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Framework for Mitigating the Risk of Waterborne Diarrheal Diseases in Peri-Urban Areas of Lusaka District Zambia

By

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A thesis submitted in fulfilment of the requirements for the degree

PhD (Public Health)

in the

School of Health Systems and Public Health

Faculty of Health Sciences

University of Pretoria

2023

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SUMMARY

Waterborne diarrheal diseases are a public health problem in developing countries including Zambia. Despite implementing various interventions, the diseases have persisted in Zambia. This study aimed to develop a framework for identifying appropriate interventions for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia.

The study employed a sequential mixed methods design. The first step of the study involved a systematic review to determine interventions for mitigating risk of waterborne diarrheal diseases. This was followed by a longitudinal study to investigate trends of diarrheal diseases over a 10 year period (2010 to 2019) using secondary data from the Health Management Information System in 15 health care facilities of Lusaka district. A scoping review was then conducted to identify frameworks for mitigating risk of waterborne diarrheal diseases. These frameworks were analyzed using Strength, Weakness, Opportunity, and Threat analysis to identify gaps and used as a basis for drafting the framework. Finally, the draft framework was validated by health workers and other WASH experts for correctness of information and acceptability, after which the refined framework was developed.

Under the systematic review, the study found 56 studies that met the inclusion criteria reporting several interventions including: vaccines for rotavirus disease (Monovalent, Pentavalent and Lanzhou lamb vaccine); enhanced water filtration for preventing Cryptosporidiosis, Vi polysaccharide for typhoid; cholera 2 dose vaccines, water supply, water treatment and safe storage, household disinfection and hygiene promotion for cholera outbreaks. The longitudinal study revealed a decrease in trends of diarrheal diseases with non-bloody and bloody diarrhea being the main cause of morbidity and mortality, respectively. The highest number of cases were recorded in 2016 and lowest 2019 with more cases in children under five years. Notably, most cases were recorded during the rainy season. First level hospitals recorded the highest number of cases and deaths compared to other health facilities. The scoping review found five frameworks for mitigating risk of diarrheal diseases including hygiene improvement framework, community led total sanitation, global action plan for pneumonia and diarrhea, participatory hygiene and sanitation transformation, and sanitation and family education. None of these frameworks was specific for waterborne diarrheal diseases. These

frameworks were used to propose a draft framework. Validation of the draft framework helped to improve the tool as the health workers and experts suggested several issues included in the final framework. The final framework consisted of the following elements: problem identification; identification and quantifying of risks; identification of evidence-based intervention(s); assessment of intervention(s) in target community; selection and adoption of intervention(s); implementing selected intervention(s); monitoring and evaluation; sustainability and system support factors.

The developed framework is envisaged to help mitigate risk of waterborne diarrheal diseases in peri-urban areas of Lusaka Zambia if implemented and ultimately improving public health in Zambia and related settings.

Keywords: Framework, waterborne, diarrheal diseases, risk mitigating, peri-urban areas, Lusaka, Zambia.

DECLARATION

I, Chisala Deborah Meki declare that the study titled “Framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia” submitted for award of a Doctor of Philosophy in Public Health at the School of Health Systems and Public Health, Faculty of Health Sciences, University of Pretoria is my own original work and that it has not been presented and will not be presented to any other University for a similar or any other degree award.

Name: Chisala D. Meki

Signature: 

Date: 02/06/2023

ETHICS STATEMENT

This Study was approved by the University of Pretoria Faculty of Health Sciences and University of Zambia Biomedical Research Ethics Committee's REF: 847/2019 and REF: 808-2020, respectively. Permission was also sought from the Ministry of Health Zambia to conduct the study. Confidentiality was ensured and all participants consented to the study.

PUBLICATIONS

The following publications were made in line with the objectives of the study:

1. Meki CD, Ncube EJ, Voyi K. Community-level interventions for mitigating the risk of waterborne diarrheal diseases: a systematic review. Systematic Rev. 2022; 11(1):73.

2. Meki CD, Ncube EJ, Voyi K. Frameworks for mitigating the risk of waterborne diarrheal diseases: a scoping review. PLoS One. 2022; 17(12):e0278184.

DEDICATION

This work is dedicated to my family Mum and Dad, Mr. and Mrs. Wallace Meki for taking care of my daughters while I was working on my thesis and their encouragement. My loving Husband Emmanuel Chileshe Lubumbashi and Children Joanna and Christine Lubumbashi for always being there and accommodating a busy Wife and Mum.

ACKNOWLEDGEMENTS

I am grateful to my supervisor, Dr. Esper J. Ncube, and co-supervisor, Prof. Kuku Voyi, for their constructive criticism and push towards the completion of this work, as well as their assistance in securing funding for this PhD. I am also thankful to the reviewers of my proposal who helped improve the PhD idea. I would like to express my gratitude to Dr. Cheryl Tosh for assisting with the language editing of the manuscripts, and to Ms. Estella Globler for helping in obtaining the articles for the reviews. I would also like to extend my thanks to all the staff at the University of Pretoria, School of Health Systems and Public Health.

I am grateful to Mr. Macmillan Kapungwe and Mr. Milupi Matokwani from the Lusaka district health office for their assistance in coordinating the validation workshop and providing essential data for the completion of the research. I would also like to thank the Water Sanitation and Hygiene Lusaka Subdistrict Coordinators and other stakeholders who participated in the validation of the draft framework.

I extend my appreciation to Mrs. Nachombe Nangamba-Kandila, Mr. Meetwell Cheelo, and Ms. Thelma Kunda from the Ministry of Local Government, Ministry of Health, and Lusaka City Council, respectively, for providing information for the development of the framework. I am also grateful to all the other participants from different WASH organizations, including Peoples Process on Housing and Poverty in Zambia (PPHPZ), Network for Environmental Concerns and Solution (NECOS), Lusaka Water Supply and Sanitation Company, National Water Supply and Sanitation Council (NWASCO) and BORDA Zambia.

I would like to acknowledge Prof. Charles Michelo, Dr. Hikabasa Halwindi, Mr. Allan R. Mbewe, and all the staff at the University of Zambia School of Public Health for their support. Additionally, I thank Kochelani Saili, Dr. Artwell Kanda and my other PhD colleagues at the University of Pretoria, School of Health Systems and Public Health.

I am grateful to my family, my parents Mr. and Mrs. Wallace Meki, and my siblings Coretta, Charity, Wallace, Linda, Webster, Bruno, and Ben, as well as their spouses, for their encouragement and support. I also express my gratitude to my husband and children for their love, understanding and support.

Lastly, I would like to thank my heavenly Father, God, for giving me the strength to complete this PhD.

SPONSORSHIP

This PhD was sponsored by the National Research Foundation the World Academy of Science Doctoral Scholarship.

LIST OF ABBREVIATIONS AND ACRONYMS

CDC	Center for Disease Control and Prevention
CLTS	Community Led Total Sanitation
CSO	Central Statistical Office
DALYs	Disability Adjusted Life Years
HIF	Hygiene Improvement Framework
HMIS	Health Management Information System
HWT	Household Water Treatment
GAPPD	Global Action Plan for Pneumonia and Diarrhea
MDGs	Millennium Development Goals
MoH	Ministry of Health
PHAST	Participatory Hygiene and Sanitation Transformation
PI	Principal Investigator
PROSPERO	Prospective Register of Systematic Reviews
SAFE	Sanitation and Family Education
SDGs	Sustainable Development Goals
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
SWOT	Strength, Weakness, Opportunity and Threat
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency International Development
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
ZNPHI	Zambia National Public Health Institute

GLOSSARY OF TERMS

Diarrhea: refers to the passage of watery stool by a person three (3) times within a 24 hour period.

Framework: refers to specific set of ideas which can be used to mitigate the risk of waterborne diarrheal diseases.

Health Authorities: refers to government ministries, institutions, and non-governmental organizations (NGOs) in-charge of health.

Mitigating: refers to actions to reduce the risk of waterborne diarrhea diseases from occurring.

Pathogens: refers to organisms that cause diarrhea such as viruses, bacteria and parasites.

Peri-Urban Area: refers to a community that is not planned with no proper services for provision of safe water and sanitation facilities for health.

Risk: refers to the probability of a person acquiring a waterborne disease.

Validation: refers to a process done to assess the correctness of information behind the draft framework by experts. It also involves testing the acceptability of the draft framework by the community.

Waterborne Diarrheal Diseases: refers to diseases caused by consumption of water contaminated with pathogens that causes a disease with diarrhea symptom.

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CHAPTER 1: INTRODUCTION

1.1 Background

Water and sanitation were declared a right by the United Nations Assembly.[1] Despite the declaration, slightly above 800 million and more than 2 billion people still lack basic drinking water and sanitation services worldwide, respectively. Most of the population that lack water (58%) and sanitation live in Sub-Saharan Africa. Hygiene is also a problem in most of the countries in sub-Saharan areas. For instance, only 15% of people in this region has basic hand washing facilities with soap and water.[2] The importance of water, sanitation, and hygiene in relation to disease can be historically traced from the 1800s when there was a Cholera epidemic in Soho, London. John Snow established the relationship between contaminated water source and cholera outbreak.[3,4]

Poor provision of water, sanitation, and hygiene results in waterborne diseases. According to Leclerc et al.[5] "Waterborne diseases are those transmitted through the ingestion of contaminated water and water acts as the passive carrier of the infectious agent (p.371)"**.** in diseases such as cholera, dysentery (shigellosis and amebiasis), typhoid, cryptosporidiosis, giardiasis, cyclosporiasis, yersiniosis, salmonellosis, campylobacteriosis, other gastroenteritis infections caused by rotavirus, adenovirus norovirus, enterovirus, caliciviruses, astroviruses and reoviruses and other diarrheal diseases.[6,7] The main route of spread of the waterborne diseases is the fecal oral route (Figure 1.1). This involves getting the infection through drinking of water that is contaminated with fecal matter.[8,9] The contamination of water is caused by the absence of sanitary facilities for safe disposal of fecal matter and contamination of water bodies or sources with fecal matter from sanitary facilities that are not well constructed or maintained.[9] The major cause of diarrheal diseases is linked to contaminated food followed by water representing 70% and 30% respectively. However, the food that are linked to outbreaks may be contaminated with water.[5] In addition to food and water, the fecal oral route can also be through direct route by fingers and other materials that can carry pathogens which may be ingested.[10]

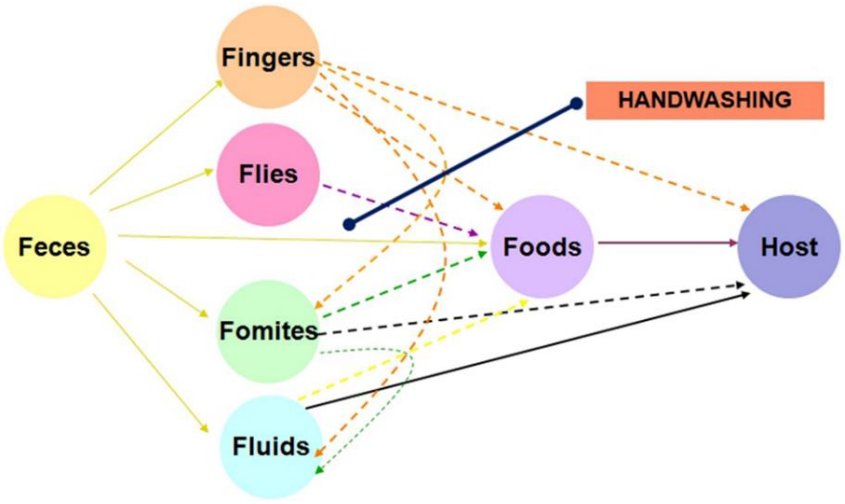

Figure 1.1: Fecal oral transmission diagram

Source: Present truth fellowship[13]

Waterborne diseases are caused by various agents divided into bacterial, parasitic, and viral.[11,12] Table 1.1 indicates pathogens responsible for waterborne diseases, causative agents, the diseases they cause and their effects.

Table 1.1: Pathogens, source, diseases, and effects of waterborne diarrheal diseases

Pathogen	Source	Disease	Effects
Bacteria			
Campylobacter	Domestic wild animal feces	Campylobacteriosis	Acute diarrhea
Escherichia coli 0157:H7 (enteropathogenic)	Cattle feces	Gastroenteritis	Vomiting, diarrhea
Salmonella typhi	Domestic and wild animal feces	Typhoid fever	High fever, diarrhea, ulceration of small intestine
Salmonella (1,700 serotypes)	Domestic and wild animal feces	Salmonellosis	Diarrhea
Shigella (4 spp.)	Infected humans	Shigellosis/ Bacillary dysentery	Bloody diarrhea
Vibrio cholerae (O1 and O139)	Sediments, shellfish asymptomatic human carriers	Cholera	Acute and Heavy diarrhea

Pathogen	Source	Disease	Effects
Vibrio cholerae (Non O1 and Non O139)	Human carrier	Cholera	mild diarrhea to severe watery diarrhea
Yersinia entercolitica	Animal feces, pork, unpasteurized milk	Yersinosis	Diarrhea
Protozoa			
Cryptosporidium	Humans, animals and bird feces	Cryptosporidiosis	Diarrhea death in susceptible population
Entamoeba histolytica	Human feces	Amebiasis (amoebic dysentery)	Prolonged diarrhea with bleeding, abscesses of the liver and small intestine
Cyclospora	Human feces	Cyclosporiasis	Diarrhea
Giardia lamblia	Human, animal and bird feces	Giardiasis	Mild to severe diarrhea, nausea, indigestion
Viruses			
Adenovirus (48 serotypes; types 40 and 41 are of primary concern)	Human	Respiratory disease, gastroenteritis	Acute respiratory disease, pneumonia, conjunctivitis, gastroenteritis
Astroviruses	Humans	Gastroenteritis	Vomiting, diarrhea
Calicivirus (e.g. Norwalk, Norwalk-like and Sapporo, Sapporo-like viruses)	Humans	Gastroenteritis	Vomiting diarrhea
Enterovirus (66 types, e.g. polio, echo, encephalitis, and Coxsackie viruses)	Humans	Gastroenteritis, heart anomalies, meningitis	Respiratory illness, common cold
Reovirus	Humans	Gastroenteritis	Vomiting, diarrhea
Rotavirus	Humans	Gastroenteritis	Vomiting and diarrhea
Clostridium difficile	Humans	Gastroenteritis	Acute diarrhea

Diarrhea is one of the main manifestations of waterborne diseases characterized by infection in the intestinal tract. It is defined as the passage of loose stool more than 3 times in a 24 hour period.[14] This disease is also the leading cause of mortality in children under-the age of five years.[15,16] Unsafe drinking water, sanitation and lack of hygiene continue to be main contributors to global death, leading to around 870,000 mortalities in 2016 of which deaths were mostly as a result of diarrheal diseases.[17]

According to Prüss-Ustün et al.[18] a projected 502,000 diarrhea deaths were caused by inadequate drinking water and 280,000 deaths because of inadequate sanitation, with 297,000 deaths of disease burden from inadequate hand hygiene in all age groups in low- and middle-income countries. According to World Health Organization (WHO)[19] safe water, improved sanitation and hygiene can prevent mortality of 36,100 under five children each. It is therefore important that children and everyone accesses these facilities for their wellbeing. Access to these facilities will also help in achieving the Sustainable Development Goals (SDGs) number six (6) and three (3) set by the United Nations which aims for clean water and sanitation for all people as well as achieving good health and wellbeing by 2030.[20,21]

It is important to know that the risks of waterborne diarrheal diseases can be mitigated. This can be done by cutting the fecal oral route as it is the means of transmission.[22] According to the consulted literature, there are several interventions that are important to curb waterborne diseases. First, hand washing, improved water quality, sanitation and hygiene are some of the interventions important in addressing the problem of diarrheal diseases. For instance, a systematic review conducted globally by Cairncross et al.[23] which focused on the effects of handwashing, improved water quality and excreta disposal, proposed diarrhea risk reductions of 48%, 17% and 36%, associated with hand washing with soap, improved water quality and proper excreta disposal, respectively. Pruss-Ustun and WHO[24] also conducted a study and revealed that improving water sanitation and hygiene can prevent 9.1% of global diarrheal disease burden and 6.3% deaths. The same findings were shown in a study conducted in Kenyan schools to determine the effect of Water Sanitation and Hygiene (WASH) on diarrheal related diseases among young siblings of school going children. The results showed that WASH interventions were effective in the reduction of diarrhea incidences in schools that had scarce water and no difference in diarrhea

incidence was observed in school that had adequate water supply before the interventions.[25] Hand washing with soap is another intervention that has been found to reduce diarrhea or water related diseases incidences.[26] Provision of drainage in areas without facilities is another intervention that has been found to be important in the reduction of diarrheal diseases. For example, a study conducted in Zambia by Sasaki et al.[27] revealed that cholera incidences were associated with insufficient drainage networks.

Vaccination is an important intervention that can be used to prevent waterborne diseases for example cholera. A study conducted in India revealed that cholera vaccine had a 67% protective efficacy.[28] During the 2017 and 2018 cholera outbreaks some Zambians were also vaccinated.[29] The effects of the vaccines in Zambia are yet to be established. Another study conducted in Zanzibar revealed that oral cholera vaccine offered a direct and indirect (herd) protection against cholera.[30] In addition, several studies have shown reduction in diarrhea in children after the Rota vaccine intervention.[31-33]

Household water treatment (HWT) has been found to be effective to reduce water borne diseases especially in areas that are not serviced with piped water such as peri-urban areas in developing countries.[34-36] HWT may reduce diarrhea by 30−40% in poor population.[37] Hunter[35] found that the HWTs used in developing countries include: ceramic filters, biosand filter, coagulation, chlorination, and solar disinfection. Another study by Luby et al.[38] in Guatemala found that households that used disinfectants for water disinfection had 39% less diarrhea that the control households.

