants through signatures or thumb prints. In addition, participation was on a voluntary basis involving adults aged 18 years and above.
- Confidentiality and privacy when handling personal information such as age and past encounters with cholera.
- Cultural sensitivity to the community by involving community leaders to explain the purpose of the research.
- Environmental and public health risks by wearing the appropriate personal protective equipment and hand sanitizer when carrying out the survey and field assessments.
- Conflict of interest: No conflict of interest influenced the research outcomes.
- Compliance with local and international ethical and research standards: Continuous guidance was sought throughout research processes from local authorities, Pan African University Institute for Water and Energy Sciences including Climate Change and the supervisor to ensure continued compliance.
- Misrepresentation during reporting and data use: Data was reported as collected, without any bias or manipulation to ensure a true representation of study area. All collected data was not transferred to unauthorized parties.

# 4. RESULTS AND DISCUSSION

## 4.1 Introduction

The earlier highlighted methodology was employed to fulfil the objectives of the study. Therefore, this section reports the obtained findings regarding cholera occurrence in Lusaka. Municipal solid waste practices and perceptions by participants were identified through household surveys and field assessments; and the challenges and opportunities for sustainable municipal solid waste management amid the changing rainfall in Lusaka were exposed by various stakeholders including the community and Lusaka Integrated Solid Waste Management Company (LISWMC) a constitutionally approved institution that oversees municipal solid waste management in Lusaka.

## 4.2 Assessment of Current Municipal Solid Waste Practices by Residents of Lusaka

To understand the practices of residents in Lusaka regarding municipal solid waste management, household surveys and field observations were used. A total of 312 respondents were subjected to questionnaires and the following information was obtained and analyzed using Microsoft Excel.

Table 4.1 Descriptive Summary of Participants in the Household Survey

| Variable | Categories | Frequency | Percentage |
|---|---|---|---|
| Gender | Female | 168 | 53.8% |
| | Male | 144 | 46.2% |
| Age (Years) | 18-25 | 60 | 19.2% |
| | 26-35 | 153 | 49% |
| | 36-45 | 54 | 17.3% |
| | 46+ | 45 | 14.4% |
| Duration of stay in area (Years) | < 2 | 72 | 23.1% |
| | 2-5 | 90 | 28.8% |
| | 5+ | 150 | 48.1% |

Regarding the occupation, all the participants indicated that they were self-employed. Participants were asked the method of disposal used for their domestic waste, selecting options from waste collection services, underground rubbish pits, open public dumpsites, and a provision to indicate any other method used. The highest method recorded was subscription to waste collection services with 135 participants (43.3%), and the least was burning at 12 participants, representing 3.8% as illustrated in figure 4.1.

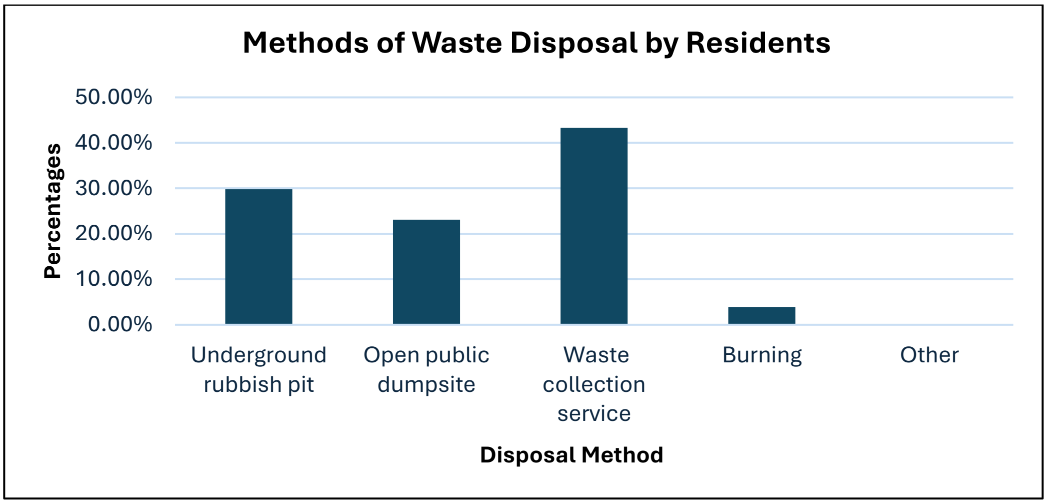


Figure 4.1 Different methods of municipal solid waste disposal by study population

Of all the methods of disposal, subscription to waste collection services was the most sustainable, while the other practices were not. When combined, the unsustainable practice entries yielded a much higher percentage confirming that there was poor waste management in the study area. That is, digging underground pits at 29.8%, the open dumping of waste at 23.1% and burning at 3.8% making a total of 56.7% which is higher than the 43.3% for waste collection services. For participants subscribed to solid waste collection services, they were further asked which institution collected their waste and the frequency of collection. These participants indicated that they subscribed to various private waste collectors known as Community-based Enterprises (CBEs) who collect waste once a week, as the local authority (LISWMC) did not directly collect household waste from their community but subcontracted specific CBEs. However, some of the encountered waste collectors could not provide documented proof as licensed CBEs under LISWMC hence qualified to be referred to as 'illegal collectors', a term used by authorities for those engaged in waste collection yet do not have a waste collection permit from LISWMC.

Constitutionally, LISWMC is mandated to conduct community patrols and apprehend or charge both the illegal collectors and residents subscribed to their services (GRZ, 2018). This is because the illegal contractors do not deposit the collected domestic waste at the designated landfill but instead dump it at any location convenient to them, giving LISWMC an additional task of directly collecting waste in residential areas thus stressing their operation and budget framework. Following such incidents, it can be concluded that despite residents subscribing to waste collection services, not all the services are sustainable as some residents had subscribed to illegal collection services which equally end up contributing to poor waste disposal in the area. To the residents, affordability determines which institution they subscribe to while to the local authorities, policies and regulations come first. Thus, there exists a discrepancy in priorities by authorities and residents and this contributes to poor waste disposal in the area.

Figure 4.2 A waste collector interviewed for credibility by the researcher on 20$^{th}$ January 2025.

The municipal waste disposal status in the study area was further assessed using random field observations conducted between December 2024 and March 2025. This was to rule out possible inconsistencies in the obtained responses and actual practices by participants in the study area. These assessments were conducted during the country's rainy season to additionally understand the interactions between rainfall and improperly disposed municipal solid waste. In this assessment, residents were seen disposing waste indiscriminately, and heaps of decomposing waste were seen along the roadside, in the drainage network and in the nearby stream. This implies that most of the generated waste in the study area does not end up in landfill for treatment or recovery as it is seen littered around. After a heavy downpour, this waste was observed to be carried in the direction of the rainwater flow, blocking portions of drainages. However, residents were seen interacting with this stagnant water as a cheaper alternative when faced with water supply disruptions as they often need to pay for alternative supply services to cover the disruptions. 69.2% of the participants indicated their drinking water was from Lusaka Water Supply and Sanitation, the official service provider in the area. However, 76% of these indicated service disruptions at least once every day and during such times, residents indicated alternative sources such as store-bought potable water and paying a fee to fetch from private residents where boreholes had been installed. Unfortunately, for a generally low-income community like the study area, these options are considered unaffordable, hence they opt for cheaper alternatives which may not be safe. For example, some residents were observed to be hand washing, fetching, cleaning property like storage buckets and vehicles, and swimming in the stagnant rainwater which had mixed with municipal solid waste. In addition, there is a possibility of people using contaminated rainwater without knowing such as market women and make-shift restaurant owners in the area. This is because when water supply was disrupted, these kinds of people were in the habit of contracting local youth to draw water for use in their business at a cheaper cost than paying to draw from private nearby boreholes. However, the youth may still fetch from any sources they found nearby, including stagnant rainwater which had interacted with domestic waste as it is readily available and does not appear contaminated to the non-observant eye. The figures 4.3 to 4.6 provide a visual representation of the field assessment.

Figure 4.3 A water stream invaded by solid waste in the study area after a heavy downpour, as captured by the researcher on 5th January 2025

Figure 4.4 Drainage network in study area blocked by poorly disposed municipal solid waste, captured on 3rd March 2025.


Figure 4.5 Drainage filled with decomposing domestic waste near a mini market in the study areas, captured on 3rd February 2025.

Figure 4.6 Accumulated waste near households in the study area, captured on 23rd February 2025.

Several studies highlight poor domestic waste disposal practices as risk factors to cholera occurrence (Mamman et al., 2024). The Centre for Disease Control and prevention further warns on the need to utilize safe water containers or storage areas because water stored in a contaminated environment becomes contaminated too (CDC, 2024b). Therefore, rainwater interacting with contaminated surfaces such as unsegregated and poorly disposed municipal solid waste is conclusively contaminated too. Thus, all these observed and discussed practices in the study area are considered risk factors to the occurrence of cholera outbreaks.