Chlorine disinfection is a commonly used treatment method. A study conducted in rural Ethiopia reported that the incidence of diarrhea was lower in households that used chlorine disinfection compared to the control group where chlorine was not used.[39] It is also important to note that even if chlorine provides a chlorine residue and is easy to use, it is not effective against certain microorganism such as Cryptosporidium and Giardia which can also be responsible for the occurrence of diarrhea.[40] It is also important to note that safe water storage must be ensured in household to protect the treated water from recontamination.[41]

Boiling water is also one of the most common home water treatments(HWT) method,[34,42] this is possibly because it is easy to treat water using this method and it kills all pathogens in water, in addition to being easy to conduct. It however has limitations of not having a residue effect and requires energy that is usually expensive.[43]

It is important to note that for the water interventions to be effective, they must be combined with hygiene practices or health education. Community education is an important part of interventions because most problems can be solved by a well-informed community.[44] For example, attempts to reduce diarrheal diseases through the promotion of handwashing with soap have yielded positive results.[2,45] Acceptability is an integral part of success of health interventions.[41] For an intervention to work it must be accepted by both the implementers and the users. These two stakeholders should be involved during development of the intervention, its implementation and evaluation.[46]

Waterborne diseases are influenced by both ecological and socio-economic factors for this reason it is not easy to prevent them. An integrated intervention approach addressing the physical, political, economic and social environment must be employed to prevent these diseases.[47] The specific interventions mentioned above including access to safe drinking water; improved sanitation; exclusive breastfeeding for children; good personal and food hygiene and, health education and vaccination must be employed at the same time for better effectiveness.[48] The waterborne diseases are even more difficult to prevent in developing countries such as Zambia due to poor provision of water, sanitation, hygiene as well as other important interventions. This study therefore aimed to come up with a framework that incorporate the various interventions to mitigate the risk of waterborne diarrheal diseases specific to peri-urban areas of Lusaka district Zambia incorporating different ideas to address the problem.

It is important to note that a few frameworks for mitigating the risks of diarrhea diseases exist. Some examples of such frameworks found in literature include Hygiene Improvement Framework[49] Community Led Total Sanitation[50] Global Action Plan for Pneumonia and Diarrhea (GAPPD)[51] and Participatory hygiene and sanitation

transformation.[52] Overall, these published frameworks provided very little information on how the frameworks were developed and whether the community and other stakeholders were involved in their development. Furthermore, most of the frameworks that were found focused on mitigating the risk of diarrheal diseases in children and for general diarrhea instead of waterborne diarrheal diseases. Creating a framework that will target different groups of the populations was helpful as diarrhea does not affect children only but adults as well.[53] It is also important to note that creating a framework with specific appropriate interventions and tailored to the study areas was important for acceptability as well as sustainability.

1.2 Problem statement

Zambia located in sub-Saharan Africa is an example of a country that has challenges of water and sanitation. According to the Central Statistics Office (CSO),[54] only 65% of the population obtain water from an improved water source and 45% have access to improved sanitation. Lack of safe water and improved sanitation has led to waterborne diseases in Zambia. For example, the prevalence of diarrhea was found to be 16% in children under the age of five. Diarrhea is also a major cause of morbidity and death among children[54] and one of the top ten causes of death in Zambia.[55] Zambia has also been affected by the recurrence of cholera, a deadly disease the country has experienced since 1977, with major outbreaks since early 1990s to date.[56,57] In 2017 and 2018, the cholera epidemic resulted in more than 103 deaths and 5190 hospitalized cases.[58] Majority of the cases (4,768) and deaths (89) were from Lusaka, particularly from peri-urban areas, an area of interest to this study.[57,58]

In 2015 diarrhea was a leading cause of death among all ages and the leading cause of DALYs (Disability Adjusted Life Years) globally.[59] Specifically, diarrhea results in missed school days for school going children and workplace absenteeism. This shows that these diseases do not only affect individuals but the nation at large. The missed school days for school going children result in decrease academic performance and likelihood of school dropout. This may result in children not attaining economic and health benefits associated with education. Workplace absenteeism is also likely to have present and future economic losses as it reduces productivity. In addition, diarrhea increases burden on health services.[10,60]

Some interventions have been implemented to curb waterborne diarrheal diseases in schools and communities of Zambia, for example household water treatment and safe storage, hygiene education, provision of drainage facilities and vaccination.[27,61-63] Despite these interventions, diarrheal diseases are still prevalent in Zambia. This is possibly because most of these interventions are not combined as diarrheal diseases require integrated approach as the diseases are attributed to different factors in the environment thus the importance of including different interventions to mitigate the risk of diseases. It was therefore important that more research was done to understand how to prevent the occurrence of the diseases. Since the diseases are more common in peri-urban areas, a study that targets interventions that can mitigate

the risk of diseases specifically in these areas was useful for the improvement of health in these communities. This study therefore aimed to develop a framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka Zambia.

1.3 Justification

This study might introduce more effective ways that will benefit people in peri-urban areas of Lusaka Zambia ultimately improving their health and wellbeing through development of the framework for mitigating the risks of waterborne diarrheal diseases tailored to the specific interventions appropriate for peri-urban areas of Lusaka district Zambia. This was achieved through the literature review that was conducted, to determine the various interventions available for mitigating the risk of waterborne diarrheal diseases and get literature on existing diarrhea frameworks which were used as a basis for development of a framework. The developed framework was validated by different stakeholders in the study areas. The study also investigated trends of diarrhea diseases in peri urban areas of Lusaka district to assess the burden of the diseases in different peri-urban areas of Lusaka district Zambia. These findings produced vital information about the target groups and areas that need more interventions.

Policy makers such as the Ministry of Health and Local Government and Housing might incorporate the framework developed in this study to formulate policies on mitigating the risk of waterborne diseases in peri-urban areas of Zambia and related settings in other countries. The results of this study have filled the identified gaps by adding to the body of literature on waterborne diarrheal diseases. The study might also instill interest among other researchers to conduct further research related to intervention for mitigating the risk of waterborne diarrheal diseases. Ultimately the findings of the study might also contribute to the attainment of the sustainable development goals 6 and 3 which aims for provision of clean water and sanitation for all and good health and wellbeing for all Zambians as Zambia is still lagging in the achievement of these goals.

1.4 Research questions

1. What interventions exists in literature for mitigating the risk of waterborne diarrheal diseases in developed and developing countries?
2. How are the trends of diarrhea diseases over a period of 10 years (2010 to 2019) in peri-urban areas of Lusaka district, Zambia?
3. What are the gaps in existing frameworks for mitigating the risk of waterborne diarrheal diseases in developing and developed countries?
4. What are the views of the communities in Lusaka Zambia about the draft framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia?
5. How can the developed framework contribute to the current ways of mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district, Zambia?

1.5 Study assumptions

Study assumptions are aspects accepted as true, or at least plausible, by researchers and other people who read the researchers work. Researchers do not have full control of these assumptions and if they disappear the study would become irrelevant.[64, 65] The following are assumptions in this study:

First, information presented in the reviews both on waterborne diarrhea interventions and frameworks can be trusted because at least two (2) reviewers were included in the review process and already available tools and methods were used in the reviews such as PRISMA framework for conducting reviews and various tools used in the quality assessment of the included literature. In addition, several databases were searched to get a wider picture of the available literature for both reviews. The second assumption was in line with considering that participants gave honest answers during data collection. This was done by ensuring that the participants gave consent to take part in the study and that confidentiality was upheld during the data collection process. Informed consent was assured by explaining the study to the participants and given time to think of whether participating or not in the study. To ensure confidentiality names of the participants who revealed specific information were not revealed in

reviews and the workshop only identity numbers were used nor their work affiliation to other members of the group in the workshop.

Thirdly, the study involved different participants that oversaw the water and sanitation in Zambia to validate the framework that was developed in addition to involving workers from health facilities and facilities catchment area. This enhanced the transferability and reliability of the study findings as triangulation was done including members' checking to ensure that the data that was obtained or transcribed was correct. The results on the trends of diarrhea diseases can be generalized to other types of government health care facilities in Zambia and or related settings.

1.6 Study delimitations

Delimitations are the characteristics that limit the scope and describe the boundaries of the study. The scope of the study refers to the parameters under which the study will be operating, what the study covers, and it is closely connected to the problem. Delimitation decisions are made during the development of the study plan by the researchers(s). This involves consciously including or excluding certain issues in the study.[64,66] Several delimitations are noted in this study presented below.

The first delimitation of this study was in terms of the scope of the study. The study only looked at waterborne diarrheal diseases. Other problematic water related diseases such as schistosomiasis, malaria, hepatitis, trachoma which do not fall under the category of waterborne diseases were left out. Secondly, the study was only done in Lusaka district and in particular peri-urban areas of Lusaka district. It is important to note that Lusaka is not the only district with a problem of waterborne diarrhea diseases, but other districts are also affected in Zambia. In addition, other areas aside the peri urban areas within Lusaka also report diarrhea cases but were not included in the study. The third delimitation was in the literature review done, the systematic review on interventions which only included studies done from 2009 to 2020.

Finally, the study only employed secondary data for the collection of information on diarrhea diseases in the trends study. It is important to note that collecting primary data could have helped to strengthen the conclusion of the findings as more variables were going to be included in this study. Further, the trends study was also only done

in government health care facilities when other health care facilities do exits with reported cases of diarrhea.

1.7 Study limitations

Limitations are constraints of the study that are largely beyond the control of the researcher but could affect the study outcome.[64,66] In this study the following limitations were observed: First, not all the years were included in the trends of diarrheal diseases. This is the period that had cases and catchment populations that were important to make proper conclusions in addition the selected years were current and gave the picture that could be used.

Second, inclusion of cases from the health center only excluded other cases that were not reported to the facilities when they had diarrhea. However, including cases of diarrhea in all the government health facilities enabled the results to be generalized as these facilities are the main health care providers in these areas. Third, use of secondary data is prone to having data from repeated visit however, the researcher controlled for this by comparing the total cases with the first visit cases for the period of interest. Finally, the secondary data that was used to assess the trends of diarrhea in the trends study did not specify the cases of diarrhea that were waterborne. Nevertheless, the study gave an idea of the trends of diarrhea diseases in the areas.

1.8 Research aim and objectives

Aim

- To develop a framework for identifying appropriate interventions for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia.

Specific objectives

1. To conduct a systematic review on interventions for mitigating the risk of waterborne diarrheal diseases in developing and developed countries.
2. To investigate diarrhea diseases trends over a period of 10 years (2010 to 2019) in peri-urban areas of Lusaka district, Zambia.
3. To identify gaps in existing frameworks for mitigating the risk of waterborne diarrheal diseases in developing and developed countries.

4. To develop a draft framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia.
5. To validate the draft framework for mitigating the risk of waterborne diarrheal diseases in selected Zambian communities.
6. To develop a refined framework for mitigating the risk of diarrhea diseases for use by Health authorities.

1.9 Thesis structure and chapter outline

This thesis is organized into seven chapters. The first Chapter presents the background of the study, problem statement, aim, objectives and research questions, study assumptions, delimitations, limitations of the study. Chapter two describes the methodology used to develop and validate the framework. Chapter three presents the results of the literature review conducted in this study; a systematic review of interventions for mitigating the risks of waterborne diarrheal diseases and a scoping review of frameworks for mitigating the risk of waterborne diarrheal diseases. Chapter four presents the results of the trends of diarrheal diseases in Lusaka district. Chapter five presents details of the development and validation of the framework. Chapter six presents the discussion and presentation of the final framework. The last chapter presents the conclusion and recommendations of the study.

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CHAPTER 2: METHODOLOGY

2.1 Introduction

This section presents the methods that were used to develop the framework for mitigating the risk of waterborne diarrheal diseases in peri-urban of Lusaka district Zambia. The development of the framework was done in four phases.

2.2 Study design

The research design refers to the plan that a researcher uses to combine the different parts of the research in a systematic and reasoned way to address the research problem. The design includes the plan of data collection, measurement, and analysis.[1] Qualitative designs refer to a systematic subjective method used to describe life experiences and give them meaning. These designs that are emergent and flexible, allow for more freedom in the collection of data as they do not include predetermined questions.[2,3] Quantitative designs refer to research that involves fixed ways of data collections using standardized tools and closed ended questions. The designs involve formal, objective, systematic processes for gathering information about a phenomenon. They are used to describe variables and determine associations and ascertain causal relationships.[1]

The study employed both quantitative and qualitative designs. Firstly, a systematic literature review was conducted to identify interventions for mitigating the risk of waterborne diarrheal diseases in developing and developed countries. Secondly, a quantitative retrospective longitudinal study was used to investigate the trends of diarrheal diseases in peri-urban areas of Lusaka district. The scoping literature review was used to determine available frameworks for mitigating the risk of waterborne diarrheal diseases. Lastly, qualitative case studies were used to validate the framework that was developed from the literature review and thereafter proposed a final framework for use by health authorities.

The use of both qualitative and quantitative method had advantages in the following ways:

Firstly, the use of the quantitative methods enabled the generalization of the results to the target population and similar settings. For example, results of trends of diarrheal

diseases and the framework that was developed. The use of qualitative methods allowed for in-depth understanding of the problem. For instance, the use of case studies in the validation of the framework facilitated deeper understanding of what the health workers and WASH experts thought about the framework that was created.[4]

Overall, the use of both qualitative and quantitative approach strengthened the understanding of the main problem of mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka districts, Zambia.

2.3 Study site

The study was conducted in Zambia a landlocked Sub-Saharan country in Africa. Zambia shares borders with Malawi, Mozambique, Zimbabwe, Botswana, Namibia, Angola, Democratic Republic of Congo and Tanzania. It has a total surface area of 752,614 square kilometers, thus ranking among the smaller countries in South Central Africa. The country has a population of just over 19 million people.[5] There are 10 provinces in the country. This study was conducted in the Lusaka Province which consists of eight districts. Lusaka province has a population of slightly over 2 million people.[5,6] Particularly, the study was conducted in Lusaka district which also happens to be the capital city of Zambia. Figure 2.1 shows Africa, Zambia and Lusaka, district.

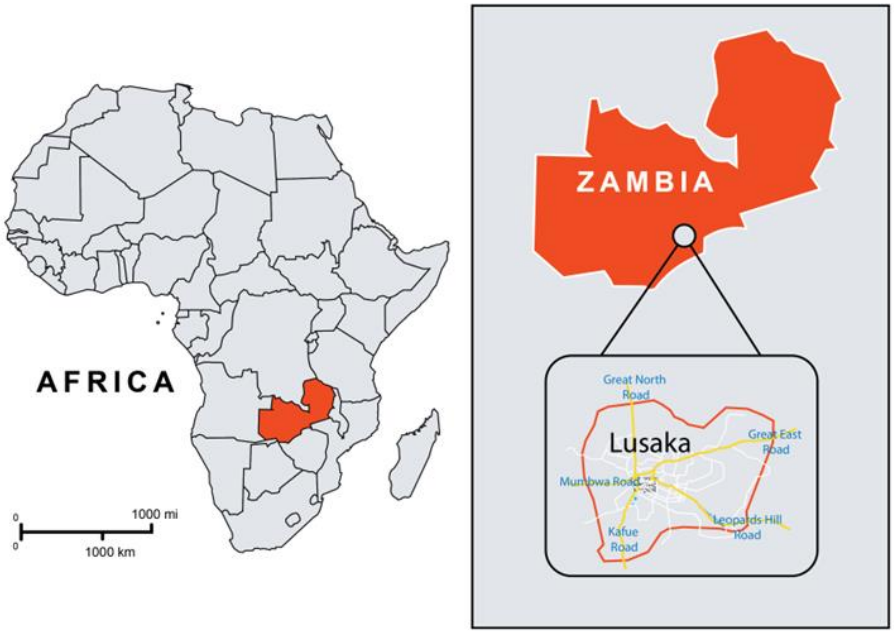

Figure 2.1: Map of Africa showing Zambia and Lusaka district

Lusaka District is the most populated area of Zambia with an approximated total population of just over 1.7 million people. Most of its population live in peri-urban areas. The peri-urban areas were developed due to the migration of people from the rural areas to town in search of greener pastures and other services that are not available in other districts. These areas are unplanned settlements with no connection to the sewerage line most of the households in these areas use pit latrines for human waste disposals. Most of the areas also lack piped water supply, drainage, proper solid waste management and other important facilities. Majority of the households use water from shallow wells. The absence of these facilities has led to outbreaks of waterborne diarrheal diseases such as cholera, typhoid, amoebic and bacillary dysentery. It is for the stated reasons that the study was conducted in Lusaka district with the anticipation that the findings might contribute to mitigating the risk of waterborne diarrheal diseases in these areas.[7-9]

2.4 Development of the framework

2.4.1 Phases of framework development

Figure 2.2 shows a summary of the development of the framework for mitigating the risk of waterborne diarrheal diseases which involved four phases. The first phase involved a systematic literature review of intervention for mitigating the risk of waterborne diarrheal diseases. Phase two a trend analysis of diarrheal diseases in the peri-urban part of Lusaka district. The third phase involved review of available frameworks for mitigating the risk of waterborne diarrheal diseases. The final phase involved development and validation of the draft framework with health workers and other WASH experts and final development of the framework was done.