### 4.3 Community Understanding of Implications of Synergy in Relation to Cholera Outbreaks

In assessing the understanding of residents regarding waste management and climate-induced rainfall, participants were asked if they had heard of the term ‘climate change’ and 90.4% confirmed hearing it, while 9.6% were hearing it for the first time. Of those that affirmed, only 40% successfully explained what the term implies while the remaining 60% had limited ideas. 40.6% of participants indicated no linkage between climate change and cholera, while 33.3% indicated a sure linkage and 26% were unsure. Residents confirmed the occurrence of cholera in the study and participants were asked which extreme weather event they had experienced the most between floods and droughts in their duration of stay in the area. 210 participants (67.3%) confirmed to have experienced more floods, while 102 (32.7%) indicated experiencing more droughts.

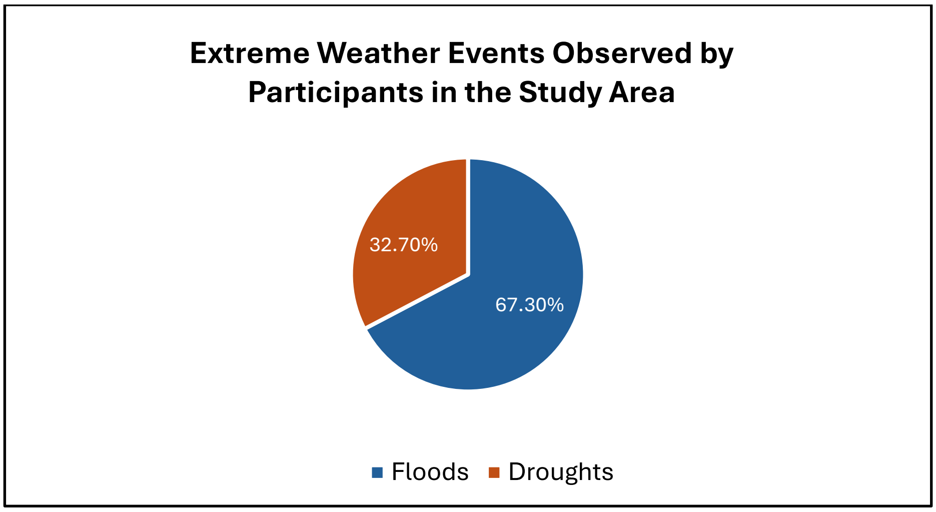


Figure 4.7 Weather events observed by participants during their duration of stay in area.

Several studies have highlighted the role of both floods and droughts in cholera outbreaks with more findings from reviewed literature leaning towards floods. Hence, participants were asked in which weather event they experienced more outbreaks and spreading of cholera in the study area, given the options: high rainfall, low rainfall, both types or none of the two. The highest entry represented by 87.5% attributed cholera outbreaks to floods, while the least entry of 1% said none of these events caused cholera, stating the epidemic occurs in other ways. 7.7% indicated both, while 3.8 indicated droughts only.

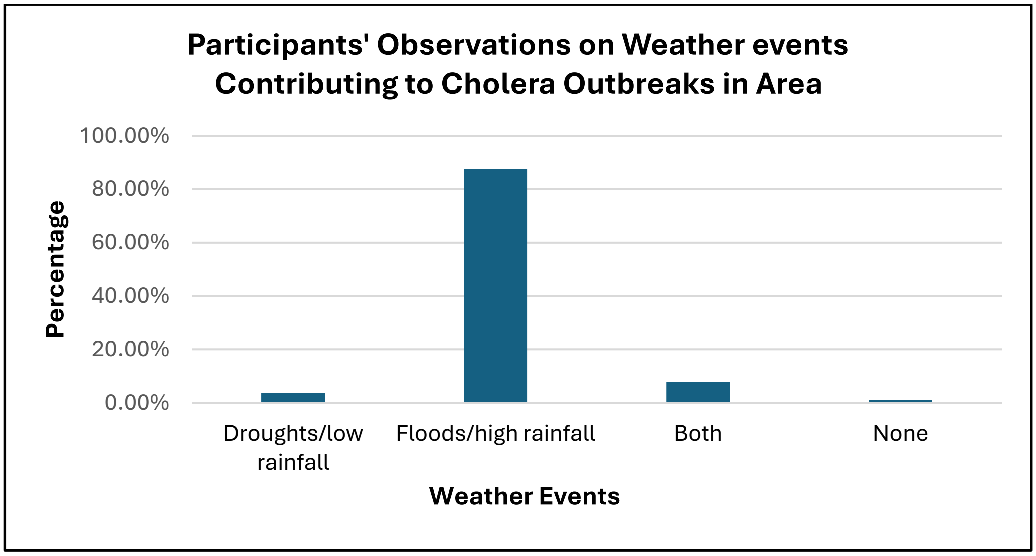


Figure 4.8 Participants’ observations on which weather event causes cholera most.

To further assess the participants' understanding of the synergy of rainfall and poor MSWM, participants were asked if they had noticed any instances of improper waste disposal within the area such as along the roadside or in the drainages, 91.3% confirmed to have encountered this, while 8.7% denied having noticed any poor household waste disposal in the area. Participants were also asked if they noticed any instances when municipal solid waste mixed with rainwater in the area, 88.5% said yes while 11.5% said no. Lastly in this assessment, respondents were requested to identify which factor they believed caused cholera in the study area, and 49% indicated poor solid waste management as the cause. This was seconded by a 32.7% indication that both rainfall and poor waste management caused cholera outbreaks in Lusaka, while 17.3% and 1% indicated rainfall only and none of them, respectively. However, when asked whether the participants had been infected with the cholera bacteria in their duration of stay in the study area, 11.2% affirmed while 88.8% denied it.

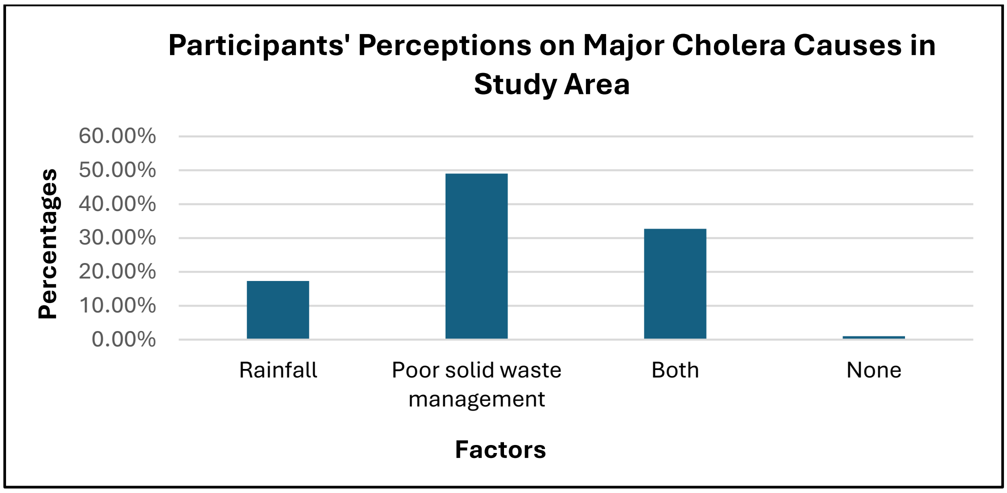


Figure 4.9 Participants' responses on major contributors to cholera outbreaks.

Based on these responses, it can be concluded that residents of Lusaka have a satisfactory understanding of the various risk factors influencing cholera outbreaks in the area. However, the majority 66.3% take the factors as independent, that is: the addition of 49% for poor MSWM only with 17.3% for rainfall only responses. This implies that residents have an inadequate understanding of the synergy between rainfall patterns and poor municipal solid waste management in the prevalence of cholera. Regarding prior cholera cases experienced by respondents and their household members, participants were asked if they had ever been infected with the cholera bacteria, 11.2% affirmed while 88.8% denied it. However, from the descriptive summary of respondents, most participants (48.1%) had indicated having lived in the study area for more than 5 years during which cholera cases were recorded in the area with a cumulative total of over 13,000 cases. Therefore, the researcher submits a potential respondent bias possibly due to social desirability as having cholera bacteria by an individual or household is often translated to poor hygiene practices within the household. Additionally, no proof exists from an individual of ever having contracted the bacteria or not, other than following through the individual's medical records at the community hospital, which is ethically inappropriate and impossible hence responses were recorded as received. Lastly, from the assessment and previous studies, the synergy of rainfall and poor municipal solid waste implies that when combined both factors play a role in the occurrence of cholera outbreaks. However, the isolated perceptions of the causes behind cholera outbreaks by residents can be deemed as a hinderance for them to adequately prevent its transmission thus, gaps may exist and practices of interacting with stagnant rainwater that had interacted with domestic waste may still be recorded in the area.

## 4.4 Challenges and Opportunities for Effective Municipal Solid Waste Management in Lusaka

### 4.4.1 Challenges Identified

The officially recognized stakeholders in MSWM in Lusaka include residents, and service providers including the LISWMC, Lusaka City Council, and Franchise collectors and CBEs, Ministry of Health, regulatory boards such as the Zambia Environmental Management Agency, and developmental partners. Policies are created by these local authorities for compliance by residents and the waste collectors that is, the Franchise collectors and CBEs. However, despite several stakeholders, few policy frameworks are in place and known by all stakeholders to allow an integrated and inclusive approach to the crisis. In the household survey, 61.5% of the participants for whom the policies are created indicated they were not aware of any policies or community programs on sustainable municipal solid waste management and cholera prevention by local authorities. However, 88.5% of the 38.5% participants that were aware of these initiatives could not satisfactorily explain the dynamics and frequency of such programs as most had never even participated before.

Furthermore, 54.8% of the participants attributed their poor waste disposal practices to unaffordable waste collection services thus informally requested the authorities to provide affordable or free alternatives. Half of the participants strongly blamed the local authorities for uncollected municipal solid waste, cholera outbreaks and flooding. They argued that waste collection should be a free service that authorities must provide unfailingly and consistently. However, on the other hand, service providers for the waste collection services particularly LISWMC indicated non-compliance by some residents regarding subscription to the recommended waste collectors and hence charged offenders. Only 22.1% of participants acknowledged that they have a greater individual responsibility in preventing cholera outbreaks in the study area through proper waste disposal practices.

These statistics indicate a lack of sufficient understanding and awareness by residents of their role in waste management and the implications of their poor waste disposal practices. In addition, residents are not aware of the need to segregate their domestic waste at source hence in addition to poor waste disposal practices, waste remains unsegregated attracting scavengers who aim to obtain recyclables and any valuables from the generation point all the way to the landfill, exposing themselves to harmful bacteria. It is evident that authorities have developed frameworks that serve the institution yet are not fully understood by residents hence most people do not comply to satisfy the need of established policies and regulations. This indicates inadequate community engagement in policy formulation, and incomplete dissemination and explanation of policies to residents leading to unmet expectations by both parties. Additionally, LISWMC faces challenges such as inadequate equipment, financial capacity and human resources for the timely execution of projects around waste management in Lusaka.

The population of Lusaka has also been rapidly growing in the past decades from almost 900,000 in 1994 to over 3 million in 2024 indicating an increase in waste generation, hence infrastructure and service delivery regarding waste management needs expansion and modification too. Additionally, climate change is an issue of concern affecting the management of waste. The climate-induced extreme weather patterns and events demand waste management improvements to prevent cholera risks, yet residents are still unsure of the crisis' multidimensional impact and authorities who ideally know more on the subject have still not climate-proofed and disseminated local waste management policies and strategies. Additionally, authorities still utilize the 2004 National Solid Waste Management Strategy which only incorporates a few principles such as the principles polluters pay, life-cycle design, waste reduction at source and cooperation by residents. The strategy has no consideration of climate change and the potential harm its interaction with waste may pose to public health such as cholera outbreaks. It further highlights several targets to be monitored regularly and evaluated every 4 to 5 years, unfortunately no monitoring and evaluation is conducted currently thus few improvements have been proposed and made. Targets for the strategy include minimizing the amount of waste produced by residents; raising sufficient public awareness on benefits of good practices; coordinating various stakeholders in waste; providing incentives for compliant residents; promoting recycling and recovery; institutional targets such as cost recovery; classifying waste; and developing a national database and waste information system. Although this strategy is not updated or climate-proof, the monitoring and evaluation of all these targets would be a commendable step in climate-action.

In addition, there is a lack of coordinated efforts by relevant stakeholders in conducting risk assessments and planning interventions for achieving sustainable waste management amid climate change, resulting in fragmented implementations. The various stakeholders highlighted must come together including the Zambia Meteorological Department and Ministry of Health to develop an Integrated Strategy for cholera prevention in Lusaka which incorporates all the possible risk factors. This will help improve the approach from reactive to proactive delivery of service and guarantee progress on the subject.

Political interference also hinders sustainable MSWM. For instance, political leaders may dictate priority areas for waste collection at the expense of other locations, often without payment of subscription fees. Other times, political cadres of the ruling party may set up waste collection services that do not satisfy the constitutional requirements yet are at liberty to collect and dump waste wherever they please. Part of them form illegal collectors but their affiliation to the ruling party makes them free from legal penalties. There is need for political leaders to be adequately involved in the intervention planning and made aware of what their actions entail in the prevention of cholera induced by poor solid waste management.

Lastly on the identified challenges, over dependence on foreign aid to fund local MSWM initiatives also challenge sustainability as funders may limit or reduce funding at any point like currently where some developmental partners have pulled away from funding certain initiatives. Other challenges include incomplete and inconsistent data recording particularly for meteorological, waste and cholera data which make comprehensive analysis of trends and relationships difficult for researchers.

### 4.4.2 Opportunities Identified

Several studies conducted on the benefits of sustainable solid waste management across the globe serve as an opportunity for practicing sustainable MSWM in Lusaka and across the country. Many more local researchers are willing to undertake such studies to promote proper waste disposal practices and ultimately sustainable development. Additionally, understanding that cholera has various risk factors including poor waste disposal, and that it often occurs following an interconnected chain of events is sufficient knowledge necessary to motivate sustainable MSWM in the study area. Ultimately, these studies and findings have the potential to inform decision-making and policy formulation for the promotion of sustainability.

Furthermore, the disintegration of the Waste Management Unit from the initial Lusaka City Council to become a fully functional independent institution now referred to as Lusaka Integrated Solid Waste Management Company also serves as an opportunity for significant progress regarding sustainable MSWM as all activities at the institution are about adequate management of waste. Critical to this goal is an integrated and inclusive approach in municipal solid waste management that incorporates all stakeholders including the community to iron out miscommunications. The integrated intervention plan should operate from the waste generation stage all the way to the disposal and recovery stage at the landfill, and should be understood by all stakeholders, with roles clearly defined.

Although climate change in the study area manifests through various factors such as extreme rainfall patterns, updated technologies and strategies are available and can be explored such as the use of Geographical Information Systems and Remote Sensing not only for mapping flood prone areas and cholera hotspots, but to also map waste accumulation across the country. Also, early warning systems should be improved and should be coupled with climate-smart cholera intervention plans. The current availability of several multisectoral experts and developmental partners in Zambia provide an opportunity for the execution of sustainable initiatives and interventions across the country. In addition, the huge negative impact left by past cholera outbreaks on the residents of Lusaka serves as an opportunity that should make everyone to be willingly engaged in dialogue that can mitigate the crisis in the long-term. Also, the presence of local funds for developmental projects in Zambian communities referred to as Constituency Development Fund had the potential to reduce reliance on external aid, hence sustainable MSW initiatives such as infrastructure rehabilitation and expansion can run with minimal interruptions if the funds are used responsibly.

In addition, the available policies and legislation, including the 2004 National Solid Waste Management Strategy, serve as a steppingstone for the development of more inclusive and climate-smart strategies. These documents entail that the country has a starting point instead of developing policies from scratch, thus making it easier to create inclusive policy documents. Regarding policies and legislation, experts and translators are available across the country, making it possible for authorities to summarize the documents and translate them into various languages then disseminate widely to the residents so that they may gain a thorough understanding of the subject. They can also conduct digital sensitization through radio, TV and social media which are available in the country so that everyone can receive a full explanation of what is expected of them. Robust dissemination, engagement and explanation can guarantee compliance from residents.

### 4.5 Proposed Policy Interventions and Measures for Improving Municipal Solid Waste Practices in Zambia

To improve municipal solid waste practices in Zambia amid climate change, there is need to resolve all existing discrepancies in the current management system from generation to final disposal phase at the landfill. Firstly, there is need to revise and update the National Solid Waste Management Strategy for 2004, making it climate-proof and inclusive. This is because Zambia has not been exempted from the impacts of the climate crisis, hence national and subnational MSWM policies and strategies must acknowledge and incorporate it. When developed, all policies and strategies should be simplified and disseminated robustly to the community. In the field assessment, most residents declared ignorance over both the Solid Waste Management and Regulation Act of 2018 and the National Solid Waste Management Strategy of 2004, which have been in existence for over several years now and this is not acceptable if sustainability is to be achieved.

Sustainable municipal solid waste management entails unbiased recognition of environmental, social and economic principles when handling waste from the source to the dumpsite. Currently, the focus of authorities is on the economic benefits obtained from the subscription of residents to solid waste collection services, as charges for noncompliance with local authorities are strictly monetary. However, a possible intervention could be the introduction of actionable tasks as penalties for noncompliance. For instance, the charge for non-subscription when issued by LISWMC can be approximately 500 USD, however instead of monetary charges, defaulters could be asked to load poorly disposed waste into the collection vehicles or arrange for the proper disposal of extra loads of waste from various locations in the city. They could even be asked to accompany LISWMC Inspectors to conduct community sensitization and engagement programs, that way it would be more difficult to repeat the offense. In addition, established penalties and punishments should hold true for any offender regardless of their political affiliation or status in community so as not to compromise the standard of the framework and emphasize the seriousness of the subject.