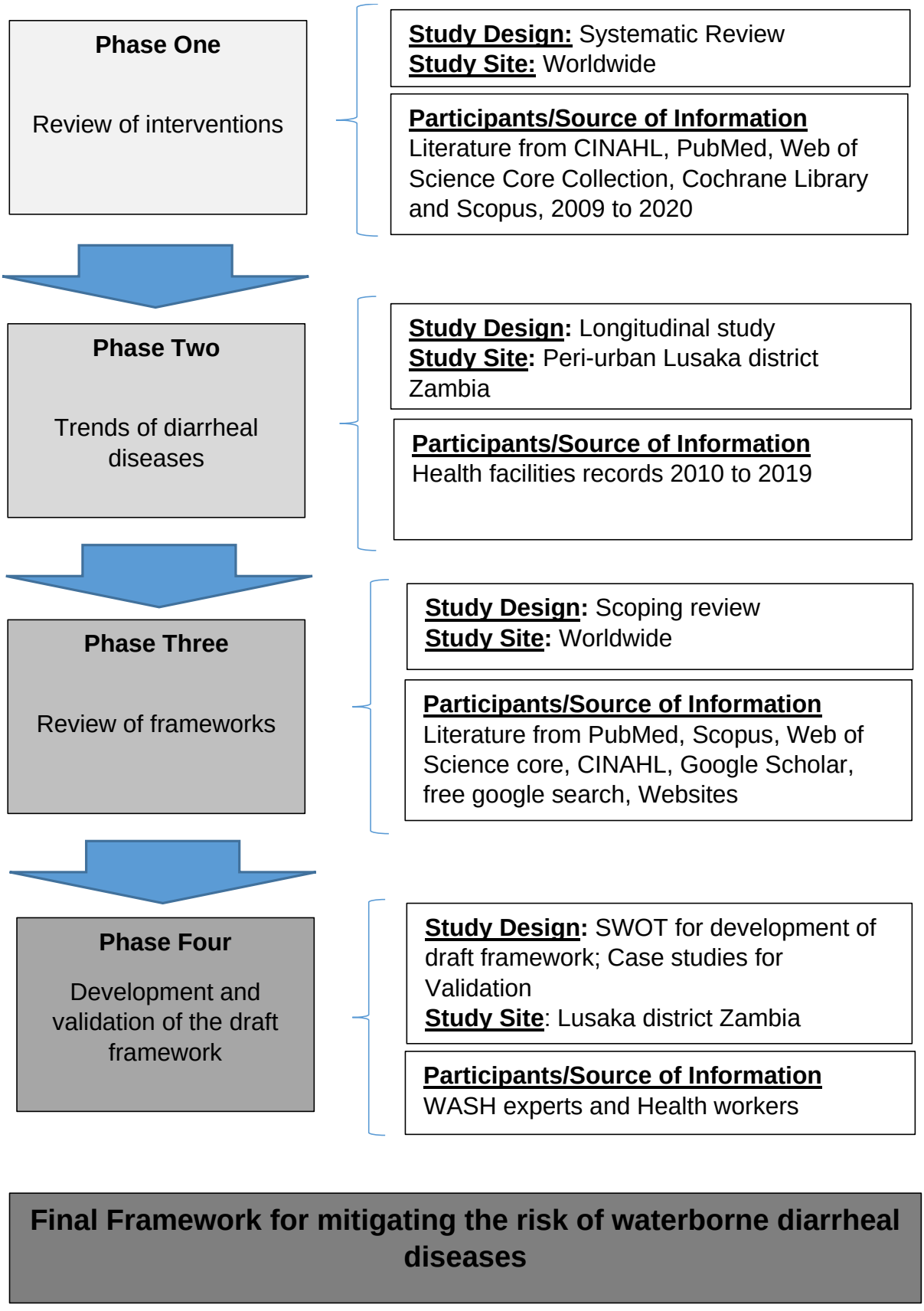

Figure 2.2: Phases in development of the framework

2.4.2 Data collection

The study employed several instruments in the data collection. The first instrument was the data caption form Appendix 4 used for secondary data on diarrheal diseases. The following information was captured on the form: diarrheal cases for each facility per month, season and year, diarrhea cases by age groups, type of diarrhea (bloody or non-bloody, Cholera), number of deaths and health facility catchment population. Data extraction forms were used to extract data from studies and other literature reviews of intervention for waterborne diarrheal diseases and existing frameworks. The forms were developed by adopting and modifying data collection form for intervention review of the Cochrane Collaboration[10] for studies and data extraction form for grey literature by the British Medical Journal Open for grey data,[11] respectively. The tools were made to include all the variables of interest to answer the research questions. The trial data extraction was conducted to make sure that the data extraction form was able to get the required data from the selected literature. Lastly, discussion guides Appendix 5 were used to facilitate the reviews and workshop used in the validation of the draft framework.

2.4.3 Data management and storage

All the data collected was checked by the principal investigator every day after data collection for completeness and consistency.

2.4.4 Data analysis

In this study, independent data analysis was done for each study design. In the retrospective longitudinal study to investigate the trends of diarrheal diseases, the data was entered, cleaned, and analyzed in Stata version 14. Frequencies and proportions were used to summarize diarrhea cases for each health facility per year or season, cases in the different age groups, deaths, type of diarrhea and so on for each health facility. Excel was used to plot the observed cases of diarrhea diseases for the different health facilities to assess the trends. Results are presented in form of tables and graphs. Level of significance was set at less than 5% p value at confidence interval of 95%. The study results were interpreted in line with the research objectives and reviewed literature.

The qualitative data collected in this study during the reviews and draft framework validation workshop was organized manually and synthesized to obtain narratives. SWOT analysis was used to analyze and identify gaps in the frameworks from literature used to develop the draft framework. The association among the themes was used to

understand the findings of the study.

2.5 Ethical considerations

Proposal approval was obtained from the ethical committees in South Africa and Zambia before the start of the study appendices 1.1 and 1.2. Permission was sought from the Ministry of Health Zambia as the custodians of secondary data and overseers of all the health facilities in Zambia appendix 2. Permission was also obtained from health facilities to get information from the health workers that were included in the study. The benefits and risks of the study were discussed with the participants. The use of secondary data in the study had minimal risk since there was no use of people's names and or identification numbers. Only necessary information was obtained for this study. No direct benefits were provided for the participants however they were remunerated for transport money and refreshments were provided during the validation workshop. The transport refund amount was based on the bus fare that each participant used, for those who used their own vehicles fuel cost was reimbursed based on the number of kilometers that they travelled to and from the venue. The researchers made sure that the workshop was kept to minimum time to avoid loss of too much time for the participants. The stakeholders who individually reviewed the draft framework were given enough time i.e., two weeks to review the framework with provision for extension when required.

2.5.1 Informed consent

Consent was obtained from the study participants including the health experts or health workers, academics and policy makers/regulators who were included in the study. Information sheets explaining the purpose and procedure of the study were shared to the participants and they were asked to sign consent forms as a sign of them accepting to be part of the study. Those potential participants who did not agree to take part in the study were thanked and not included in the study. The information sheets and consents forms used in this study were adopted from World Health Organization Appendices 3.1 and 3.2.

2.5.2 Confidentiality

Confidentiality was considered as names were not exposed in the study. Participants were identified using the identification numbers that were created. Furthermore, the study results were used purely for academic purposes. After data collection, the data

was stored under lock and key and the data was stored on a computer with password only accessible to the principal investigator and the supervisors.

2.5.3 COVID-19 measures

Considering the COVID -19 pandemic, all precautions such as wearing of masks and social distancing were observed during the data collection to avoid possible transmission. Free hand sanitizers and face masks were given to the participants. Brief health talks on COVID-19 were given to the participants before data collection.

2.6 Validity and reliability

2.6.1 Validity

Validity is the degree to which a concept is precisely measured and generalization of the study findings to the total study population and similar settings.[12] Validity in this study was ensured by including all the variables of interests in the study instruments. This helped in getting the data to answer the research questions. The research instruments were also reviewed by the supervisors and other research experts who gave their opinions about them. To ensure that the results were generalizable, the study ascertained that all the government health facilities in peri-urban areas were included in the study. In addition, all the diarrheal records available for the study period were included in the study. The study also guaranteed generalization of findings by ensuring that the literature included in the systematic and literature review were from world over. For the systematic review, existing checklists were used to assess the quality of the studies and other literature that was included in the study. This facilitated consistency of the literature included. Several data bases were checked for literature to get representative. The study also involved two people with experience in conducting similar reviews who assisted in determining the studies to be included in the systematic review. This ensured that the appropriate studies were included in the review.

Further, validity was guaranteed by triangulation. Particularly, triangulation included collection of data from different participants including experts and health care workers and used reviews and a workshop to validate the framework. The use of multiple data sources helped to strengthen the conclusions of the study as in-depth information from the different participants with different experiences and viewpoints were combined. Lastly, member checks were also applied to ensure validity. This involved taking back the raw data and interpreted results to participants and data collectors to ensure that the findings were true.

2.6.2 Reliability

Reliability entails the extent to which the findings of the study are consistent overtime and a true representation of the total study population. Reliability also relates to the instrument producing the same results if it is used in the same situation on repeated occasions.[13,14]

Reliability was made certain in different ways. Firstly, tools that were used in this study were made from already existing tools. These tools were pretested in an area outside the study but with similar characteristics to prevent data contamination, and on literature that was not included in the study for data extraction forms. All the research assistants were trained to ensure that data collection was uniformly conducted. The data collectors were also given the same time and resources to collect the data. The issue of data saturation was ensured in the qualitative approaches and details of the research processes were explained to allow for replicability of the findings.

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CHAPTER 3: LITERATURE REVIEW

3.1 Introduction

This chapter presents two reviews that were conducted. The first part is a systematic review on interventions for mitigating the risk of waterborne diarrheal diseases and the second part is the scoping review of frameworks for mitigating the risk of waterborne diarrheal diseases.

3.2 Community Level Interventions for Mitigating the Risk of Waterborne Diarrheal Diseases: A Systematic Review[a]

3.2.1 Abstract

Background

Waterborne diarrhea diseases are among the leading causes of morbidity and mortality globally. These diseases can be mitigated by implementing various interventions. The literature was reviewed to identify available interventions to mitigate the risk of waterborne diarrheal diseases.

Methods

A systematic database review was conducted using CINAHL (Cumulative index to nursing and Allied Health Literature), PubMed, Web of Science Core Collection, Cochrane library and Scopus. The search was limited to articles published between 2009 and 2020. The review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement checklist. The identified studies were qualitatively analyzed.

Results

Our initial search returned 28 773 articles of which 56 studies met the inclusion criteria. The included studies reported interventions, including vaccines for rotavirus disease (Monovalent, Pentavalent and Lanzhou lamb vaccine); enhanced water filtration for preventing Cryptosporidiosis, Vi polysaccharide for typhoid; cholera 2 dose vaccines, water supply, water treatment and safe storage, household disinfection and hygiene promotion for controlling cholera outbreaks.

[a] Manuscript published: BMC Systematic Reviews. 2022; 11(1):73

Conclusions

A few studies were retrieved on interventions against waterborne diarrheal diseases in low-income countries. Interventions were to be specific to each type of waterborne diarrheal disease to be effective. Stakeholders must ensure collaboration in providing and implementing multiple interventions for the best outcomes.

Systematic review registration number: The review protocol is registered under PROSPERO registration number (CRD42020190411).

3.2.2 Background

Waterborne diseases are transmitted through drinking water that is contaminated with human or animal fecal matter containing pathogenic microorganisms,[1] including viruses, bacteria and protozoa that survive and multiply in food, water and other surfaces.[2,3] Most waterborne diseases including cholera, dysentery (Shigellosis and Amebiasis), typhoid, cryptosporidiosis, giardiasis, cyclosporiasis, yersiniosis, salmonellosis, campylobacteriosis and other gastroenteritis infections caused by rotavirus, adenovirus norovirus, enterovirus, caliciviruses, astroviruses and reoviruses manifest as diarrhea.[4] Diarrhea is one of the major causes of mortality and morbidity around the world especially among children.[5-8]

Morbidity and mortality from diarrheal diseases can be reduced by applying various interventions that help to cut the fecal oral transmission route. These interventions include providing adequate and safe water, proper sanitation, hand washing facilities, practicing personal hygiene and food hygiene, education, and vaccinations.[9-14] Exclusive breastfeeding has also been shown to reduce infant morbidity and mortality from diarrheal diseases.[15-17]

The risk of diarrhea can be reduced by washing hands (48%), improving water quality (17%) and disposing of excreta properly (36%).[18] At a global scale, proper water sanitation and hygiene may reduce the global diarrheal disease burden by 9.1% and reduce mortality by 6.3%. [19] Despite water, sanitation and hygiene being critical in preventing and controlling diarrheal diseases, only 71% of people globally have access to safely managed water sources, 45% of people have access to adequate safely managed sanitation and 60% of people have access to basic hand washing facilities.[20]

The different interventions available to prevent and control diarrheal diseases on a global scale have been reviewed and summarized previously. Previous reviews focused

on the importance of proper excreta management in preventing diarrhea diseases,[21] improving water quality for preventing of diarrhea,[22] house fly control to prevent diarrhea,[23] hand washing to prevent diarrhea[24], a review of the rotavirus vaccine[25] and a review on vaccines for preventing cholera, shigella, Enterotoxigenic *Escherichia coli* (ETEC) and rotavirus.[10] In this review, we limited our search to the most recent studies, those published between 2009 and 2020. This will provide an updated review of available interventions against waterborne pathogens that cause diarrhea. Instead of reviewing interventions to reduce the risk of diarrhea in general, interventions to mitigate the risk of waterborne diarrhea diseases at the community level were reviewed. The review focused on diseases caused by pathogens that are found in water contaminated by human or animal excreta. These diseases include cholera, dysentery (shigellosis and amebiasis), typhoid, cryptosporidiosis, giardiasis, cyclosporiasis, yersiniosis, salmonellosis, campylobacteriosis and other gastroenteritis infections caused by rotavirus, adenovirus norovirus, enterovirus, caliciviruses, astroviruses and reoviruses.

Systematic reviews are critical to informing evidence-based policy. This review may help to formulate new policies to mitigate the risk of waterborne diarrhea diseases. Mitigating the risk of waterborne diarrhea disease is vital to achieving the Sustainable Development Goal (SDG) goal number six (SGD 6), ensuring access to water and sanitation for all. To achieve this goal, it is vital that we know which interventions are available to mitigate the risk of waterborne diarrheal disease, globally.

Review question

Which community level interventions exist to mitigate the risk of waterborne diarrheal diseases?

3.2.3 Methods

3.2.3.1 Protocol and registration

The review was conducted between May 2020 and February 2021. The review protocol was registered on University of York Prospero registration number CRD42020190411. The protocol is currently available on: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020190411.

3.2.3.2 Eligibility criteria

Only studies published from 2009 to 2020 were included to ensure the inclusion of current information. Only studies published in English were included due to a lack of resources for translation. Studies conducted from across the globe were included.

3.2.3.3 Participants/Population

Studies that included participants of all ages from all communities affected by waterborne diarrheal diseases were reviewed. The review focused on intervention(s) of interest including water supply, sanitation, hygiene including hand washing, health promotion and education, vaccinations, and breast-feeding. A specific comparison/control group in this review was not included and studies without control groups were also not considered.

3.2.3.4 Inclusion criteria

Studies of any design that had complete methods, results and discussion sections were included. To avoid duplication of results, other reviews were excluded. Documents that summarized other studies such as letters to editors, comment papers, brief reports, abstracts and research news were also excluded. Table 3.1 presents the inclusion and exclusion criteria applied in this review.

Table 3.1 Inclusion and exclusion criteria used to select studies describing interventions for mitigating the risk of water borne diarrheal disease

Inclusion criteria
1. Studies published from 2009 to 2020
2. Full and complete studies
3. Studies conducted across the world
4. Studies conducted in real community level settings i.e., schools, health facilities and households in humans
5. Studies with water supply, sanitation, hygiene, breastfeeding, and vaccination interventions
6. Studies with a waterborne diarrheal disease outcome or water quality outcome
7. Studies reporting effective intervention outcome
8. Studies with confirmed uptake of an intervention(s)
Exclusion criteria
1. Studies not published in English language
2. Studies with waterborne diarrheal disease(s) and another disease(s) outcome
3. Studies that the researcher did not have full text access to.

4. Studies that reported hospital acquired infections/nosocomial infection

3.2.3.6 Condition studied

Studies of waterborne diarrheal diseases that are transmitted to humans when they consume water contaminated with pathogens of human or animal excreta were reviewed. Specifically, waterborne diseases with a diarrheal outcome including cholera, dysentery (shigellosis and amebiasis), typhoid, cryptosporidiosis, giardiasis, cyclosporiasis, yersiniosis, salmonellosis campylobacteriosis and other gastroenteritis infections caused by rotavirus, adenovirus norovirus, enterovirus, caliciviruses, astroviruses and reoviruses.

3.2.3.7 Effect measure

Studies that reported the following measures: frequencies, proportions, prevalence, odds ratios, rate ratio (incidence rate ratio), relative risk, period incidence, median /range, and risk of disease were reviewed. The review did not exclude studies based on predetermined measures of effects.