Waste segregation should be legislated and promoted at the point of generation as this will further reduce the number of scavengers that dig through the waste and risk their health. These scavengers start at the point of generation and follow waste even at the landfill to recover recyclable material but often do not wear any personal protective equipment. Sometimes, they are seen eating leftover food which they recover directly from the waste. When they discover that recyclables are no longer part of the waste, the number of scavengers would reduce drastically, and their direct exposure would be hindered thus a huge step in cholera prevention.

Regarding the existing gap between the community and authorities, a more integrated approach needs to be administered that not only dictates but involves all relevant stakeholders. Concerning the fixing of waste subscription fees, authorities must not neglect including the community in discussions. When included, residents can argue about affordability and other issues that could possibly hinder their compliance, thus the implementation of the agreement would be successful with limited resistance. In some cases, residents were penalized for subscribing to the wrong waste collection service and they argued not knowing which service providers were licensed and which ones were illegal. Therefore, a control measure would be widely circulating the list of licensed CBEs and franchise contractors for a particular area and issuing them unique forms of identity which are clearly understood by all stakeholders including the community. Meetings with community members should also be widely advertised beforehand to ensure a true representation of the residents as sometimes only politically affiliated residents show up when called upon. The community should be made to understand their critical role in sustainable municipal solid waste management amidst the changing climate to prevent cholera prevalence in the area. Additionally, motivation should be made readily available for residents who consistently observe proper solid waste management practices such as waste reduction, re-using and recycling. The community should also be encouraged to register as CBEs or to establish recycling facilities converting waste into useful material and energy. With a mindset shift from community level regarding the need for proper MSWM practices amid climate change, significant improvements would be noted throughout the waste management chain and cholera can be prevented. These can be reinforced in public places such as markets, schools, churches, commercial buildings among others. Social media and influential brands or people should also be utilized in communicating policies, initiatives and expectations as most residents currently spend a lot of time online.

The established CBEs should be enlightened on need to make climate considerations when offering the waste collection services such as frequent collections during the rainy season to prevent waste overflow and use of climate-resilient equipment like sealed waste bins among others. Furthermore, approved CBEs and franchise contractors should be tightly monitored to ensure they too are not indiscriminately disposing of some of the collected waste to avoid costs as they are charged to dispose of waste at the landfill based on the quantity. In a few cases, residents complained of being bypassed during collection hence monitoring the CBEs and franchise contractors would prevent such incidences. This monitoring should be done using tracking devices or Global Positioning Systems to obtain routes of service delivery and by auditing these contractors. Additionally, although the local authority LISWMC does not directly collect waste from households, the institution should have a database of the CBEs service households and maintain contact with them through appropriate platforms. The community should be made aware of their important role in providing accurate information about services received and free to lodge any complaints against uncollected waste, poor disposal by waste collectors among other responsibilities.

In conclusion, the task of ensuring responsible MSWM is huge and requires additional human resources and a comprehensive approach. Therefore, authorities should consider budget adjustments to incorporate more experts and infrastructure to help with the execution of climate-smart initiatives. A rapid response team including some community members could also be set up to respond to solid waste emergencies such as resistant offenders. Most of the challenges noted in this study such as unsegregated waste, poor disposal and poor management systems among others were highlighted during the formulation of the 2004 National Solid Waste Management Strategy thus it is alarming to see them worsening today, over twenty years later. This situation implies that some policies for sustainable development are formulated yet are not monitored or evaluated for their effectiveness. Therefore, authorities must improve in this regard by not only crafting policies, legislation and strategies, but also monitoring them so that improvements can be made, and sustainable development achieved.

### 4.6 Discussion Summary

The study exposed various factors related to the occurrence of cholera outbreaks in Lusaka. From the household survey and field assessment, it can be concluded that residents are practicing poor municipal solid waste disposal in undesignated locations where the interaction with rainfall occurs such as in drainages. To understand this further, a correlation analysis was performed using IBM SPSS Statistics 27 between rainfall statistics and cholera cases for a 31-year duration from 1994 to 2024 to understand the relationship between the variables. This analysis measures the strength and direction of the relationship between the two variables. To determine the type of correlation analysis to employ, certain guidelines were followed including observing the data distribution, size of data set, presence of outliers and linearity. Upon inspection of the data, the normality tests revealed that the rainfall data appeared normally distributed with a significance of 0.884 while the cholera data was not normally distributed represented by a significance of less than 0.001and a non-normal curve. The scatter plot method was used to detect linearity, and results depicted a non-linear relationship between the variables. The data inspected satisfied the requirements for Spearman's correlation; hence it was used to perform the correlation analysis. Obtaining a value close to positive one for the correlation-coefficient means a positive correlation, and a value less than one indicates a negative correlation, while zero represents no correlation. Therefore, Spearman's rank correlation was computed to assess the relationship between rainfall and cholera, and the correlation coefficient was found to be 0.394, indicating a moderate positive correlation between the two variables, statistically significant with a p-value of 0.028.

Table 4.2 Correlation Analysis for Cholera and Rainfall Data as Extracted from SPSS

**Spearman's-rho Correlations**

| | | | Rainfall 1994-2024 | Cholera 1994-2024 |
|---|---|---|---|---|
| Spearman's rho | Rainfall 1994-2024 | Correlation Coefficient | 1.000 | .394* |
| | | Sig. (2-tailed) | . | .028 |
| | | N | 31 | 31 |
| | Cholera 1994-2024 | Correlation Coefficient | .394* | 1.000 |
| | | Sig. (2-tailed) | .028 | . |
| | | N | 31 | 31 |

*. Correlation is significant at the 0.05 level (2-tailed).

These results imply that the two variables, rainfall and cholera, change in the same direction, but possibly not at the same rate, that is, when one variable increases, the other variable is expected to increase as well. This does not imply that rainfall is solely responsible for cholera outbreaks in the study area but its interaction with other risk factors must be observed. In the field assessment, heaps of waste were vividly seen in undesignated places including along the roadside, drainages and in the nearby stream. After a heavy downpour, some of the waste mixed with rainwater thus causing other public health issues such as blocking drainages and decomposing there. Such locations may cause direct contamination of rainwater and any interaction with that water by residents is a potential cholera risk. In some cases, such locations served as a hiding place where more unsanitary practices were performed such special waste disposal as soon as residents noticed accumulating waste. Another practice noted in the study area was the improper disposal of infants used disposable diapers together with household waste in drainages, allowing blockages, decomposition and fecal matter intrusion into the rainwater. Therefore, although rainfall cannot be singled out as the cause of cholera, the relationship between the two variables is existent and statistically significant, thus its interaction with other risk factors such as domestic waste poses a risk to more cholera outbreaks. During the field assessment, 69.2% of the participants indicated their potable water source as the official Lusaka Water Supply which is disrupted at least once every day for over 6 hours. Various interactions were observed with rainwater that had been exposed to poorly disposed unsegregated waste especially during such times of water supply disruption. Logically, waste is contaminated and when it interacts with rainfall, the output rainwater is potentially contaminated as well, and ingestion of the contaminated water ultimately causes disease. From what is globally known, it has been accepted that exposure to contaminated water and food leads to the transmission of bacteria such as the cholera bacteria *vibrio cholerae* (Koua et al., 2025).

In summary, the findings of the study align with previous research such as one conducted at national and subnational level by Perez-Saez et al. (2022) where the Bayesian statistical model revealed that southern Africa where Zambia lies experiences the peak of cholera risk and outbreaks between December and April which is considered a rainy season due to the interaction of rainwater with other cholera risk factors. The findings further align with the research conducted by Khadka et al. (2022) where disrupted waste transportation to the landfill caused poor waste disposal in the area. The result was increased cholera cases which worsened by the interaction of the waste with stormwater during the monsoon season.

Therefore, the researcher submits that rainfall alone may not be a huge threat to cholera prevalence, but its interaction with other risk factors such as unsegregated and indiscriminately disposed domestic waste has public health implications such as facilitating cholera outbreaks. Thus, more country-level and scientific studies should be conducted over time on the subject to expose more possible causes, interactions and variations, and prevent annual recurrence in Lusaka and other parts of the country.

# 5. CONCLUSION

The study concludes by acknowledging that there are several risk factors for cholera prevalence in Lusaka and the interaction of these factors worsens the severity. Climate change is a crisis still persistent in the country Zambia and is manifesting through various impacts such as extreme rainfall patterns. In this study, the interaction of climate-induced rainfall with other risk factors to cholera specifically poorly disposed municipal solid waste was assessed. First, Spearman's correlation was conducted using IBM SPSS Statistics 27 between rainfall and cholera cases for a 31-year duration from 1994 to 2024 and the correlation coefficient was found to be 0.394, thus indicating a moderate positive correlation between the two variables a p-value of 0.028. This implies that as the rainfall in Lusaka increases, the cholera cases are equally expected to increase. However, this is not to indicate that rainfall causes cholera, but knowledge that cholera cases increase with more rainfall should be enough to desire the prevention of rainwater from interacting with other risk factors to cholera such as domestic waste. Furthermore, it can be noted that majority of residents in Lusaka practice poor municipal solid waste disposal represented by 56.7% derived by adding the individual poor practices recorded. Findings revealed that residents dispose of waste along the roadside, in drainages and in the nearby stream. However, residents do not have sufficient understanding that cholera has several risk factors such as the synergy between climate-induced rainfall and poorly disposed domestic waste. About 49% indicated only poor solid waste management as the major factor while 32.7% indicated that both rainfall and poor waste management cause cholera outbreaks in Lusaka, and 17.3% indicated that none of the factors cause cholera. This limited perception may explain why residents were seen exposing themselves to rainwater that had interacted with poorly disposed domestic waste thus compromising their health.

The impacts and interactions of the rainfall were assessed through household surveys and field assessments and the findings revealed that poorly disposed waste interacts with rainwater, sometimes causing blockages in locations where rainwater is meant to flow such as drainages and streams. This stagnant water that has interacted with the municipal solid waste is considered contaminated and is usually the source of the problem as residents are seen interacting with it through fetching and directly swimming in the water. It has been globally established and understood that the ingestion of water or food contaminated by the *vibrio cholerae* bacteria causes cholera. Therefore, by understanding that untreated municipal solid waste which is not segregated is contaminated with bacteria, rainwater interacting with it is conclusively considered contaminated too and should be avoided. Other times, the poorly disposed waste along the roadside turns into larger disposal areas for residents, turning into abandoned heaps of waste that are left there to decompose and further interact with rainwater. Such heaps also turn into sites for other poor sanitary practices such as urination and open defecation as they are seen as hidden places. With rainfall already analyzed to increase with cholera cases, its interaction with other risk factors such as poorly disposed waste should be prevented and closely monitored to prevent adverse effects by all possible means. Proper domestic waste disposal practices must also be enforced by authorities and offenders must be punished. The understand is that if there is no waste indiscriminately disposed of along the roadside or drainage, rain would fall on relatively clean ground and that alone may not be a serious threat to public health as the rainwater would interact with minimal risk factors to cholera occurrence.

The main challenge noted in improved MSWM amid extreme rainfall is the discrepancy that exists between residents' understanding of policies and legislation, and the authorities' need for implementation. Residents do not fully understand what has been documented while authorities assume they do and go ahead to warn and charge offenders. In addition, there is inadequate stakeholder involvement in the planning phase hence execution is often a challenge. Other stakeholders are seemly uninvolved in intervention planning hence LISWMC uses plans and strategies that were created in isolation particularly the 2004 National Municipal Solid Waste Management Strategy. This strategy was created by the Environmental Council of Zambia which has since rebranded as Zambia Environmental Management Agency. The strategy has no consideration of climate change and the potential harm its interaction with waste may pose to public health. In addition, among the several stakeholders identified, the Zambia Meteorological Department was not included implying insufficient stakeholder identification and engagement. The country also is overdependent of foreign aid and allows politics to interfere with the operations surrounding waste management. All these factors meeting with rapid population growth in Lusaka pose huge challenges to sustainable municipal solid waste management. Possible opportunities include leveraging the potential of the newly created institute LISWMC to deal solely with the affairs of waste management in Lusaka. Several studies have been conducted on sustainable MSWM hence the country has a good starting point in developing working management systems. Also, the presence of experts and local funds such as Constituency Development Fund will significantly aid the achievement of sustainability in waste management.

In summary, cholera outbreaks in Lusaka do not occur due to an independent factor but are due to the interaction of various factors including poor municipal solid waste disposal practices; rainwater interaction with waste; poor rainwater use practices; ignorance of existing policies and strategies; inadequate stakeholder identification and engagement, and the inability to review, update and disseminate existing policies on the subject. Additionally, a gap exists between the residents' and authorities' understanding of policies and legislation. Some residents demand free waste collection services and subscribe to various CBEs without confirming credibility while service providers quote the constitution and demand subscription to recommended waste collectors. All these factors hinder the progress towards ensuring the effective and climate-sensitive prevention of cholera prevalence in Lusaka.

# 6. RECOMMENDATIONS

The discrepancies that exist between residents and authorities in understanding policies and regulations require adequate stakeholder engagement in policy formulation to guarantee compliance. When all stakeholders including residents are part of the formulation and intervention planning, they will ask questions during the process and once they are clarified and policies are established, residents will understand what is expected of them and what to expect from authorities. The goal of achieving effective and sustainable waste management should begin with such steps at the waste generation point. When residents have a clear understanding of their roles, the problem of poor waste disposal at source will improve, then other stages of the waste management process will be achieved with much more ease provided resources, experts and a proper integrated management strategy are in place. For policies and legislation already in place to prevent poor waste disposal, translation and adequate dissemination is necessary to promote appropriate waste disposal practices by residents. Beyond promoting proper waste management practices, adequate sensitization is required for residents to understand the implications of interacting with contaminated rainwater. Even with water supply crises being recorded across the country, authorities must sensitize and educate residents of better practices such as rainwater harvesting at a small scale. For instance, residents can be taught how to construct their houses to create a simple rainwater harvesting technique that runs from the roof into safe storage containers instead of them interacting with the stagnant contaminated rainwater. Some incentives can be provided by authorities using local funds such as Constituency Development Fund to support the installation of such simple but safe initiatives.

Climate change is real, but several opportunities can be explored to ensure smooth adaptation to it. Residents need to further be educated on the synergy between climate-induced rainfall and poor waste disposal as a significant combined risk for the occurrence of cholera. Sufficient understanding of the interaction of various risk factors will significantly aid in efforts to prevent cholera prevalence in Lusaka. In addition, the knowledge that rainfall is correlated with cholera outbreaks should be transferred into all stakeholders including the community, and its interaction with other risk factors should be consistently monitored to prevent adverse effects to public health.

Although primarily, residents and LISWMC are deemed the major stakeholders in cholera prevention through proper waste management practices. Other stakeholders exist including Zambia Meteorological Department and the Ministry of Health among others thus should be officially identified and incorporated. All should come on board and bring their unique expertise to develop an Integrated Cholera Intervention Plan that is relevant amid climate change. The intervention plan should be more proactive than reactive, as it would acknowledge all risk factors such as rainfall, sanitation sensitization, municipal solid waste management among others. For an annual problem like cholera, this intervention will greatly aid and prevent uncontrolled recurrence. Climate change is real and existent in the country hence requires adequate preparedness even in the waste management sector from the generation point at household level to the disposal and recovery stage at the landfill.

The 2004 National Solid Waste Management Strategy also needs to be reviewed, updated and climate-proofed so that it serves its purpose diligently. In preparing an Integrated Intervention Plan, the 2004 Strategy should be consulted to establish the starting point as the document still embodies some initiatives significant to sustainable MSWM in Zambia. Additionally, all the policies, strategies and intervention plan created must be comprehensive and adequately disseminated and translated so that all stakeholders including the community may have a clear understanding of their expected input in the prevention of cholera. Beyond understanding the contents, all interventions must be periodically followed up, with targets and indicators adequately exposed, monitored and evaluated as it would be of no use to formulate policies whose effectiveness is unknown.

This study's findings should pave way for advances studies on the subject from national to community level to expose even more intricate details on the cholera crisis in Zambia. Authorities may consider providing funding opportunities for more scientific research on the subject as independent studies like this one often face logistical barriers that prevent the exploration of scientific proof for all the identified factors. Such studies require costly multi-stage ethical clearance and analyses which are often complicated for independent researchers. In addition, the various institutions including Zambia Meteorological Department, Ministry of Health and Lusaka Integrated Solid Waste Management Company must be urged to record data correctly and consistently as this would facilitate the execution of future studies on the subject. Lastly, obtaining the rainfall, cholera and waste data should be made easier provided researchers provide the necessary proof of its use for academic purposes.

Overall, the challenges identified through this study as contributing factors to the cholera crisis in Lusaka should be addressed and opportunities explored for significant reductions in its occurrence could be guaranteed. Although the disease is complex with multiple risk factors and challenges, a good and comprehensive intervention plan that incorporates all stakeholders and experts and makes significant climate change considerations would be sufficient in promoting good public health. However, beyond understanding the synergy of climate-induced rainfall and poor waste disposal in causing cholera; adhering to correct waste disposal practices; making policy improvements; and regular policy monitoring among other recommendations suggested, and the adoption of simple yet effective sanitary practices such as handwashing, treating water regardless of how safe one may assume the source is and eating food that is free from bacterial contamination should be upheld and promoted in the prevention of the cholera disease. This is because ultimately, cholera disease will only be prevented when there is no ingestion of contaminated water or food. After handling the domestic waste, handwashing should be mandatory, and mini-waste storage areas in households must also be covered to prevent flies from transporting the bacteria from the waste to food or water. Lastly, in waiting for the weekly collection services, precautionary measures must also be taken by residents including preventing rainwater intrusion into the waste and disinfecting storage bins, areas and all waste handling equipment.