3.2.3.8 Information about searches

Databases including CINAHL via EBSCOHOST, PubMed, Scopus, Cochrane Library and Web of Science Core Collection were searched. Databases were searched in CINAHL using major headings and free search; PubMed using title and abstract, mesh terms; Scopus using titles /abstract; Web of Science using topics and Cochrane library using title/abstract and Mesh terms. The search terms were identified with the help of a librarian. Synonyms for the key words were identified and used in the search. Truncations were used to retrieve variants of key words and Boolean operators ‘OR’ and ‘AND’ were also used to combine words for searching in each database. Full search strategies for each database are presented in (Appendix 7)**.**

3.2.3.9 Data selection process

After the initial search, all studies were downloaded to Endnote reference manager. Firstly, duplicate articles were removed. Two reviewers screened the title and abstracts of all the articles. All articles that did not meet the inclusion criteria were excluded, and then read the remaining articles in detail. After the preliminary screening, two independent reviewers read the full text articles, a third reviewer validated the screening and resolved any disputes. We extracted data from included studies using a data

extraction form (Table 3.2) adapted from Cochrane, available online: https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.MR000044/full. The data collection sheet was piloted before use. Two reviewers extracted data and a third reviewer resolved any disputes. We searched the reference lists of included articles to check for relevant studies, but we could not identify any new studies.

Table 3.2: Data extraction sheet used to extract information from studies describing interventions for mitigating the risk of water borne diarrheal diseases

Items	Comments
1. Title of study	
2. Authors details	
3. Year of publication	
4. Aim or objective(s) of the study	
5. Type of waterborne diarrheal disease(s)	
6. Study design	
7. Country setting (rural or urban or mixed)	
8. Type of community settings (school, household, heath facility)	
9. Participants and cases	
10. Participant's comparison or control group if available	
11. Sample size	
12. Types of intervention(s)	
13. Intervention comparison or control group if available	
14. Data analysis outcome measures	
15. Results and effects of the interventions	
16. Conclusion	
17. Funding	

3.2.3.10 Data synthesis

Data were synthesized qualitatively, and results summarized narratively. Meta-analysis was not done because the studies had different study designs, outcomes, participants, sample sizes, interventions, locations, contexts and so on. Data were synthesized using thematic analysis and presented under different themes guided by the data extraction tool and findings.

3.2.3.11 Risk of bias (quality) assessment

A librarian from the University of Pretoria, Faculty of Health Sciences was involved at all levels of the study to ensure quality. The librarian helped to formulate search strategies and identify the right search terms, keywords, and synonyms. The librarian helped to retrieve relevant literature. The inclusion and exclusion criteria of the search was created with the help of supervisors. This was followed by the selection of the literature, quality assessment, and data analysis. One of the supervisors helped to resolve disagreements between the two reviewers. The quality of each study included in this review was checked using checklists from Joanna Briggs Institute (JBI) University of Adelaide and the strobe checklist for observational studies at the point of data extraction. This was done to ensure that all the included studies reported the elements required to assess the quality of studies. The risk of bias across studies was not assessed because this was not a meta-analysis.

3.2.4 Results

3.2.4.1 Study selection

The initial search returned 28,773 studies. After removing duplicates, the titles were screened and abstracts of 17,688 articles, of which 143 remained to be screened in full. Eighty-seven articles were excluded after full screening. After full screening, 56 studies that met the inclusion criteria were finally included in the review. The details for the selection of studies are presented in the PRISMA diagram figure 3.1.

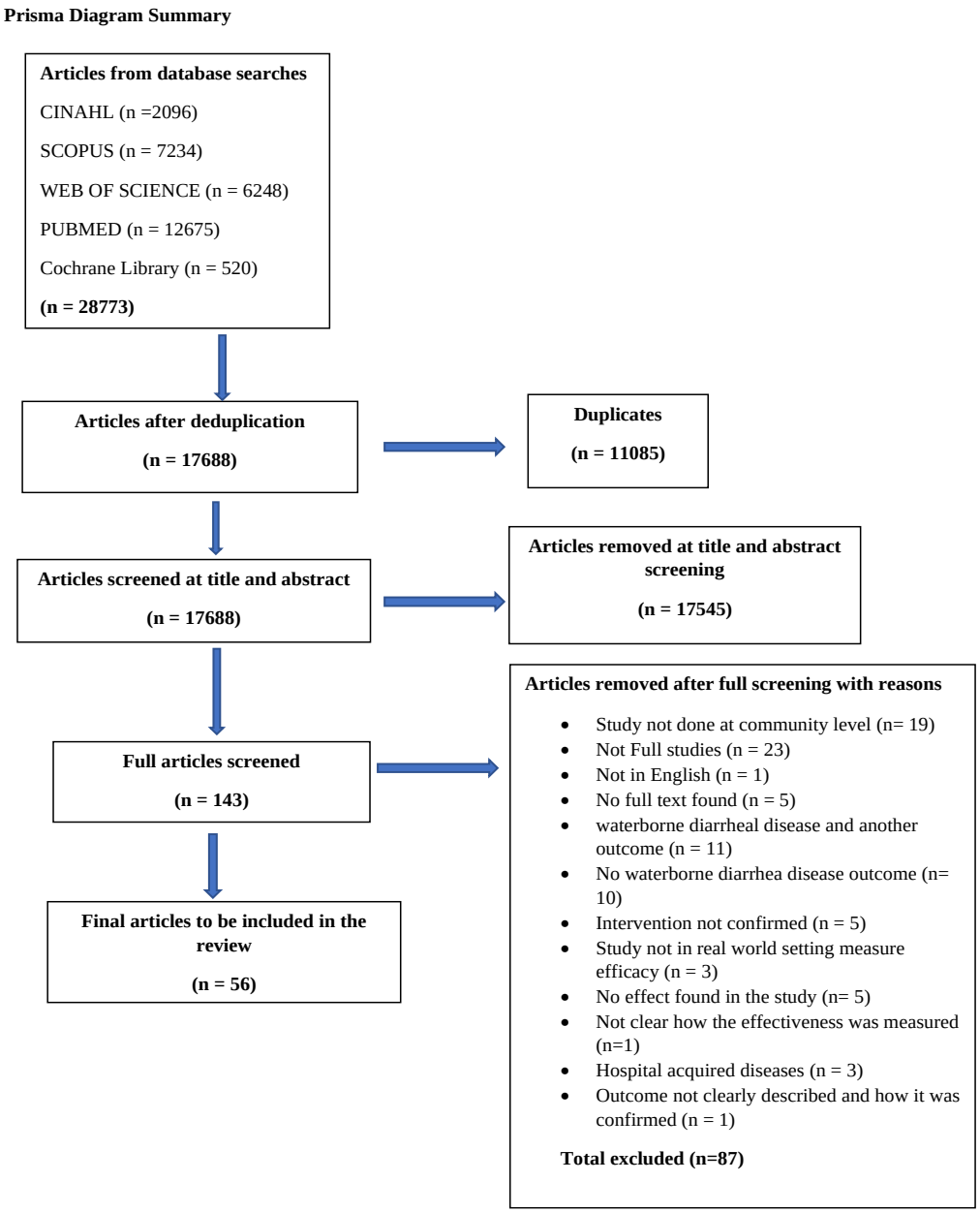

Figure 3.1 PRISMA diagram on selecting studies describing interventions for mitigating the risk of water borne diarrheal diseases

3.2.4.2 Characteristics of studies

Type of waterborne diarrheal diseases

Most of the studies done at community level reported interventions against rotavirus diseases (n=49), five studies reported interventions against cholera, and one study looked at typhoid and another cryptosporidiosis (Appendix 8). We could not find any studies that met the inclusion criteria describing interventions against dysentery (shigellosis and amebiasis), giardiasis, cyclosporiasis, yersiniosis, salmonellosis

campylobacteriosis and other gastroenteritis infections caused by adenovirus norovirus, enterovirus, caliciviruses, astroviruses and reoviruses.

3.2.4.3 Study settings

Studies conducted at the community level were selected, most of these studies were conducted in healthcare facilities (n=51), followed by households and other community settings (n=5) (Appendix 8).

3.2.4.4 Study designs

A total of 22 case control studies were reviewed and 13 studies that were combined surveillance and case control studies. Nine of the included studies were surveillance studies and three were cohort studies. The rest of the included studies were a preliminary community trial (n=1), cluster randomized control trial (n=1), cluster randomized effectiveness trial study (n=1), case study (n=1), retrospective observational study (n=1), retrospective database study (n=1), combined case control and cohort study (n=1), retrospective analysis (n=1) and a combined time series and case control study (n=1) (Appendix 8)

3.2.4.5 Countries and economic status of the included studies

The included studies were conducted in 37 countries, with most studies from the United States (n=7), three conducted in China and the rest from a variety of other countries. According to the World Bank economic classification, most of the studies were conducted in high income countries (n=24), followed by lower middle-income countries (n=15) then upper middle income (n=11) and six studies in low-income countries (Appendix 8)

3.2.4.6 Age groups of study participants

Selected studies included participants of different age categories. Most of the studies looked at interventions to mitigate the risk of waterborne diarrheal diseases in children younger than 5 years old (n=47), children and adults (n=6), children younger than 16 years (n=1), older than 12 years (n=1) and another study involved children younger than 8 years old (Appendix 9).

3.2.4.7 Types of interventions

Many studies (n=49) looked at Rotavirus vaccine of which 22 reported rotavirus Monovalent (RV1) Rotarix vaccine; nine studies investigated Pentavalent (R5) Rotateq vaccine; 16 studies investigated Rotarix and Rotateq vaccine and two other studies addressed Lanzhou lamb rotavirus vaccines. One study considered emergency water supply, household water treatment and safe storage, home disinfection and hygiene promotion at the community level. Four (4) studies reported 2 dose oral Cholera vaccine. Another study reported water treatment through enhanced filtration and another study reported Vi polysaccharide vaccination. The details of all the interventions are presented in (Appendix 9).

Rotavirus vaccines

Monovalent (RV1) Rotarix vaccine

Twenty-two studies reported using monovalent (RV1) Rotarix vaccine to reduce the risk of rotavirus diseases. The monovalent Rota virus vaccine is given orally at 2 months and 4 months of age.

In Zimbabwe, Mujuru et al.[26] showed that the RV1 vaccine was protective against rotavirus of any severity by 61% and against severe rotavirus disease by 68%, in children younger than 5 years and at least 6 months. In Australia, Maguire et al.[27]showed that the two RV1 dose vaccine was effective against 88.6%, 83.7% and 78.7% in children aged 6 to 11 months, 1 to 3 years, and 4 to 9 years, respectively. The vaccine was effectiveness against 89.5% of rotavirus disease in the first year which dropped to 77.05% at 5 to 10 years post vaccination.[27] In Kenya, a surveillance study by Wandera et al.[28] showed that children were protected by one and two doses of RV1 vaccines, with two doses being more effective than one dose. Hospitalization was reduced by 48% after the rotavirus vaccine was introduced in Kenya.[28]

In Zambia, Mpabalwani et al.[29] showed that children younger than five years old had fewer hospitalizations due to rotavirus disease, with hospitalizations dropping by 40% in the first year and 29% in the fourth year after vaccination. In Bangladesh, a trial by Zaman et al.[30] showed that children younger than two years old who had the monovalent rotavirus vaccine had a lower incidence of rotavirus (29%), with higher effectiveness in the first year compared to the second-year post vaccination. In villages that received the rotavirus vaccine, children had a lower incidence of Rotavirus disease, 2.8 per 100

person years compared to 4.1 per 100 person years in villages where the vaccine was not administered.[30]

In Armenia, Sahakyan et al.[31] showed that when vaccinated, children between 0 and 59 months old had 48% fewer hospitalizations due to rotavirus in the first year after vaccination and ≥75% fewer hospitalizations in the 2nd and 3rd year post vaccination. Interestingly, unvaccinated children also had more than 30% fewer hospitalizations, suggesting other community level factors affecting the incidence of rotavirus disease.[31] The two-dose monovalent vaccine reduced the incidence of rotavirus disease of any severity by 62% in children aged 6 to 23 months; 68% in those aged 6 to 11 months and 60% in children aged 12 to 23 months.[31] In Moldova, the introduction of a vaccination program for children aged 6 months to 5 years, led to hospitalizations for rotavirus dropping from 45% to 25% and 14% in the first and second years, respectively.[32] The two-dose rotavirus vaccine was also effective in preventing 79% of rotavirus hospitalizations and 84% of hospitalization for severe disease.[32] The reduction in hospitalizations was also seen in unvaccinated children.[32] In Botswana, children older than 4 months who received the two-dose vaccine had 54% fewer hospitalizations after two doses and 48% fewer hospitalizations after one dose.[33]

In Malawi, children younger than five years old, who received the monovalent rotavirus vaccine were 70.6% and 31.7% less likely to be hospitalized for rotavirus disease, in the first and second year of life, respectively, irrespective of nutritional status or HIV exposure.[34] In Malawi, the introduction of a rotavirus vaccination program for children younger than 5 years led to hospitalizations for rotavirus dropping from 50% to 40% and 31% in the years following vaccination introduction.[35]

In Brazil, children between 4 and 24 months old, who received 2 doses of the RV1 vaccine had 72% fewer hospitalizations and those who received one dose had 62% fewer hospitalizations for rotavirus diarrhea.[36] In South Africa, children aged 18 to 23 months who received two doses of RV1 vaccine had a 57% reduced risk of being hospitalized, while children who received one dose had a 40% reduced risk of being hospitalized for rotavirus diarrhea, irrespective of HIV exposure status.[37]

In Bolivia, among children of at least 8 weeks old, those who had received the RV1 vaccine were 69% less likely to be hospitalized compared to rotavirus negative controls and 77% less likely to be hospitalized compared to non-diarrhea controls.[38] As with other studies, one dose of the RV1 vaccine resulted in protection, but to a lesser degree: 36%

for negative controls and 56% for non-diarrhea controls.[38] In addition, the study showed sustained protection of the vaccination and protection of vaccine against various serotypes.[38] In Belgium, children of at least 14 weeks old, who received two doses of RV1 vaccine had 90% reduction in hospitalizations for rotavirus gastroenteritis.[39] The vaccine was also protective against 86% of co-infected cases (adenovirus, astrovirus and/or norovirus).[39] In Brazil, children who were at least 12 weeks old, who received the RV1 vaccination had a 75.8% reduced risk of hospitalization compared to neighborhood controls and a 40% reduced risk compared to hospital controls.[40]

In Zambia, children up to five years old, who were vaccinated with two doses of the RV1 vaccine, showed between 26% and 56% fewer hospitalizations depending on age.[41] In Tanzania, the introduction of a vaccination program led to reduced detection of rotavirus in children younger than five years old.[42] Children between 5 and 23 months old, who received one dose of monovalent vaccine showed 53% fewer hospitalizations, while those who received two doses of vaccine showed 49% fewer hospitalizations.[42] In Canada, increased vaccine coverage in children between eight weeks and three years old led to a 70.1% reduction in rotavirus prevalence, with a 1% increase in coverage leading to a 3.8% decrease in prevalence.[43] In Morocco, children younger than five years old who received the rotavirus vaccine, were 41% less likely to be hospitalized.[44]

In Colombia, children of at least 8 weeks old were vaccinated and followed up.[45] Between 6 and 11 months old, vaccine effectiveness was 79.19%, and 39.75% among children older than one year. Hospitalizations were reduced by 84.42% among children 6 to 11 months old, and by 79.49% among children older than one year.[45] In Nairobi, Kenya, the introduction of a vaccination program for children younger than five years led to a decline in rotavirus infections from 22.1% in 2015 to 14.8% in 2016 to 10% in 2017.[46] In Italy, the introduction of a vaccination program led to a 49.2% reduction in hospitalizations for rotavirus disease.[47]

Pentavalent (RV5) Rotateq

Nine studies reported the use of Pentavalent vaccine as an intervention for rotavirus. The vaccine is given to children at 2months, 4 months and 6 months.

In these children, vaccine effectiveness was 77% in children aged 6 to 59 months and 86% in children aged 6 to 23 months for children who received the full dose, while an incomplete doses 72% and 75% protection for the respective age categories in a study done in Israel.[48] In Bukina Faso, the introduction of the vaccine resulted in reduced

hospital admission from 36% in 2014 to 22% in 2015 to 20% in 2016 among children under the age of five.[49] The reduction in hospitalizations was even more pronounced for infants, dropping from 38% in 2014 to 21% in 2015 to 17% in 2016.[49] In Burkina Faso, the full three dose RV5 vaccine offered 58% protection against rotavirus hospitalization in children 6 to 11 months old and 19% in children older than one year.[49]

In Finland, among children younger than 16 years old who received three doses of the RV5 vaccine, vaccine effectiveness was 92.1%.[50] In Finland, the introduction of the vaccination program led to a 78% reduction in hospitalizations.[50] In Israel, a surveillance study showed that vaccine effectiveness was 63% against emergency department (ED) visit or hospitalization for children between six months and five years old who had received the full vaccination schedule.[51] For different age groups, vaccine effectiveness was 64% for children aged 6 to 11 months and 71% for children between 12 to 23 months.[49] Vaccine effectiveness was 59% against hospitalization and 67% against ED visit.[51]

In Nicaragua, vaccine effectiveness was reportedly 87% for children younger than five years old who had received three doses of the RV5 vaccine compared to community controls, 64% for hospital controls and 76% when the groups were combined.[52] In France, the introduction of the RV5 vaccine led to the halving of hospitalizations within two years of vaccine introduction, and a risk reduction of 98% for hospitalizations for rotavirus diarrhea.[53]

In Nicaragua, RV5 vaccination with 3 doses was associated with a lower risk of rotavirus diarrhea requiring overnight admission or intravenous hydration (odds ratio [OR] 0.54) and a progressively lower risk of severe (OR, 0.42) and very severe rotavirus diarrhea (OR, 0.23).[54] In Nicaragua, vaccine effectiveness of RV5 was 46% against rotavirus disease requiring admission or treatment with intravenous hydration, 58% against severe rotavirus diarrhea and 77% against very severe rotavirus diarrhea.[54] In the USA, in children younger than five months old, vaccine effectiveness was 74% after one dose, 88% after two doses and 87% after three doses.[55] For infants enrolled in the IVANHOE surveillance study, a RV5 vaccination program led to a 2.6 to 11 fold reduction in rotavirus hospitalizations for premature infants.[56]

Rotarix and Rotateq

Sixteen studies reported on the combined use of Rotarix and or Rotateq vaccine to mitigate the risk of Rotavirus at a community level.

In Japan, the RV1 and RV5 vaccines had a combined effectiveness of 70.4% against hospitalization due to rotavirus gastroenteritis in children younger than 5 years old.[57] In China, vaccine effectiveness for either rotavirus vaccine was 92% against hospitalization of children between one month and five years old.[58] In the USA, the RV1 and RV5 vaccines had similar effectiveness,[59] with two doses of RV1 resulting in vaccine effectiveness of 84% among children aged 8 to 23 months and 82% among children older than two years old, against emergency department visits or inpatient care. For the same age groups, three RV5 doses had a vaccine effectiveness of 80% and 87%, respectively.[59]

In Guatemala, the RV1 (63%) and RV5 (69%) vaccines were shown to have a similar effectiveness.[60] Combined vaccine effectiveness was 74% with hospital controls, and 52% with test-negative controls against visiting the emergency department or hospitalization.[60] In Portugal, vaccine efficacy was lower for at least one dose of RV1 (83.7%) compared to one dose of RV5 (96.1%) in a cohort of children between 8 weeks and three years old against acute gastroenteritis.[61]

In Taiwan, two doses of the RV1 vaccine had an effectiveness of 90.4% and 92.5% with RV-negative acute Gastroenteritis (AGE) and non-AGE controls, respectively, against hospitalization for rotavirus gastroenteritis for children between eight months and three years old.[62] Three-dose RV5 had a greater effectiveness, of 96.8% and 97.1% compared to RV-negative AGE and non-AGE controls, respectively.[62] In the USA involving, three doses of the RV5 vaccine (84%) than two doses of the RV1 vaccine (70%) in preventing rotavirus-associated hospitalizations and emergency department visits of children younger than five years old.[63] In Spain, the RV1 and RV5 vaccines had similar effectiveness in preventing rotavirus gastroenteritis (78%) and hospitalization (83%) in children between three months and five years old.[64]

In the USA, vaccine effectiveness against hospitalization with rotavirus gastroenteritis for at least one dose of vaccine was 94.3% for hospitalized controls and 96.9% for community controls.[65] In Saudi Arabia, the introduction of a national vaccination program reduced hospitalizations due to rotavirus-positive gastroenteritis from 38.5% to 13.2% and increased the median age of infection from 16 to 44 months.[14]

In Japan, RV1 and RV5 vaccines had similar effectiveness of 80.6% and 80.4%, respectively. [66] Although vaccine effectiveness reduced with age, an effectiveness of greater than 70% was maintained up to 2 years after vaccination.[66] Vaccine

effectiveness against severe gastroenteritis, requiring intravenous rehydration or hospitalization, was 97.3%.[66] In Lebanon, combined vaccine effectiveness of the RV1 and RV5 vaccines was 68.4%, children who were rotavirus negative 21% more likely for to be vaccinated compared to unvaccinated children who were rotavirus positive.[67]

In the USA, combined vaccine effectiveness for full RV1 and RV5 vaccines was 80% in children younger than eight years old.[68] In the USA, Mohammed et al.[69] showed that children were still protected if they received combined vaccines (single vaccine OR 0.21 vs combined OR 0.29). In Belgium, hospitalizations declined in children younger than two years old, in the first year after vaccination (65%) and the second year after vaccination (80%).[70] For children younger than two months, hospitalizations declined by 50% and 64% in the first- and second-year post vaccination, respectively.[70] For children older than two years, hospitalizations declined by 20% in the first-year post vaccination and by 64% in the second year post vaccination .[70] In the USA, a cohort study, linking stool samples with immunization records showed that vaccine effectiveness was similar for RV1 (91%) and RV5 (92%).[71]

Lanzhou lamb rotavirus vaccine

Two studies reported on the Lanzhou Lamb Rotavirus vaccine. Both were case control studies involving children younger than 5 years, both conducted in China. The first study by Li et al.[72] found a vaccine effectiveness of one dose vaccine verses zero vaccine to be 34.9%, 87.7% effective against severe disease, and 36.2% for children 2 to 35 months old. Fu et al.[73] found a vaccine effectiveness 44.3% for children 9 to 11 months old, 52.8% for children 12 to 17 months old and 51.8% for children 18 to 35 months old for one dose.[73]

3.2.4.8 Combined water supply, household water treatment and safe storage

In Kinshasa, interventions to implement an emergency water supply, household water treatment and safe storage, home disinfection and hygiene promotion led to a 71% reduction in the cholera cases in 4 weeks among people two years and older.[74]

3.2.4.9 Oral cholera vaccine

Four studies reported on two dose oral cholera vaccines. In Guinea, two dose vaccines were 86.6% effective in preventing cholera among cholera suspects older than 12 years.[75] In India, a two dose and single dose cholera vaccine was 69.0% and 33% effective, respectively.[76] In Haiti, the cumulative 4-year vaccine effectiveness of 2 doses

was 76% and predicted effectiveness of the single dose was 79%, which was not effective by the second years after vaccination.[77] In Tanzania, a two dose vaccine for people older than two years old resulted in protection of 79% against, this protection seemed to extend to non-vaccinated individuals who stayed in households were neighbors had been vaccinated.[78]

3.2.4.10 Water filtration

Only one study, from Scotland reported on use of enhanced filtration of drinking water as an intervention for cryptosporidiosis, where the incidence of cryptosporidiosis was associated with unfiltered water supply to homes (OR 1.86).[79]

3.2.4.11 Vi Polysaccharide vaccination

At the community level, Vi polysaccharide vaccines have been tested against typhoid in one study. In India, the incidence of *Salmonella Typhi (S. Typhi)* and *Salmonella Paratyphi (S. Paratyphi)* reduced after two years of vaccination from 194/100,000 and 104/100,000 to 190/100,000 and 170/100,000, respectively.[80]

3.2.5 Discussion

In this review, 56 studies were retrieved, mostly case control studies that reported on interventions to reduce the incidence or prevalence of waterborne diarrheal diseases at a community level. Waterborne diarrheal diseases included rotavirus, cholera, typhoid, and cryptosporidiosis with most of the studies reporting rotavirus diseases. Interventions included rotavirus vaccines (Monovalent, Pentavalent and Lanzhou Lamb), emergency water supply, household water treatment and safe storage, home disinfection and hygiene promotion. Other studies reported on two dose cholera vaccines, enhanced water filtration for cryptosporidiosis and Vi Polysaccharide vaccine for typhoid.[81] The identified studies mostly reported interventions targeting children younger than 5 years old. Most of the studies were conducted in the USA, in high income countries and developing countries. In addition, some studies reported indirect effects of the interventions on reducing the risk of diseases. Across the world, diarrheal diseases are commonly caused by waterborne pathogens. Diarrheal disease is a leading cause of mortality among children in developing countries.[82-84] Young children generally have poor immunity to diarrheal disease due to their poorly developed digestive system and higher risk of dehydration. In developing countries, exposure to unsafe drinking water, poor sanitation and hygiene may also contribute to increased risk.[85] In the USA, rotavirus was the major cause of severe diarrhea among children before vaccines were

developed.[86] The development of vaccines may explain why so many studies have been conducted in the USA. Rotavirus is common in developing countries, including African countries, and vaccines have led to a reduced burden of disease in these areas.[87,88] The disproportionate risk of children to diarrheal disease may also explain why most studies focus on this age group.

Most of the interventions, identified at the community level, focused on the effectiveness of rotavirus vaccines. The review identified studies that reported three (3) types of vaccine for rotavirus including Rotarix (RV1), Rotateq (RV5) and Lanzhou Lamb. These are the three most commonly available rotavirus vaccines.[83,89] These vaccines have been successfully implemented across the world and have reduced hospitalizations of infants requiring rehydration in many countries.[90,91] Our review revealed that cholera is a common problem in lower-middle income and low-income countries or developing countries such as Democratic Republic of Congo, Tanzania, Guinea, Haiti and India.[92] In these countries, the high incidence of cholera can be attributed to poor provision of water, sanitation and hygiene facilities and poor health care systems.[93,94] We identified studies that tested the effectiveness of a two-dose cholera vaccine, which was effective in people older than 12. One dose was less effective than two doses in protecting against cholera infection.[95] Governments of developing countries must aim to improve water supply, sanitation, and hygiene facilities to control cholera outbreaks.

The limited time frame of the search may explain why vaccines featured so heavily in the returned results. One study, from Kinshasa DRC, investigated the use of combined interventions including emergency water supply, household water treatment with chlorine and safe storage, home disinfection and hygiene promotion activities and accessories such as soap and health messages to households to reduce cholera cases. Taylor et al.[100] also reported that a combination of interventions, including treat at point of use, hygiene promotion, water storage in disinfected vessels and household disinfections helped to control cholera outbreaks in developing countries. Improving sanitation infrastructure such as toilets can also help to control cholera outbreaks, especially in developing countries that lack basic infrastructure and do not always have access to vaccines.

Recently, one study from Scotland, reported using advanced water filtration techniques to remove cryptosporidiosis from household water supply. In the USA, Betancourt and Rose[101] also reported using ultra and micro filtration to remove cryptosporidium cysts from the water supply. These tiny cysts cannot be removed from water using standard

water treatment techniques.[102] Identifying and treating water-borne pathogens at a community level is important, because different pathogens will require different interventions.

Several studies that showed indirect effects (herd immunity) of various interventions to reduce the risks of waterborne diarrheal diseases were reviewed. In Moldova and Bolivia, Gheorghita et al.[32] and Patel et al.[38] reported a drop in hospitalizations among vaccinated and unvaccinated children. This has been noticed before where both RV1 and RV2 had indirect effects on unvaccinated people.[104] Similar effects were reported for cholera vaccines and the Lanzhou Lamb vaccines.[105]

3.2.6 Limitations

Articles written in other languages were not reviewed. This might have resulted in missing important studies from non-English speaking populations. However, different databases were searched to ensure that a variety of studies were included in the review. The search was not restricted to a particular region or area. A meta-analysis was not conducted; however, the qualitative narratives give a general idea of the existing interventions to mitigate the risks of waterborne diarrhea diseases at a community level.

Only studies that reported interventions with positive outcomes were included. This was important because the aim was to identify effective interventions for mitigating the risk of waterborne diseases. The inclusion of different types of study designs most of which cannot conclude causation, is a limitation. Further, the reviewed studies included were all peer reviewed to ensure quality.

3.2.7 Conclusions

Currently several interventions exist to mitigate the risk of waterborne diarrhea diseases including vaccines for Rotavirus diseases (Monovalent, Pentavalent and Lanzhou lamb Vaccines), 2 dose cholera vaccines, water supply, household water treatment and safe storage, home disinfection and hygiene promotion for cholera, enhanced filtration of water for Cryptosporidiosis and use of Vi polysaccharide vaccine for Typhoid. Results from this study show that interventions for waterborne diseases must be concentrated in developing countries as they are the main areas where these diseases are most common. The interventions must also concentrate mostly on control of the disease in children even though adults are also affected. At a community level, vaccines seem to be the most effective interventions and are probably the easiest to implement.

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3.3 Frameworks for Mitigating the Risk of Waterborne Diarrheal Diseases: A Scoping Review [b]

3.3.1 Abstract

Background

Diarrhea is one of the major causes of death and morbidity around the world.

Objectives

This scoping review summarizes existing frameworks that aim to mitigate the risks of waterborne diarrheal diseases and describe the strengths and weaknesses of these frameworks.

Eligibility criteria

Published frameworks designed to mitigate the risks of waterborne diarrheal diseases. Frameworks published in English, from around the world and published since inception to date.

Sources of evidence

PubMed, Scopus, Web of Science, Google Scholar, Google Free Search, organization websites and reference lists of identified sources.

Charting methods

Data were charted using the Joanna Briggs Institute tool. Results were summarized and described narratively. A criterion to score the strengths and weaknesses of the included frameworks was also developed.

Results

Five frameworks were identified including: the hygiene improvement framework, community led total sanitation, global action plan for pneumonia and diarrhea, participatory hygiene and sanitation transformation, and sanitation and family education.

These frameworks shared several common components, including identification of problems and risk factors, identification and implementation of interventions, and evaluation and monitoring.

[b] Manuscript published: PLoS One. 2022; 17(12): e0278184

The frameworks had several interventions including different infrastructure, health promotion and education, enabling environment and clinical treatments. Most of the frameworks included health promotion and education. All the frameworks were strengthened by including strategies for implementing and delivering intervention, human resource aspect, community involvement, monitoring, and evaluation. The main weakness included not having components for collecting, storing, and transferring electronic data and the frameworks not being specifically for mitigating waterborne diarrheal diseases. In addition, the identified frameworks were found to be effective in mitigating the risk of diarrhea diseases among other health effects.

Conclusions

Existing frameworks should be updated specifically for mitigating waterborne diarrheal diseases that includes the strengths and addresses weaknesses of reviewed frameworks.

3.3.2 Introduction

Diarrheal diseases are a major cause of morbidity and mortality around the world, especially in developing countries. The burden of diarrheal diseases is greatest in children under the age of five.[1-3] According to the World Health Organization (WHO), diarrheal diseases caused by unsafe drinking water, poor sanitation and hygiene have resulted in the deaths of an estimated 829,000 people[4,5] The burden of diarrheal diseases is likely to grow because more than 2 billion people across the globe lack access to safely managed water services, safely managed sanitation services and basic services for handwashing.[6]

Most diarrheal diseases are caused by waterborne pathogens that are ingested when people drink unsafe water that contains fecal matter. Waterborne diarrheal diseases include cholera, campylobacteriosis, typhoid fever, salmonellosis, shigellosis/ bacillary dysentery, cholera yersinosis, cryptosporidiosis, amebiasis (amoebic dysentery), cyclosporiasis and giardiasis and other gastroenteritis diseases caused by Adenoviruses, Astroviruses, Caliciviruses (e.g., Norwalk, Norwalk-like and Sapporo, Sapporo-like viruses), Enteroviruses (e.g., polio, echo, encephalitis, and Coxsackie viruses), Reovirus and Rotavirus.[7-9] The fecal-oral route plays an important role in understanding the transmission of diarrheal diseases.[3] Most available interventions that aim to prevent diarrheal diseases focus on halting the fecal-oral transmission route.[10]

Many interventions are available to mitigate diarrheal diseases.[11,12] All these interventions can contribute to the holistic prevention of diarrheal diseases. These interventions include vaccines (e.g., rotavirus and measles), early and exclusive breastfeeding, vitamin A supplements, promoting handwashing with soap, improved water quantity and quality, household treatment and safe storage, providing sanitation services for solid and liquid waste management, health education and promotion. Many community clinics also have diarrhea treatment packages that include fluid replacement and zinc treatment.[11,13,14] To maximize effectiveness and long-term sustainability, these interventions should be supported in legal and policy frameworks, have the necessary resources and involve stakeholders from the community, government, private sector and international communities.[11,15]

Despite the availability and application of these interventions, waterborne diarrheal diseases are still recorded in developing countries.[14] In developing countries, the high incidence of waterborne diarrheal diseases may be due to various factors ranging from noncompliance to interventions and interventions not being available where they are most needed.[14,16] Aside from individual interventions, operational frameworks and or approaches have been developed to reduce the risk of diarrheal diseases in communities. Examples of these frameworks include 'Community Led Total Sanitation' (CLTS), 'Participatory Hygiene and Sanitation Transformation' (PHAST) and the 'Hygiene Improvement Framework' (HIF).[17] These frameworks consist of rules and ideas that aim to systematically deal with a particular problem, in this regard waterborne diarrheal diseases.[18]

To date, no reviews have summarized the available frameworks for reducing the risk of waterborne diarrheal diseases. A scoping review of the available frameworks to reduce the risks of waterborne diarrheal diseases was conducted. Findings of this review may provide a platform for developing new frameworks or updating existing frameworks, which might ultimately help to attain the Sustainable Development Goals numbers three and six which addresses good health and wellbeing, and clean water and sanitation for all by 2030.[19]

Objectives

The aim of this scoping review was to identify the frameworks for mitigating the risk of waterborne diarrhea diseases and critically review the frameworks to identify their strengths and weaknesses.

A scoping review was selected as it is important to identify and map existing literature as well as identify key concepts and gaps in research.[20]

3.3.3 Methods

The Preferred reporting items for systematic reviews and meta-analysis for scoping reviews (PRISMA-ScR) was adhered to in this review.[21] The protocol for this scoping review was not published.

3.3.3.1 Eligibility criteria

Data bases were searched with no limits on date of publication or setting. However, only frameworks reported in English were included due to lack of financial resources for translation. The review excluded proposals and only included final documents.