# 7. REFERENCES


ACEN Foundation. (2023). Zambia Circular Economy Study. *Accelerated Growth for SMEs in Zambia (AGS) Programme*. https://acenfoundation.org/project/circulareconomy-market-study-in-zambia/

Adipah, S., & Kwame, O. N. (2019). A Novel Introduction of Municipal Solid Waste Management. *Journal of Environmental Science and Public Health*, *03*(02), 147–157. https://doi.org/10.26502/jesph.96120055

African Union. (2023). *Nairobi Declaration on Climate Change and Call to Action*. 1–12. https://healthpolicy-watch.news/wp-content/uploads/2023/09/Nairobi-Declaration-on-Climate-Change-Eng.pdf

Banda, K., Mwanaumo, E., & Mwanza, B. (2023). Circular Economy: An Antidote to Municipal Solid Waste Challenges in Zambia. *Intech*, *i*(tourism), 13. https://doi.org/http://dx.doi.org/10.5772/57353

Banda, K., Mwanaumo, E., & Mwanza, B. (2024). Municipal Solid Waste Management: An Assessment of the Management Framework In Zambia. *Journal of Law and Social Sciences*, *6*(1), 67–78. https://doi.org/10.53974/unza.jlss.6.1.1204

Bertuzzo, E., & Mari, L. (2017). Hydrology, water resources and the epidemiology of water-related diseases. *Advances in Water Resources*, *108*, 329–331. https://doi.org/10.1016/j.advwatres.2017.09.011

CDC. (2023). *About Waterborne Disease Surveillance*. https://www.cdc.gov/healthy-water-data/about/index.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fhealthywater%2Fsurveillance%2Findex.html

CDC. (2024a). *Implications of Waterborne Diseases*. https://www.cdc.gov/mmwr/volumes/73/ss/pdfs/ss7301a1-H.pdf

CDC. (2024b). Safe Water Storage. In *Encyclopedia of Public Health* (pp. 1273–1274). https://doi.org/10.1007/978-1-4020-5614-7_3081

CDC. (2024c). *What is Public Health?* https://www.cdcfoundation.org/what-public-health#:~:text=Public health is the science,and responding to infectious diseases.

CDP. (2021). CDP Africa Report. In *Disclosure, Insight, Action*. https://www.assets.signify.com/is/content/Signify/Assets/signify/global/20210211-cdp-supply-chain-report-transparency-to-transformation.pdf

Charnley, G. E. C., Kelman, I., Green, N., Hinsley, W., Gaythorpe, K. A. M., & Murray, K. A. (2021). Exploring relationships between drought and epidemic cholera in Africa using generalised linear models. *BMC Infectious Diseases*, *21*(1), 1–12. https://doi.org/10.1186/s12879-021-06856-4

Charnley, G. E. C., Kelman, I., & Murray, K. A. (2022). Drought-related cholera outbreaks in Africa and the implications for climate change: a narrative review. *Pathogens and Global Health*, *116*(1), 3–12. https://doi.org/10.1080/20477724.2021.1981716

Chioatto, E., Khan, M. ., & Sospiro, P. (2023). *Sustainable solid waste management in the European Union: Four countries regional analysis*. *33*. https://doi.org/https://doi.org/10.1016/j.scp.2023.101037

Chisanga, A., Daka, S., Simbeye, T. S., Masebe, E., Mulenga, R., Mary, C., Mwape, K., Mukupo, F., Chirwa, E., Nyahoda, I., Katunga, M., Kaonga, V., Wezi, K., & Luse, N. (2024). Assessment of Solid Waste Management Practices in High-Density Residential Townships: A Case Study of Mtendere Township in Lusaka, Zambia. *INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)*. https://doi.org/https://dx.doi.org/10.47772/IJRISS.2024.803032

Chiwele, D., Lamson-Hall, P., & Wani, S. (2022). Informal settlements in Lusaka: Key messages. *International Growth Centre and the UN-Habitat.*, 25. https://www.theigc.org/sites/default/files/2022/02/Informal-settlements-in-Lusaka-web.pdf

Chu, H., Wei, J., Qiu, J., Li, Q., & Wang, G. (2019). Identification of the impact of climate change and human activities on rainfall-runoff relationship variation in the Three-River Headwaters region. *Ecological Indicators*, *106*(October 2018), 105516. https://doi.org/10.1016/j.ecolind.2019.105516

Climate Champions. (2022). *Lusaka, Zambia: The African city championing climate resilience through solid waste management (SWM)*. https://climatechampions.unfccc.int/lusaka-zambia-the-african-city-championing-climate-resilience-through-solid-waste-management-swm/

Clube, R. K. M., & Hazemba, M. (2024). From waste to resource: demystifying the policy challenges and identifying opportunities for a circular economy in Zambia. *Frontiers in Sustainability*, *5*(March), 1–15. https://doi.org/10.3389/frsus.2024.1300904

ECDC. (2024). *Cholera Worldwide Overview*. https://www.ecdc.europa.eu/en/all-topics-z/cholera/surveillance-and-disease-data/cholera-monthly

Eligon, J., & Moyo, J. (2024). Dealiest Cholera Outbreak in Southern Africa in the Past Decade. *New York Times*. https://www.nytimes.com/2024/02/13/world/africa/cholera-outbreak-zimbabwe-zambia-malawi.html

EPA. (2023). *Climate Change Indicators-Health and Society.pdf*. Environmental Protection Agency. http://www.epa.gov/climateclimate-indicators/health-society

Fernando, S. J., & Zutshi, A. (2023). *Municipal Solid Waste Management in Developing Economies: A Way Forward*. Research Gate. https://research.usq.edu.au/download/fe2511d8b5279418f618efdd6fe7e2df6396de79e3247d3270bd9753cd053ead/2247716/1-s2.0-S2772912523000295-main.pdf

FEWS. (2024). Droughts persist in southern Africa while flooding continues in most parts of eastern Africa. *Relief Web*, 1–5. https://fews.net/global/global-weather-hazards/april-2024

GRZ. (2018). *Solid Waste Regulation and Management Act of 2018*. *20*, 353–404. https://www.parliament.gov.zm/sites/default/files/documents/acts/The Solid Waste Regulation and Management Act%2C 2018.pdf

Idowu, I., Atherton, W., Hashim, K., Kot, P., Al Khaddar, R., Alo, B., Shaw, & A. (2019). An analyses of the status of landfill classification systems in developing countries: Sub Saharan Africa landfill experiences. *Waste Management*, *87*, 761–771. https://doi.org/https://doi.org/10.1016/j.wasman.2019.03.011.

IPCC. (2023). Summary for Policymakers: Synthesis Report. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1–34. https://www.ipcc.ch/report/ar6/syr/summary-for-policymakers/

Kapotwe, B., & Tembo, G. (2021). An Analysis of the Factors Affecting Zambia's GDP Per Capita. *American Journal of Economics*, *11*(1), 19–30.

https://doi.org/10.5923/j.economics.20211101.03

Khadka, A., Khadka, A., & Parajuli, A. (2022). *Municipal Solid Waste and its Implication in the 2022 Cholera Epidemic in Kathmandu*. *June*, 1–10. https://www.nepjol.info/index.php/ppj/article/view/48009

Koua, E. L., Moussana, F. H., Sodjinou, V. D., Kambale, F., Kimenyi, J. P., Diallo, S., Okeibunor, J., & Gueye, A. S. (2025). Exploring the burden of cholera in the WHO African region: patterns and trends from 2000 to 2023 cholera outbreak data. *BMJ Global Health*, *10*(1). https://doi.org/10.1136/bmjgh-2024-016491

Kurniawan, T. A., Meidiana, C., Goh, H. H., Zhang, D., Othman, M. H. D., Aziz, F., Anouzla, A., Sarangi, P. K., Pasaribu, B., & Ali, I. (2024). Unlocking synergies between waste management and climate change mitigation to accelerate decarbonization through circular-economy digitalization in Indonesia. *Sustainable Production and Consumption*, *46*(March), 522–542. https://doi.org/10.1016/j.spc.2024.03.011

Lai, H., Hales, S., Woodward, A., Walker, C., Marks, E., Pillai, A., Chen, R. X., & Morton, S. M. (2020). Effects of heavy rainfall on waterborne disease hospitalizations among young children in wet and dry areas of New Zealand. *Environment International*, *145*, 106136. https://doi.org/10.1016/j.envint.2020.106136

López-Vélez, R., & Presotto, D. (2021). Cholera in travellers: improving vaccination guidance in Europe. *Journal of Travel Medicine*, *28*(1), 1–11. https://doi.org/10.1093/jtm/taaa209

Lusaka Times. (2024). *National Heros Stadium a Cholera Centre*. https://www.lusakatimes.com/2024/01/05/national-heroes-stadium-designated-as-cholera-centre-amid-rising-cases/

Macrotrends. (2024). *Lusaka, Zambia Metro Area Population 1950-2025*. https://www.macrotrends.net/global-metrics/cities/23277/lusaka/population

Makondo, C. C., & Thomas, D. S. G. (2020). Seasonal and intra-seasonal rainfall and drought characteristics as indicators of climate change and variability in Southern Africa: a focus on Kabwe and Livingstone in Zambia. *Theoretical and Applied Climatology*, *140*(1–2), 271–284. https://doi.org/10.1007/s00704-019-03029-x

Mamman, A. A., Kuti, I. ., Yisa, M. ., & Idris, I. . (2024). Risk Factors to Cholera Outbreaks in Parts of Minna, Niger State. *Environmental Technology and Science Journal*, *15*(2), 28–36. https://www.ajol.info/index.php/etsj/article/view/284169

MGEE. (2023). *NATIONAL ADAPTATION PLAN FOR ZAMBIA October 2023*. *October*. https://www.gwp.org/globalassets/global/about-gwp/publications/gcf-outputs/national-adaptation-plan-for-zambia---october-2023.pdf

Milimo, M., Hinchliffe, G., & Michael, P. (2023). PHOTOGRAMMETRY BASED ANALYSIS FOR THE RISKS ASSOCIATED WITH LANDFILLING IN DEVELOPING COUNTRIES: CASE STUDY, CHUNGA LANDFILL, LUSAKA, ZAMBIA. *Research Gate*. https://www.researchgate.net/publication/369816651_photogrammetry_based_analysis_for_the_risks_associated_with_landfilling_in_developing_countries_case_study_chunga_landfill_lusaka_zambia

Ministry of Energy. (2024). *ZAMBIA'S ENERGY SECTOR OVERVIEW*. https://www.moe.gov.zm/?page_id=2198

Nanzaluka, F. H., Davis, W. W., Mutale, L., Kapaya, F., Sakubita, P., Langa, N., Gama, A., N'Cho, H. S., Malambo, W., Murphy, J., Blackstock, A., Mintz, E., Riggs, M., Mukonka, V., Sinyange, N., Yard, E., & Brunkard, J. (2020). Risk factors for epidemic cholera in Lusaka, Zambia-2017. *American Journal of Tropical Medicine and Hygiene*, *103*(2), 646–651. https://doi.org/10.4269/ajtmh.20-0089

NOAA. (2019). *Water Cycle*. https://www.noaa.gov/education/resource-collections/freshwater/water-cycle

NOAA. (2023). *Inter-Tropical Convergence Zone*. https://www.noaa.gov/jetstream/tropical/convergence-zone#:~:text=The Inter-Tropical Convergence Zone (ITCZ) appears as a,broken into smaller line segments.

OECD. (2021). *Municipal waste*. https://www.oecd.org/en/data/indicators/municipal-waste.html

Olajide Mariam, O., Tajudeen Kaosarat, O., Popoola Victor, O., Onyeanusi Sandra, A., Makinde, A., Oladapo Rasaq, K., Onyinyechi Patience, O., Oyetola Afeez, B., Adekunle, O., & Akinrinde, B. (2022). Cholera Scourge in Nigeria: Promoting Environmental Sanitation Practice to Achieving Good Health for All. *Journal of*

*Infectious Diseases and Epidemiology*, *8*(1), 6–11. https://doi.org/10.23937/2474-3658/1510246

Ormsby, M. J., Woodford, L., White, H. L., Fellows, R., Oliver, D. M., & Quilliam, R. S. (2024). Toxigenic Vibrio cholerae can cycle between environmental plastic waste and floodwater : Implications for environmental management of cholera. *Journal of Hazardous Materials*, *461*(July 2023), 132492. https://doi.org/10.1016/j.jhazmat.2023.132492

Peach, J. (2024). *Seven Differences Between Waste Management in the Global North and Global South*. Smart Cities Dive. https://www.smartcitiesdive.com/ex/sustainablecitiescollective/seven-differences-between-waste-management-global-north-and-global-south/230236/

Perez-Saez, J., Lessler, J., Lee, E. C., Luquero, F. J., Malembaka, E. B., Finger, F., Langa, J. P., Yennan, S., Zaitchik, B., & Azman, A. S. (2022). The seasonality of cholera in sub-Saharan Africa: a statistical modelling study. *The Lancet Global Health*, *10*(6), e831–e839. https://doi.org/10.1016/S2214-109X(22)00007-9

Perkins, T. A., & Rohr, J. R. (2020). Theories of Diversity in Disease Ecology. *Theoretical Ecology*, 221–242. https://doi.org/10.1093/oso/9780198824282.003.0013

Qiaohong, S., Francis, Z., Xuebin, Z., & Yaheng, T. (2023). *The Effect of Greenhouse Gas – Induced Warming on the Impact of El Nin ˜ o and La Nin ˜ a Events on Daily Precipitation Extremes in the Boreal Cold Season*. https://doi.org/10.1175/JCLI-D-22-0713.1

Ritchie, H., & Roser, M. (2020). Zambia: CO2 Country Profile. *Atmospheric and Climate Sciences*, *13*(4). https://www.scirp.org/reference/referencespapers?referenceid=3580761

Robertine, L. F., Payne, V. K., Honorine, N. T., Mounchili, S., Saturine, M. M., Manjuh, B. R., Aboubakar, N. N., & Roland, B. (2021). Trends of potential waterborne diseases at different health facilities in Bamboutos Division, West Region, Cameroon: A retrospective appraisal of routine data from 2013 to 2017. *Journal of Water and Health*, *19*(4), 616–638. https://doi.org/10.2166/WH.2021.027

Sakanyi, G., & Kooma, E. H. (2022). *Challenges and Opportunities Associated with Solid Waste Management in Chililabombwe District , Zambia Ministry of Health Hdq ,* *Public Health Specialist , National Malaria Elimination Program*. https://doi.org/10.21522/TIJPH.2013.10.02.Art030

Schneider, D. (2023). Heavy rain, flooding and dam bursts: “The water swept our vegetables away. *CARE International*. https://www.care-international.org/stories/heavy-rain-flooding-and-dam-bursts-water-swept-our-vegetables-away

Semenza, J. C., & Ko, A. I. (2023). Waterborne Diseases That Are Sensitive to Climate Variability and Climate Change. *New England Journal of Medicine*, *389*(23), 2175–2187. https://doi.org/10.1056/nejmra2300794

StudyCorgi. (2022). *Environmental Health Theory and Climate Change*. https://studycorgi.com/environmental-health-theory-and-climate-change/

UNDRR. (2023). *Sendai Framework Terminology on Disaster Risk Reduction*. https://www.undrr.org/terminology/vulnerability

UNICEF. (2023). *A triple threat of water-related crises is endangering the lives of 190 million children - UNICEF*. https://www.unicef.org/wca/press-releases/triple-threat-water-related-crises-endangering-lives-190-million-children-unicef

UNICEF. (2024). Zambia: All school-aged children out of school as deadly cholera outbreak kills over 500 people. In *Relief Web*. https://reliefweb.int/report/zambia/unicef-zambia-flash-update-cholera-08-april-2024

United Nations. (2023). *The Ocean-The World’s Greatest Ally Against Climate Change*. https://www.un.org/en/climatechange/science/climate-issues/ocean#:~:text=As the planet’s greatest carbon,trapped in the Earth’s system.

WHO. (2023). *Drinking Water*. https://doi.org/https://www.who.int/news-room/fact-sheets/detail/drinking-water

World Atlas. (2025). *Maps of Zambia*. Retreieved February 27, 2025, from https://www.worldatlas.com/maps/zambia

World Bank. (2023). A New Era in Development. *Optics & Photonics News*, *March*. https://scorecard.worldbank.org

World bank group. (2020). World Bank Climate Change Knowledge Portal (CCKP) | for global climate data and information! In *Climate change knowlwdge portal*. https://climateknowledgeportal.worldbank.org/

World Bank Group. (2019). What a waste. In *Urban Development* (Vol. 73, Issue 6). https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html?utm_source=chatgpt.com

World Bank Group. (2021). *Current Climate: Zambia*. Retrieved December 21, 2024, from https://climateknowledgeportal.worldbank.org/country/zambia/climate-data-historical#:~:text=Zambia experiences a predominantly sub,May to mid-August).