3.3.3.2 Inclusion and exclusion criteria

Frameworks for mitigating the risk of diarrheal diseases were included. These included frameworks for preventing diarrhea, or frameworks for preventing and controlling or treating waterborne diarrheal diseases. The review considered the most recent versions of these frameworks and the frameworks had to be published in a reliable source. Frameworks that focused only on clinical treatment of diarrheal diseases, frameworks published in unreliable sources, frameworks that focused on animals and articles that we did not have access to were excluded. Further, studies that only reported interventions and mathematical models were also excluded. An eligibility criterion was created before literature search. Importantly, only frameworks that addressed diarrheal diseases in general were found. None of the existing frameworks specifically addressed waterborne diarrhea diseases.

3.3.3.3 Information sources

The following databases were searched: PubMed (13th April to 31st August 2021), Scopus (22nd April to 2nd August 2021) and Web of Science (22nd April to 2nd August 2021). Google Scholar (23rd to 29th June 2021) and Google Free Search (2nd to 16th August 2021) were also searched. Further, websites of organizations including the WHO, United Nations Children's Fund (UNICEF), WaterAid, United States Agency for International Development (USAID), World Vision and the Foreign, Commonwealth and Development Office, World Bank and the Asian Development Bank were searched. Lastly, the reference lists of identified frameworks were also searched but found no additional frameworks. The search terms and full search strategies for PubMed, Scopus

and Web of Science are presented in (Table 5.1) Chapter 5. The search terms were obtained from literature and refined in conjunction with a librarian at the University of Pretoria, South Africa and all the authors. The search strategy was also peer reviewed by independent researchers who have conducted similar reviews.

3.3.3.4 Selection of articles

After the initial search, all the articles were downloaded into Endnote software where the duplicates were identified and removed. Two independent reviewers screened the titles and abstracts and selected the articles that presented suitable frameworks. A third reviewer acted as arbitrator to help resolve disputes.

3.3.3.5 Data charting process

A data charting form was used to extract data from selected articles. The Joanna Briggs Institute (JBI) scoping review data extraction tool was modified to suit the review. The data charting form included the following key items:

- Author(s)/developers
- Year of publication
- Origin/country of origin (where the source was published or conducted)
- Aims/purpose
- Components of framework
- Intervention type, implementation areas, target groups
- Effects of the framework/outcome measure
- Outcome measure

The charting process was interactive, and the tool was modified as data were extracted. Two reviewers charted the data, with a third reviewer acting as arbitrator.

3.3.3.6 Identifying strengths and weaknesses of frameworks

A scoring sheet to identify any strengths and weaknesses in the selected frameworks was developed. The scoring sheet was based on two existing frameworks, namely the Center for Disease Control and Prevention (CDC) framework for preventing or controlling communicable diseases[22] and the national framework for control of communicable diseases, Australia.[23] These frameworks were used as a benchmark because they both contain general components of frameworks. These two frameworks focus on general communicable diseases of which waterborne diarrheal diseases are a part.

In addition to the components obtained from the two standard frameworks, other components were added to the score sheet, including whether the framework identified and quantified risk, whether the intervention targeted multiple groups, whether the intervention could be implemented within existing structures, whether the framework was sustainable and focused on waterborne diarrhea diseases[24-27] and included electronic means of data collection, storage and transfer. The 17 components included in the score sheet is presented in Table 3.3. The frameworks were independently scored by two individuals with an independent arbitrator.

The results of the reviews are presented in tables, and diagrams of the frameworks are also included. Each framework is also explained in a narrative synthesis. A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis was conducted to score the frameworks, using the scoresheet presented in table 3.3.

Table 3.3: Score sheet used to assess the strengths and weaknesses of existing frameworks for mitigating the risk of diarrheal diseases

	Criterion and sources	Score	Definition
1	Problem identification[22, 23]	1	Identify the problem using epidemiological and laboratory surveillance
		0.5	Include only epidemiological surveillance or laboratory surveillance but not both
		0	No problem identification
2	Risk identification and quantification (authors)	1	Has a component of risk identification and quantification
		0.5	Included only risk identification or quantification
		0	No component of risk identification and quantification
3	Identification of interventions[22, 23]	1	Identification of intervention
		0	No identification of interventions
4	Integrated approach[22]	1	Include at least hardware and software interventions
		0	Includes either the software or hardware intervention(s)
5	Interventions target multiple groups (authors)	1	Intervention targets multiple groups in the community
		0	Interventions only targets one group in the community e.g., children under 5 years only
6	Implementation and delivery of interventions[22]	1	Has component of implementation and delivery of intervention
		0	No component of implementation and intervention delivery
7	Means of financing and or resource mobilization[22, 23]	1	Has a component of means of financing or resource mobilization
		0	No component of financing and or and resource mobilization

	Criterion and sources	Score	Definition
8	Human resources[23]	1	Component of required human resources in the program
		0	No component of human resources required in the program
9	Implementation of interventions/program within existing structures (authors)	1	Intervention or programs implemented within existing structures
		0.5	Not clear whether the program is implemented within existing structures but there is a component of implementation
		0	No component on of implementation in existing structures
10	Multiple stakeholders' involvement[22, 23]	1	Involvement of different stakeholders in diarrhea mitigation activities or program
		0.5	Not too clear whether multiple stakeholders are involved in the program or activities
		0	No involvement of multiple stakeholders
11	Community involvement[22, 23]	1	Community involved in the whole process
		0.5	Not clear whether there is community participation or not
		0	No component of community involvement
12	Monitoring - follow-up[22, 23]	1	Component of monitoring available
		0.5	Not clear of monitoring component
		0	Monitoring component not available
13	Evaluation - measure of success[22, 23]	1	Evaluation component available
		0.5	Not clear of availability of evaluation
		0	No evaluation component
14	Electronic means of data collection, storage and transfer[22, 23] (authors)	1	Availability of electronic means of data collection, storage and transfer
		0	No means of electronic data collection, storage and transferring
15	Means of sustainability (authors)	1	Has a component of sustainability and explains the means of sustainability
		0.5	Has a component of sustainability but means of sustainability not clearly explained
		0	No component of sustainability
16	Focuses on waterborne diarrhea diseases (authors)	1	Framework focuses on waterborne diarrhea diseases
		0	Framework does not focus on waterborne diarrheal diseases
17	Laws and policy development and improvement on intervention[22, 23]	1	Component of laws and policy development or improvement
		0	No component of laws and policy development or improvement

Note: Authors - These components were included by the researchers. Multiple stakeholder involvement: Program involving different government department or institutions, private sectors, non-governmental organizations, and international communities etc.

3.3.3.7 Critical appraisal of evidence

The included frameworks were not critically appraised, as they did not have specific study designs or outcomes that can be measured using existing tools. To ensure quality, only frameworks published in reputable sources and by known organizations were included.

3.3.4 Ethical considerations

This study was approved by the Faculty of Health Science Research Ethics Committee of the University of Pretoria (REF: 847/2019) and the University of Zambia Biomedical Research Ethics Committee (UNZABREC) (REF: 808-2020). Informed consent was not considered in this study since no individual participants were included. The review only included already published literature.

3.3.5 Results

3.3.5.1 Selection of sources

Initially, a total of 9,582 sources were retrieved from Scopus (n = 2,641); Web of Science (n = 2,575) and PubMed (n = 4,227), and a further 139 sources from Google Scholar, Google Free Search, and organization websites. After removal of duplicates, 6,246 documents were retained for title and abstract screening. A total of 6,185 ineligible documents were removed, leaving 61 sources for full screening. After full screening, 56 sources were excluded for various reasons (Figure 3.2). Finally, five frameworks we identified and included for review.

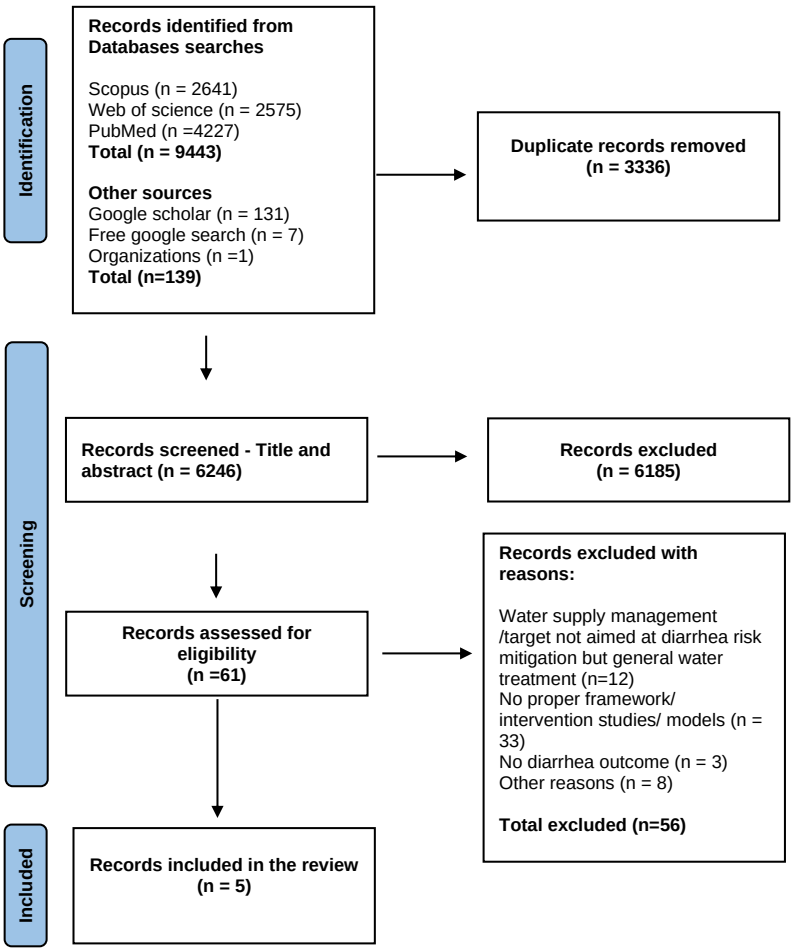

Figure 3.2: PRISMA diagram for scoping review of frameworks for mitigating the risk of waterborne diarrheal diseases

3.3.5.2 Study characteristics

Five eligible frameworks were identified namely: the hygiene improvement framework (HIF), community led total sanitation (CLTS), global action plan for pneumonia and diarrhea (GAPPD), participatory hygiene and sanitation transformation (PHAST) and the sanitation and family education (SAFE) framework. Since no frameworks that specifically addressed waterborne diarrheal diseases were found, frameworks that looked at diarrhea in general were included. The included frameworks were developed between the years of 1993 and 2009 and were developed by different organizations in different countries. The frameworks were developed to be implemented in different settings; one framework in rural areas, two frameworks in both rural and urban areas, and one framework at national level and another framework with no specified setting. Most of frameworks targeted communities and one framework targeted different groups including children, adults, households, and societies (Table 3.4).

Table 3.4: Characteristics of frameworks aimed at mitigating waterborne diarrheal diseases included in the scoping review

	Name of framework	Sources	Year/ started	Implementation areas	Target population	Country / Organization
1	Hygiene improvement framework	Kleinau et al., and Environmental Health Project (EHP); UNICEF/ Water[28,29]	1999	Rural and urban	Community, children, adults, households	EHP/USAID USA
2	Community led total sanitation	Kar and Chambers[30]	1999	Rural	Community	Bangladesh/ WaterAid
3	Global action plan for pneumonia and diarrhea	WHO/ UNICEF[31]	2009	National level	National	WHO and UNICEF
4	Participatory hygiene and sanitation transformation	WHO[32]	1993	Rural and urban	Community	WHO/water and sanitation programs
5	The sanitation and family education	Bateman et al.[33]	1995	Not stated in the reference	Community	Bangladesh/ CARE

EHP: Environmental Health Program

3.3.5.3 Description of frameworks

Hygiene improvement framework

The hygiene improvement framework is a comprehensive framework for preventing diarrheal diseases that was created by the Environmental Health Program (EHP) and USAID in the USA. The framework has three facets, namely, health promotion, access to hardware and creating an enabling environment (Figure 3.3).

The hygiene promotion facet promotes hygiene by teaching and supporting behaviors that reduce diarrheal diseases in children and their caregivers. Household behaviors are encouraged including safe disposal of feces, washing hands correctly at the right times and, storing and using safe water for drinking and cooking. Preliminary community level studies should determine community members' knowledge about the causes of diarrhea, risk behaviors, enablers, and barriers to adopting appropriate behaviors. This will allow organizations to develop appropriate hygiene promotion interventions that will be accepted by the community. Hygiene promotion interventions include mass communication, social mobilization, community participation, social marketing and

advocacy. Mass communication aims to increase awareness of hygiene facilities and good health practices through different channels including social media, music, dance, drama, literature, videos and home visits. Mass communication can happen at any community gathering, health facilities, learning institutions and households. In some settings, targeted training of health workers, teachers and community agents is an important communication strategy. Social mobilization and social marketing aim to involve all members of the community in disease control and hygiene promotion. To effectively promote hygiene behaviors, stakeholders, and civil societies, including governmental and non-governmental organizations, need to advocate for improved hygiene behaviors and interventions to support these behaviors. For example, providing hygiene education as well as water, sanitation and hand washing facilities for boys and girls in public schools may be a good entry point for sustainable hygiene improvement.

The second facet of the hygiene improvement framework is the hardware component. Hygiene can only be improved if there are adequate sanitation facilities for safe disposal of human waste. Adequate facilities such as latrines are needed to safely dispose of human excreta and avoid fecal contamination. The second hardware component necessary for good hygiene is adequate and good quality water supply. Household hygiene can also be improved by providing materials such as soap, safe water containers, household water treatment and potties for babies.

Hygiene promotion and having adequate hardware will only succeed if there is an enabling environment created by policy and legislative framework that improves hygiene, institutional governance, community participation, planning and financing, and private-public partnerships. An enabling environment will ensure the sustainability of any frameworks that are implemented. Even though the facets of the framework can be implemented individually, the hygiene promotion framework recommends that existing interventions be integrated into existing programs. The framework also recommends that the facets be implemented sequentially beginning with the hygiene promotion component for better outcomes with spillover effects on other diarrheal diseases related problems.[28,29]

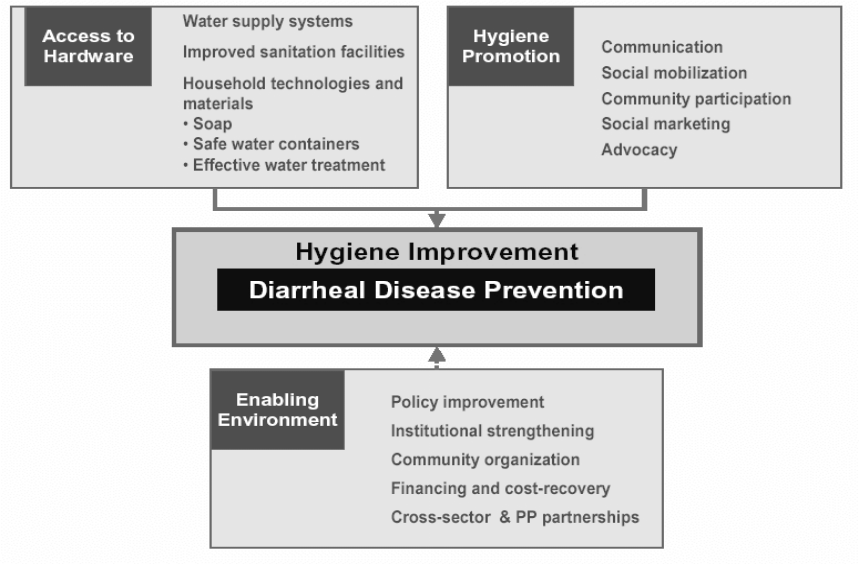

Figure 3.3: The hygiene improvement framework[34]

Community led total sanitation

Community-led total sanitation (CLTS) aims to prevent open defecation and keep rural communities free of open defecation. The community-led total sanitation approach was developed in Bangladesh by WaterAid with the aim of reducing open defecation in the communities. This approach raises awareness on the harms of open defecation to promote safe disposal of human waste. Communities are assisted to make ideal sanitary related decisions and attain their own sanitation solutions once they collectively decide to improve their sanitation practices. In the CLTS, communities must change their attitudes and behaviors, and adopt the use of community toilets. Community toilets were generally not used by community members and did very little to improve sanitation and hygiene, as well as prevent diseases.

The CLTS uses three stages to trigger collective behavioral change by encouraging and motivating people to confront the detrimental effect of open defecation. These stages are pre-triggering, triggering and post-triggering. In the pre-triggering stage, communities are selected, and facilitators are trained. Facilitators then collect baseline information and coordinate entry into the community. During the triggering stage, facilitators organize a community-wide meeting and conduct participatory exercises intended to trigger shame and disgust with open defecation. The first exercise is a ‘walk of shame’ where community members observe areas of open defecation. These areas are mapped, and volume of feces is calculated to quantify the amount of open feces lying in the area. The risk of disease transmission in specific areas is quantified using

feces mobility mapping. It is likely that community participants will be more motivated towards improving their sanitary situation. In the post-triggering stage, routine follow-up visits are conducted to check the construction of latrines and extent of behavioral change. The open defecation free status of areas is verified, certified, and monitored.[30,35]

Global action plan for pneumonia and diarrhea

Another framework, the GAPPD proposes a multi-sectoral, integrated approach to reducing morbidity and mortality due to pneumonia and diarrhea in children younger than five at national level by 2025. This framework was developed by the WHO and UNICEF. Pneumonia and diarrhea are the main causes of death and mortality among children globally. The GAPPD proposes an integrated framework of interventions proven to protect, prevent and treat childhood pneumonia and diarrhea in a coordinated way. Pneumonia and diarrhea both have similar determinants, preventive measures, and platforms to deliver interventions (Figure 3.4). The GAPPD was created primarily for national governments and their partners, and can also be used by global organizations, donor agencies and other organizations working on pneumonia and diarrhea. The GAPPD recognizes that strategies can only be implemented if communities and community members cooperate.[31]

The GAPPD provides specific targets for each component. The protection component aims to ensure that 50% of children are exclusively breastfeed until they are six months old. The prevention component aims to achieve 90% immunization coverage of each of the following vaccines: pertussis, measles, Haemophilus influenzae type b (Hib), pneumococcal conjugate and rotavirus. For the treatment component, the GAPPD recommends that 90% of children with suspected pneumonia have access to treatment by an appropriate health care provider and access to antibiotics. Ninety percent of children with diarrhea should also have access to treatment with oral rehydration solution and zinc supplements. To save resources, the GAPPD recommends that these components should be implemented in existing healthcare services instead of working vertically.

The GAPPD recommends that governments address various components to achieve the specified goals:

• **Develop a clear country-level strategy and work plan, with assigned key responsibilities:** Generate political that will lead to responsive situation analysis for

pneumonia and diarrhea and prioritize interventions. The strategy should include a costed medium to long term plan for accelerated action. Harmonization and collaboration between programs and sectors is critical to include private sector, academia, and civil society. Groups at greater risk or missed by services should be identified and targeted approaches should be implemented. Progress should also be monitored by developing a set of common indicators.

• **Coordinate implementation:** Establish a designated national working group for pneumonia and diarrhea prevention and control. This will help to mobilize resources, apply lessons from other integrated disease prevention and control efforts, track effective execution and evaluate systematic progress.

• **Engage and embed critical partners in the overall work plan/approach:** Involve other programs and sectors including the private sector, NGOs, United Nations agencies and other development cooperation partners.

• **Other actions:** Promote innovation, generate demand and ensure supply to overcome barriers to service delivery. Stakeholders should focus on implementing research and identifying optimal modes of delivery to reach those most in need.[31,36]

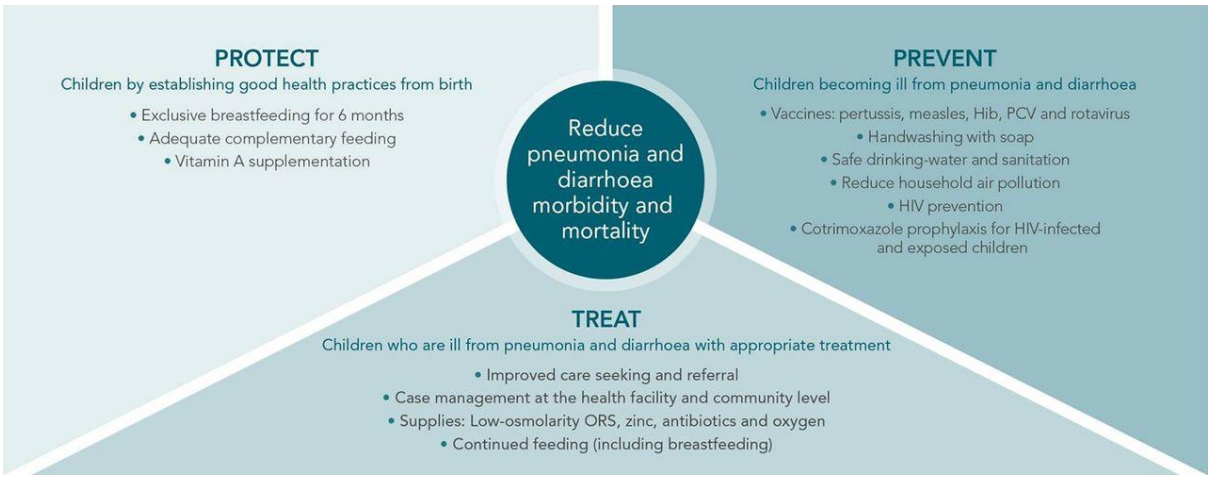

Figure 3.4: GAPPD protect, prevent, and treat framework to reduce pneumonia and diarrhea[31]

Participatory hygiene and sanitation transformation (PHAST)

Participatory hygiene and sanitation transformation empowers communities to improve their hygiene behaviors, reduce diarrhea diseases and effectively manage water and sanitation. Community members are involved in planning and implementing interventions and hence experience a sense of ownership. Community members may

say what they want or not in interventions. Community members are involved in monitoring and evaluating, which provides good feedback for improving activities. The PHAST comprises seven steps including problem identification, problem analysis, planning for solutions, selecting options, planning for monitoring and evaluation, and participatory evaluation (Figure 3.5). Each step is coupled with activities and tools that involve the community. The framework can be completed and implemented in about two weeks to six months. The PHAST should also be implemented sequentially to ensure best results.[32,37]

The PHAST works on the principles of involving facilitators to improve community awareness of water sanitation and hygiene through several activities. Through PHAST, community members formulate plans to improve sanitation by constructing and managing facilities as well as changing behaviors in the community and at individual level. The PHAST uses several tools including a picture series depicting local issues including water and sanitation. The PHAST requires that community members participate in workshops where they evaluate the local situation, identify problems and suggest solutions. Pocket charts are used to glean knowledge from participants and record their votes for possible solutions to ensure confidentiality. All the participants, including the facilitator, must be viewed as equals to ensure success.[17,32]

Figure 3.5: The PHAST framework for community planning to prevent diarrheal diseases[32]

Sanitation and family education

The sanitation and family education (SAFE) approach promotes management of water, sanitation and hygiene using soft strategies. The SAFE approach followed on from the care water and sanitation/hygiene (WASH/CARE) project which was developed as a cyclone relief project in Bangladesh Chittagong in April 1991. The WASH/CARE project primarily rebuilt sanitation infrastructure including latrines, repaired damaged tube wells and built new tube wells. Following on from rebuilding, the SAFE project developed effective and replicable hygiene education strategies to promote behavior change, tested different models for health and hygiene education outreach, and designed and implemented a behavior-based monitoring system. The SAFE project had two outreach models. The first model focused on tube well caretakers, their spouses and tube well users. The second model involved outreach activities including school programs, child to child activities, and activities with key influencers in the community. These two models were compared to determine whether the more intensive outreach program would better

influence hygiene behaviors. The SAFE program was implemented by facilitators in group discussions, demonstrations, participatory action learning exercises, flash card displays, folk songs, role playing, comic story sessions and games. These activities were designed and tested carefully to ensure relevance and appropriateness to local contexts.

The components of the SAFE included:

1. Hygiene education interventions based on information collected in small qualitative and quantitative research activities, rather than depending on stock messages and materials. Interventions reinforced existing positive behaviors or developed specific, appropriate alternatives to existing behaviors.

2. Hygiene behaviors were incrementally improved. Rather than promoting many ideal hygiene behaviors, SAFE identifies those behaviors most strongly associated with diarrhea in children and targets these priority behaviors with locally appropriate interventions.

3. Problems are identified using a behavior-based monitoring and improvement system. Community members are involved in analyzing problems and developing solutions. SAFE activities are continuously adjusted and improved.

4. Community members are encouraged to participate in every aspect of the project, including program design, outreach activities, monitoring and evaluation (Figure 3.6).

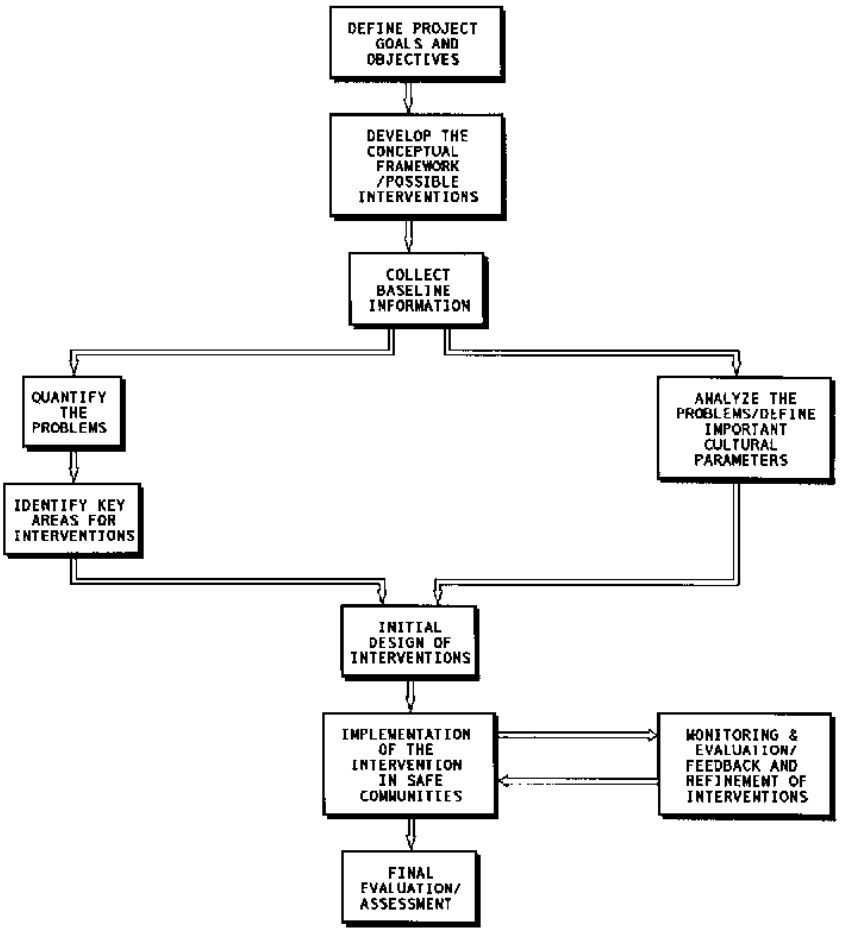

Figure 3.6: The SAFE project life cycle

The SAFE approach is outlined in five steps (Figure 3.6). The first step determines goals and objectives. This is followed by developing a conceptual framework and outline of possible interventions. Specific behavioral interventions are then developed focusing on breaking the fecal-oral transmission route, including clean water, latrines and feces disposal, environmental cleanliness, hand washing, food hygiene and diarrhea management. Key problems are identified using baseline information on hygiene behavior and key areas for interventions. Baseline data are primarily collected using qualitative and quantitative studies. A monitoring system then measures key indicators for specific interventions. Key indicators are used to justify any necessary changes. The final surveys are essentially a repetition of the baseline surveys, and results are compared to evaluate effects of the SAFE intervention.[33]

Strengths and weaknesses of frameworks

The five frameworks included in this scoping review were scored using the 17 criteria outlined in Table 3.3. The following strengths were identified in all the frameworks. All the frameworks included facets describing implementation and delivery of interventions, human resources, community involvement, monitoring and evaluation. Strong frameworks also identified and quantified risks and involved all stakeholders. Frameworks were strengthened if they identified specific interventions and measures of sustainability. Three of the five frameworks targeted multiple groups and described financing and resource mobilization (Table 3.5). The frameworks scored half in problem identification and implementation of intervention or programs within existing structures (Table 3.5).

Three frameworks did not include suggestions for integrating laws and developing and improving policies. Similarly, three frameworks did not follow an integrated approach. None of the frameworks included electronic means of collecting, storing and transferring data. None of the frameworks focused specifically on mitigating waterborne diarrheal diseases (Table 3.5). None of the frameworks scored 17/17, but all the frameworks scored at least 9.5/17. The GAPPD framework scored the highest with 12.5/17 and SAFE scored the lowest (9.5/17).

Table 3.5: Strengths and weaknesses of frameworks for mitigating the risks of diarrheal diseases

	Criteria /Component	Framework and Score					Total
		HIF	CLTS	PHAST	GAPPD	SAFE	
1	Problem identification	Z(0.5)	Z(0.5)	Z(0.5)	Z(0.5)	Z(0.5)	2.5
2	Risk identification and quantification	Z(0.5)	Y(1)	Y(1)	Y (1)	Y(1)	4.5
3	Identification of interventions	N(0)	Y(1)	Y(1)	Y(1)	Y(1)	4
4	Interventions integrated approach	Y(1)	N(O)	N(0)	Y(1)	N(0)	2
5	Interventions target multiple groups	N (0)	Y(1)	Y(1)	N(0)	Y(1)	3
6	Implementation and delivery of interventions	Y (1)	Y(1)	Y(1)	Y(1)	Y(1)	5
7	Financing and or resource mobilization	Y(1)	N(0)	Y(1)	Y(1)	N(0)	3
8	Human resources	1	1	1	1	1	5
9	Implementation of interventions/program within existing structures	Y(1)	Z(0.5)	N(0)	Y(1)	N(0)	2.5

	Criteria /Component	Framework and Score					Total
10	Multiple stakeholders' involvement	Y(1)	Y(1)	Y(1)	Y(1)	Z(0.5)	4.5
11	Community involvement	Y(1)	Y(1)	Y(1)	Y(1)	Y(1)	5
12	Monitoring – follow up	Y(1)	Y(1)	Y(1)	Y(1)	Y(1)	5
13	Evaluation - measures of success	Y(1)	Y(1)	Y(1)	Y(1)	Y(1)	5
14	Electronic means of data collection, storage and transferring	N(0)	N(0)	N(0)	Z(0)	N(0)	0
15	Means of sustainability	Y(1)	Y(1)	Z(0.5)	Y(1)	Z(0.5)	4
16	Focuses on waterborne diarrhea diseases	N(0)	N(0)	N(0)	N(0)	N(0)	0
17	Laws and policy development and improvement on intervention	Y(1)	N(0)	N(0)	Y(1)	N(0)	2
	Total	12	10	11	12.5	9.5	

N= Not available = 0; Y= available =1; Z= Available but not too clear or adequate = 0.5

In addition to the 17 components assessed in the criteria, the reported effectiveness of the identified frameworks was assessed. Positive findings have been revealed in implementation of the frameworks in different places world over. An assessments of the effectiveness of CLTS has revealed increase in construction of latrines and use as well as reduction in diarrhea cases in areas of implementation in Ethiopia, Ghana and Uganda.[17,38-41] However, evidence from Mali showed no difference in diarrhea cases between CLTS implemented and non-implemented areas.[42] In terms of PHAST, no study was found that reported on the effectiveness of the approach to prevent diarrhea diseases. However, some assessments have revealed effectiveness of the approach in the promotion of sustainable hygiene behaviors change, improved sanitation and conveying health messages.[17,43,44] In the case of GAPPD, deaths due to Pneumonia and diarrhea have fallen by 27% globally since the framework was introduced despite low- and middle-income countries still lagging in achievement of the GAPPD goals.[45] Implementation of the HIF framework in Guatemala revealed a reduction in diarrhea diseases among under-fives children by 4.5% through hand washing interventions that was implemented within the HIF framework.[28] Lastly, implementation of SAFE approach in Chittagong Bangladesh revealed a two third reduction in the cases of diarrhea in safe interventions groups compared to the controls.[46]

3.3.6 Discussion

In this scoping review, five frameworks that aimed at mitigating the risk of diarrheal diseases were included. These frameworks were developed by different organizations, implemented at different levels, and all aimed to prevent diarrhea especially among

children. All these frameworks had components of community involvement, problem and risk factor identification, identification and implementation of interventions and methods of evaluating and monitoring, which were regarded as strengths. Most of the frameworks recommended that hygiene could be improved by providing hardware, including sanitation infrastructure. Soft interventions included health promotion and creating an enabling environment for changing behavior. The frameworks had several strengths and weaknesses. One of the key weaknesses was that none of the frameworks included strategies for collection, storage, and transfer of electronic data. In addition, none of the frameworks focused specifically on waterborne diarrhea diseases. The identified gaps were seen as the major weaknesses of the frameworks.

Notably, all the frameworks in this scoping review contained a component of problem identification even though none of the frameworks used epidemiological assessments and laboratory tests to determine the cause of diarrheal diseases. Laboratory tests are important for identifying specific pathogens which will then determine the specific mitigation measures.[47] For example, chlorine, which can be used to destroy most diarrheal diseases pathogens, cannot destroy cryptosporidium parasites which cause cryptosporidiosis, a type of diarrhea disease.[48] All the frameworks also identified and quantified risk factors, and appropriate interventions. This is important as each community usually has unique risk factors for diarrheal diseases which need to be addressed with specific interventions to be effective.[26] Most of the frameworks targeted multiple groups in the community, which ensures that all people in the community are reached, and uptake is maximized.[49] Even though most interventions aim to reduce diarrhea in children, interventions must benefit all community members since adults are also affected by diarrhea.[50,51] Community involvement will also increase ownership which is integral to the sustainability of health programs.[52,53] Most of the frameworks in this review addressed sustainability which is an important aspect of health programs. Without sustainability plans, programs may waste resources. Diarrhea interventions should also be continuous to prevent reoccurrence of disease.[24]

All the frameworks had components of monitoring and evaluation which are important aspect of sustainability. Sanitation infrastructure and water quality should be continuously monitored to ensure that everything is working well and to check for the effectiveness of interventions to help improve implementation when needed.[54,55] The majority of the frameworks also addressed the availability of human resources, which are required at almost all levels of health program implementation.[56] The availability of

human resources also ties in with the involvement of multiple stakeholders. All the frameworks required the involvement of multiple stakeholders. Improved hygiene requires different players to be involved including government institutions such as local authorities and health departments, as well as the private sector and international communities.[57] Involving multiple stakeholders will facilitate financing and resource mobilization.[57,58]

In this review, some of the frameworks lacked certain important components for mitigating diarrhea diseases. For example, not all the frameworks were designed to be implemented in existing programs, nor did they describe how they should be integrated into laws and policies. Few frameworks described an integrated approach such as using multiple interventions to prevent diarrheal diseases. When interventions are implemented in existing programs, sustainability and efficient use of resources will be promoted. This is less expensive than designing new programs from scratch and running vertical health programs.[27] Frameworks should describe how they can be implemented in laws and policies to ensure that standards are maintained.[58] For example, laws should dictate which type of toilet should be built to avoid ground water contamination in specific areas. Frameworks should also allow for an integrated approach depending on the needs of the community. Some communities may require better sanitation infrastructure and water treatment services, while other communities may need to be educated about better hygiene behavior and the importance of vaccinations.[59,60] None of the frameworks included a component for collecting, storing and transferring electronic data. Electronic collection, storage and transfer of data eases data management and facilitates easy decision making.[58] Another weakness was that none of the frameworks specifically addressed waterborne diarrheal diseases.