World Meteorological Orgaization. (2019). *International Cloud Atlas*. Retrieved July 15, 2024, from https://cloudatlas.wmo.int/en/definitions-and-descriptions-of-meteors.html

World Population Review. (2024). *Lusaka, Zambia Population 2024*. Retrieved October 20, 2024, from https://worldpopulationreview.com

Worldometer. (2024). *Zambia Population*. Retrieved September 9, 2024, from https://www.worldometers.info/world-population/zambia-population/

Worlds Aid. (2023). *Heavy Rainfall in Zambia's Southern and Eastern Regions*. Retrieved December 16, 2024, from https://www.worldsaid.com/node/1822

ZNBC. (2024). National Heroes Stadium is a designated Cholera Centre. *ZNBC Today*. Retrieved August 9, 2024, from https://www.youtube.com/watch?v=DvgoFRp0uS8

# 8. APPENDICES

**Appendix A:**

**Questionnaire for Residents**

I am a final year master's student of MSc Climate Change Policy at The Pan African University in Algeria, conducting research titled: *"Evaluating the Influence of Rainfall Patterns and Inadequate Municipal Solid Waste Management on Cholera Outbreaks in Lusaka, Zambia."* This questionnaire aims to gather information on how rainfall and poor municipal solid waste management contribute to cholera outbreaks in Lusaka, particularly Mutendere Community. Your responses will help me understand the relationship between these factors and the spread of cholera and will inform future decision-making for public health interventions amid climate change.

**Section 1: Demographic Information**

1. **Age:** .......................

2. **Gender:** ................................

3. **Duration of stay in Mutendere Community:** ................................

4. **Number of people in household:** ..............................

5. **Occupation**: .......................................

**Section 2: Perceptions on Rainfall and Waterborne Diseases**

1. i. Between droughts and floods, which one have you experienced more in your area in the year(s) you have lived there? *(Droughts=1; Floods=2)* .........

ii. Do you think your choice in part (i) above contributes to the spread of cholera in your community? *(Yes=1, No=2)* ........

1. Have you heard of the term "climate change"? *(Yes=1, No=2)* ........

**Section 3: State of Drinking Water**

1. i. What is the source of drinking water for your household?

*Lusaka Water Supply=1; Borehole=2; well=3; other=4 (Indicate here)* ..............

ii. Have you witnessed interruption in water supply from your preferred source in the years you have lived here? *(Yes=1, No=2)* ........

iii. What is your alternative source of drinking water when there is an interruption in supply? ...................................

1. How would you rate the cleanliness of your drinking water sources?

*(Very clean=1; moderately clean=2; not clean=3)* ..................

1. Do you treat your drinking water before consumption?

*(Yes=1, No=2)* ........

**Section 4: Municipal Solid Waste Management**

11 i. How do you dispose solid waste from your household? *List all that apply* ......................

*Dug a rubbish pit within the yard=1*

*Public dumpsite=2*

*Official solid waste collection services=3*

*Others=4 (specify ............................................)*

ii. How often is your household waste collected/disposed?

*(Daily=1; once a week=2; several times a week=3; not frequent=4)* .................

iii. Have you noticed any instances of improper waste disposal by others in your area (e.g., dumping in waterways or by the roadside)? *(Yes=1, No=2)* ........

iv. Do you think improper waste management contributes to the occurrence of cholera in your area? *(Yes=1; No=2; not sure=3)* ........

v. What challenges do you face in waste management after heavy rainfall? ..........................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.............

**Section 5: Interaction between Rainfall and Poor Municipal Solid Waste Management**

12. Have you noticed any instances where accumulated solid waste has mixed with rainfall in your area? *(Yes=1; No=2)* ........

13. Between poor solid waste management and rainfall, which one do you think contributes more to the occurrence of cholera in Lusaka?

*(Both=1; Rainfall=2; Poor Solid Waste Management=3; None=4)* ................

**Section 6: Cholera Experience and Awareness**

14. Have you or a family member ever contracted cholera in the past 5 years?

*(Yes=1; No=2)* ........

15. What measures do you take to prevent cholera in your household? ........................................................................................................

16. Are you aware of any community programs or education on waste management, extreme rainfall and waterborne diseases? *(Yes=1; No=2)* .............

17. i. Who do you think must take the greater responsibility in addressing cholera, poor waste management?

*(Government=1; Individual/household=2; Both=3; None=4)* .....................

ii. On a scale of 1 to 5 satisfied are you with the government's response to waste management, high rainfall and cholera outbreaks in your area?

*(Very dissatisfied=1; very satisfied=5)* .............

iii. Do you feel you play a significant role in addressing cholera outbreaks in your area?

*(Yes=1; No=2; Not sure=3)* ........

**Section 7: Additional Comments**

Thank you for taking the time to complete this questionnaire. Your input is highly valuable to this research. Is there any additional information or comments you would like to share regarding the impact of rainfall and poor municipal solid waste management on cholera in Lusaka?

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

***Thank you for your participation***

**Appendix B:**

**Ethical Clearance Certificate from ERES Converge**

ERES CONVERGE

Plot No. 272, Cnr Olive Tree Meanwood Road,
Meanwood Ibex
Lusaka - Zambia
Tel: +260 955 155 633
+260 955 155 634
Cell: +260 977 493 220
Email: eresconverge@yahoo.co.uk

I.R.B. No. 00005948
F.W.A. No. 00011697

# Final Decision Certificate

This document certifies that the study:

***"Evaluating the Influence of Rainfall Patterns and Inadequate Municipal Solid Waste Management on Cholera Outbreaks in Lusaka, Zambia."***

**Principal Investigator:** Ms. Rhodah Chabinga

**Reference number:** 2024-Dec-028

Was reviewed and received the following status:

**"Approved"**

**Additional Comments:**

No comments from the Committee.

Where Research Ethics and Science Converge

## Appendix C:

## Permission Letter from Lusaka District Health Office

*All correspondence should be addressed to the Provincial Health Director*
*Telephone: +260 211 256813*
*Fax: +260 211 256814*
*Telephone: +260 211 256815*
*Cell: +260 956 399643*
*+260 963 908260*

REPUBLIC OF ZAMBIA

MINISTRY OF HEALTH

*In Reply please quote:*

*File No.:* **LSKPHO/101/8/1**

Lusaka Provincial Health Office
P.O. Box 32573
LUSAKA

6th January, 2025

Rhodah Chabinga
Institute for Water and Energy Sciences
PAUWES, Algeria
mwandochabinga@gmail.com
0971961244

**PERMISSION TO CONDUCT RESEARCH**

My office is in receipt of your letter requesting for permission to conduct a study titled **"Assessing the Impacts of Rainfall and Poor Municipal Solid Waste Management on the Occurrence of Cholera in Lusaka"**

My office is glad to inform you that it has no objection to your request provided that;

1. The relevant Institution Director where the study is being conducted are fully appraised;
2. Progress updates are provided to Lusaka Provincial Health Office and the District Health Office biannually from the date of commencement of the study;
3. The final study report is cleared by NHRA before any publication or dissemination within or outside the country;
4. After clearance for publication or dissemination by NHRA, the final study report is shared with all relevant Provincial and District Directors of Health where the study was being conducted.

Kindly ensure minimum interruption in health service delivery at selected health facilities.

By copy of this letter, the District Health Office / Institution are advised to allow you undertake the above-mentioned research and provide you with the relevant support.

Yours faithfully,

Dr. Simulyamana Aspha Choonga
**Provincial Health Director**
**LUSAKA PROVINCE**

**CC:** District Health Director – Lusaka

Physical Address: 3 Saise Road, Longacres, Lusaka, Zambia.

**Appendix D:**

**Informed Consent Form**

Title of study: **Evaluating the Influence of Rainfall Patterns and Inadequate Municipal Solid Waste Management on Cholera Outbreaks in Lusaka, Zambia.**

Principal Investigator:

**Rhodah Chabinga (+260971961244)**

**Pan African University Institute of Water and Energy Sciences including Climate Change- Algeria**

**Purpose of Study:** You are invited to participate in a research study that aims to understand how rainfall patterns and poor municipal solid waste management contribute to cholera outbreaks in Zambia. The findings will help inform future strategies to reduce cholera cases and improve public health systems.

**Procedure:** If you agree to participate in the study, you will be asked to respond to a questionnaire by other writing or responding verbally while I write for approximately 10 minutes. The questions are on solid waste practices, rainfall and any experience with cholera.

**Voluntary participation:** Participation in this study is completely voluntary and you may choose to participate or withdraw at any point without any penalty.

**Risks:** There are minimal risks in the study as we will not request any sensitive personal information.

**Benefits:** The study will help improve the understanding of what causes cholera in Lusaka for better approach in future. However, no monetary compensation will be given to participants.

**Confidentiality:** Your responses will be kept confidential and will be used only for research. Your identity will not be revealed at any time. For any concerns you may contact me in the number above.

**Statement of Consent: I have read and understood the information provided above and I voluntary agree to participate in this study. I understand that I can with draw at any time without penalty.**

…………………………………………. ……………………….

Signature/Thumbprint Date