Of the frameworks reviewed in this study, particularly the GAPPD framework addressed most of the components included in scoring sheet used in this review. Although the framework scored the highest, the GAPPD did not target multiple groups as it only targeted children under the age of five. In addition, it had no means of electronic data collection, storage and transfer, and did not specifically focus on waterborne diarrheal diseases. This framework probably included the most favorable components because it is a global plan to reduce diarrhea and pneumonia mortality and morbidity. After the GAPPD, the HIF framework included the most components followed by PHAST then CLTS. The SAFE framework included the fewest desirable components.

Proposed framework

Based on the findings of this review, this study proposes the use of the various components in the identified frameworks as basis for the development of future frameworks. This is in consideration that the identified frameworks were found to be effective in mitigating the risk of diarrhea diseases among other health benefits.[17,28,38-44,46] The proposed framework consists of six (6) components which should be implemented in series:

The first component is **problem identification** involving community surveillance must be conducted to determine the burden, disease causative agent,[61] high risk areas, characteristics of cases and other related factors of waterborne diarrhea diseases. The second component is **Identification and quantifying of risks** factors in the community should be done focusing on water supply, sanitation, and hygiene (hand washing) the major risk factors of waterborne diarrhea diseases[60,62] and other demographic, social economic behavioral and environmental related factors.[63] This should be followed by **identification of evidence-based intervention(s)** based on the risk's factors identified. Use of multiple interventions is proposed since diarrhea has multiple risk factors.[8,31] Prioritizing interventions based on the needs of the community and provision of long terms investments in water supply and toilets is proposed as these are fundamentals of diarrhea prevention.[28] Then **assessment of intervention(s) in target community** involving getting information on past and current interventions from the target communities and other relevant stakeholders must be done. This information will be used as basis of deciding on the required and best way of implementation of the interventions. **Selection and adoption of intervention(s)** of the diseases should then be done based on the risks, interventions identified as well as the assessment of intervention in the community. This selection should be based on appropriateness and acceptability of the interventions through evidence-based literature, experts' knowledge and community involvement.

The last component involves **implementing the selected intervention(s)** in the community. This should be followed by **monitoring** and **evaluation** of the implementation involving checking the progress of the implementation and effect of the implemented intervention(s). Means of **sustainability** of the intervention(s) must also be considered to avoid reoccurrence of diseases. Sustainability should be ensured by involving the community in all the stages of the framework to encourage ownership.[52,53]

In addition to the six components, **system support factors** have been identified including: Intersectoral participations; government will; human and financial resources and resource mobilization; policies and laws; strengthening collection and recording of data through electronic means; adapting the components to emerging problems and new solutions; working within available structures: horizontal approach of programming; institutional strengthening; provision of laboratory facilities for testing and development or strengthening of a national preparedness program for waterborne diarrheal diseases outbreaks.[28,31] A country level framework for use in mitigating the risk of waterborne diarrhea diseases in peri-urban areas of Zambia and similar settings will be developed based on the proposed components.

3.3.7 Limitations

Databases that were not in English were not searched, but a variety of databases were searched. Gray literature was also searched. The literature searches were also done over a limited six-month period but all literature from inception to date were included. Quality checks were not conducted on the included frameworks, but only included frameworks that were created by reputable organizations and obtained from reputable websites or databases were included. It is also important to note that one of the components that was used to assess the strengths and weaknesses of the framework's availability of an electronic means of data collection, storage and transferring, may not necessarily be a weakness for most of the frameworks as they were created before advancement in electronic means. Nevertheless, it was included as it is applicable to the current frameworks and is an important component for inclusion in future frameworks. Some of the frameworks reviewed were clearly not frameworks but rather approaches thus their low rating. These plans or approaches still provided some important information to mitigate the risk of waterborne diarrhea diseases and can be used to develop and improve the framework.

3.3.8 Conclusions

This study reviewed frameworks for mitigating the risk of diarrheal diseases. No frameworks specifically addressing waterborne diarrheal diseases were found thus only frameworks aiming to mitigate diarrheal diseases in general were included. Further, 17 favorable components that could be included in future frameworks were identified. Most of the frameworks in this review had the favorable components of identifying problems and risk factors, identifying and implementing interventions and evaluating and

monitoring outcomes. The interventions ranged from improving sanitation infrastructure and water quality to hygiene promotion and education, whilst creating an enabling environment. None of the frameworks included an element on collecting, storing or transferring electronic data, or focused specifically on waterborne diarrhea diseases. The identified frameworks were found to be effective in mitigating the risks of diarrhea among other health effects. Based on these results, this review has proposed a framework that will consist of six components including: problem identification; identification and quantifying risk factors; identification of evidence-based interventions; assessment of interventions in target communities; selection and adoption of interventions and implementing, monitoring and evaluation and means of sustainability of the interventions. Lastly, system support factors of these components must also be considered to mitigate the risk of waterborne diarrhea diseases.

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CHAPTER 4: TRENDS OF DIARRHEAL DISEASES IN PERI-URBAN AREAS OF LUSAKA DISTRICT: A LONGITUDINAL STUDY[C]

4.1 Abstract

Diarrhea is one of the major causes of morbidity and mortality especially among children under the age of 5 years in developing countries.
This study aimed to assess trends of diarrhea diseases (non-bloody, bloody and cholera) in peri-urban areas of Lusaka district Zambia.

A longitudinal study was conducted in 15 health facilities of peri-urban areas of Lusaka district. Secondary data of diarrheal diseases from the Health Management Information System (HMIS) was collected for the period 2010 to 2019.

The study found reduction in trends of diarrheal diseases during the period under review. A total of 731237 cases were recorded with non-bloody diarrhea presenting the highest cases 96.5% followed by bloody diarrhea 1.9% and then cholera 1.6%. The highest number of cases were recorded in 2016 while 2019 recorded the lowest. Most of the cases were recorded in the rainy season. Chipata first level hospital, one of the 15 health facilities had the highest number of cases (17.2%) with Mtendere urban clinic recording the lowest cases (3.2%). Bloody diarrhea was the highest cause of deaths followed by non-bloody and lastly cholera. These cases of diarrhea diseases were highest in children under the age of five. Age, year, season and facility zone or sub-district were found as best predictors of deaths due to non-bloody diarrhea in the zero inflated Poisson model.

This study calls for provision of area specific diarrhea interventions in peri-urban areas of Lusaka with focus on the facilities with the highest burden of the diseases, after conducting needs assessment of the different areas to prioritize the interventions.

4.2 Background

Diarrhea is one of the major causes of mortality and morbidity all over the world especially among children under the age of 5 years. The disease is common in developing countries due to poor provision of water, sanitation and hygiene services. Diarrhea is defined as the passage of 3 stools or more within a period of 24 hours.[1,2]

[c] Manuscript under review

Diarrhea is caused by different organisms including viruses, bacteria, parasites and other organisms[3] Diarrhea is spread through the fecal oral route where an infected person can shed the organism that cause diarrhea in feces and the next person acquires infection through food or drinking of contaminated water.[3,4] There are various interventions that can be implemented to prevent diarrhea diseases which essentially target the fecal oral route chain. These interventions include provision of safe and adequate water supply, hygiene promotion, vaccination etc.[1,5]

Several studies have been done to assess the trends of diarrhea across the globe. The general trends show reduced diarrhea episodes and consequent deaths, as reported in a global study on diarrhea for the period 2005 to 2015. The study showed 2.39 billion episodes of diarrhea recorded in 2015 with incidence decreasing by an average of 8.15% among all ages. The number of people dying from the disease also reduced by 20.8% in the same period.[6]

Most of the studies conducted in different countries also showed a decline in trends of diarrheal diseases. For example, a study conducted in Ghana by Anyorikeya et al.[7] on trends of diarrheal diseases in children under five years at the War Memorial Hospital-Navrongo in the period 2010 to 2013 showed decreasing trends in diarrheal diseases. Similarly, a study by Emina and Kandala[8] on the trends in the prevalence of diarrhea in the Democratic Republic of Congo found that the overall prevalence of diarrhea decreased by 26% in 2001 and 2007.

An ecological time series study was conducted in Brazil by Oliveira and Latorre[9] between 1995 and 2005 to assess the trends in hospital admission and infant mortality. The study revealed that 1,505,800 hospitalizations and 39,421 deaths were due to diarrhea among children under one year. The study further found reductions in hospitalizations and infant deaths from diarrhea in the country. Majority of the study areas showed reductions only in mortality from diarrhea, whereas some showed decreases only in hospitalization. The combined analysis showed reduction in the cases of diarrhea. Another study conducted in Brazil on the temporal trends and inequality in under 5 mortalities from diarrhea by Melli and Waldman[10] revealed that from 1980 to 2000 a total of 1360 deaths, 94.3% which were before 1 year and 75.3% of which were before 6 months were due to diarrhea. Overall, the study showed diarrhea reduction in the mortality of children studied. Other studies that revealed decline in diarrheal diseases include studies conducted in Vietnam[11] and United States[12] on hospitalization and healthcare utilization due to diarrheal diseases, respectively.

Although most of the studies showed reduction in trends of diarrheal diseases, some studies revealed different results. For example, a study to assess the trends in healthcare usage attributable to diarrhea between 1995 and 2004 by Pont et al.[13] showed that the rates of hospitalization during the study period remained stable. Children aged 0 to 35 months experienced 1,627 outpatient and 792 emergency department visits, and 148 hospitalizations per 10,000 child-years. A study with similar results was conducted by Guerra-Godínez et al.[14] The study aimed at assessing trends in prevalence, morbidity, and lethality in persistent diarrhea of infancy in 1988 to 1991, 1993 to 1994, and 1997 to 1999 in Mexico. The study found that the average age on admission was just over 13 to 24 months. Even though the prevalence of admissions for diarrhea decreased gradually from 31.7 to 13.8% within the study period, rates of lethality and mortality remained unchanged. Tetteh et al.[15] conducted a study in Jasikan district Ghana for period January 2012 to December 2016 on trends of diarrhea morbidity. The study showed that there were 17740 cases within the study period. The incidence rate of diarrhea within the study period was 272.02 per 1,000 person.

In Zambia very little information is available on studies that have looked at trends of diarrhea diseases. One study found was on the trends of dysentery conducted by Katemba et al.[16] from 2016 to 2018 in the 10 provinces of Zambia. The study found that the highest number of cases were recorded in the fourth quarter of each year with 2016 recording 13,450 suspected cases, 2017 (18,866) and 2018 (15,347). It was generally observed that more laboratory confirmed cases were observed in first quarter of each year; 2016 (88.2%), 2017 (72.6%) and 2018 (29.8%). It is important to note that more cases were reported in the first and fourth quarter of the years probably because these are quarters that fall in the hot and rainy seasons. The study also revealed that only one death was recorded within the period of study. The incidence rate of dysentery suspected cases during 2016 to 2018 in Zambia showed an overall increase.

Studies from different countries revealed that diarrhea was highest in children especially those under five.[7,15,17] Analysis by gender indicated divided findings with some studies showing that most of the affected were female[7,15] while others found the opposite.[11,14] In terms of the season**,** diarrhea was common in the dry[11,15] and rainy seasons.[7,10,16]

Overall, in literature there exists studies that have looked at trends of diarrheal diseases around the world. In Zambia, while the available study looked at dysentery, this study will look at trends of dysentery (bloody diarrhea), non-bloody diarrhea and cholera in disease prone peri-urban areas of Lusaka Zambia. Assessing the trends in these areas

will give the magnitude of the problem. Knowing the trends may also help policy makers and other stakeholders to plan for effective and target specific interventions for implementing.

4.2.1 Objective

To assess the trends of diarrheal diseases in peri-urban areas of Lusaka district Zambia for the period 2010 to 2019. Specifically, the study assessed the trends of non-bloody, bloody diarrhea and cholera; diarrhea diseases according to seasons, facilities; prevalence of diarrhea according to age and deaths from diarrhea diseases according to facilities.

4.3 Methods

4.3.1 Study design: A longitudinal study was used to investigate the trends of diarrheal diseases in the peri-urban areas of Lusaka district. This design is appropriate for this part of the study as the data on diarrhea was obtained repeatedly over a period of 10 years for the same health facilities.[18]

4.3.2 Study settings

The study was conducted in Zambia a landlocked Sub-Saharan country in Africa. Zambia has a population of just over 19 million people in 2017.[19] This study was conducted in Lusaka district the capital city of Zambia with a population of about 2 million people.[19,20] Figure 4.1 shows Africa, Zambia and Lusaka, district.

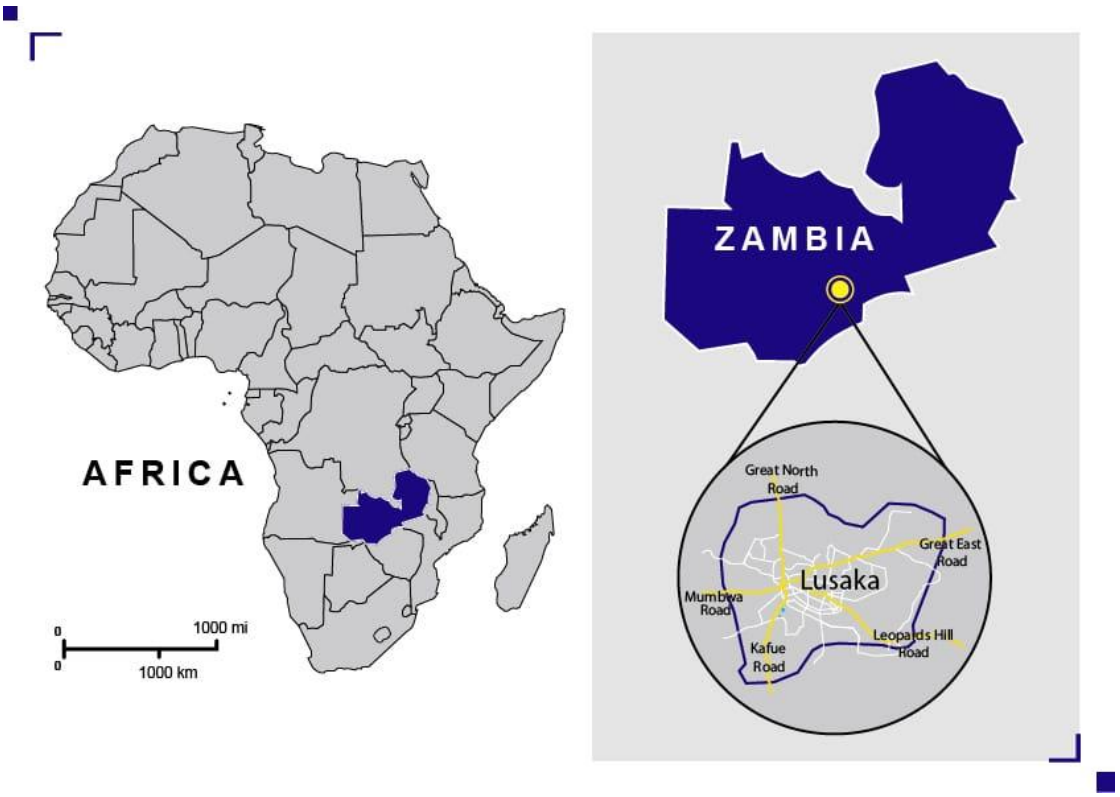

Figure 4.1: Map of Africa showing Zambia and Lusaka district

Most of the population in Lusaka live in peri-urban areas with poor provision of water and sanitation services exposing people to risk of waterborne diarrheal diseases thus the reason for conducting this study in these areas.[21-23]

4.3.3 Study area: The study was conducted in the peri-urban areas of Lusaka district. Specifically at 15 government health facilities namely Bauleni, Chainda, Chaisa, Chawama, Chazanga, Chipata, George, Kalingalinga, Kanyama first level, Kanyama west, Mandevu, Matero first level, Matero Reference, Mtendere and Ngombe (Figure 4.2). This is because government health facilities are the main health care services providers. In all there are a total of 174 health facilities in Lusaka district of which 45 are government owned.[24] These facilities are also the ones that usually report high cases of diarrheal diseases in Lusaka.[23,25]

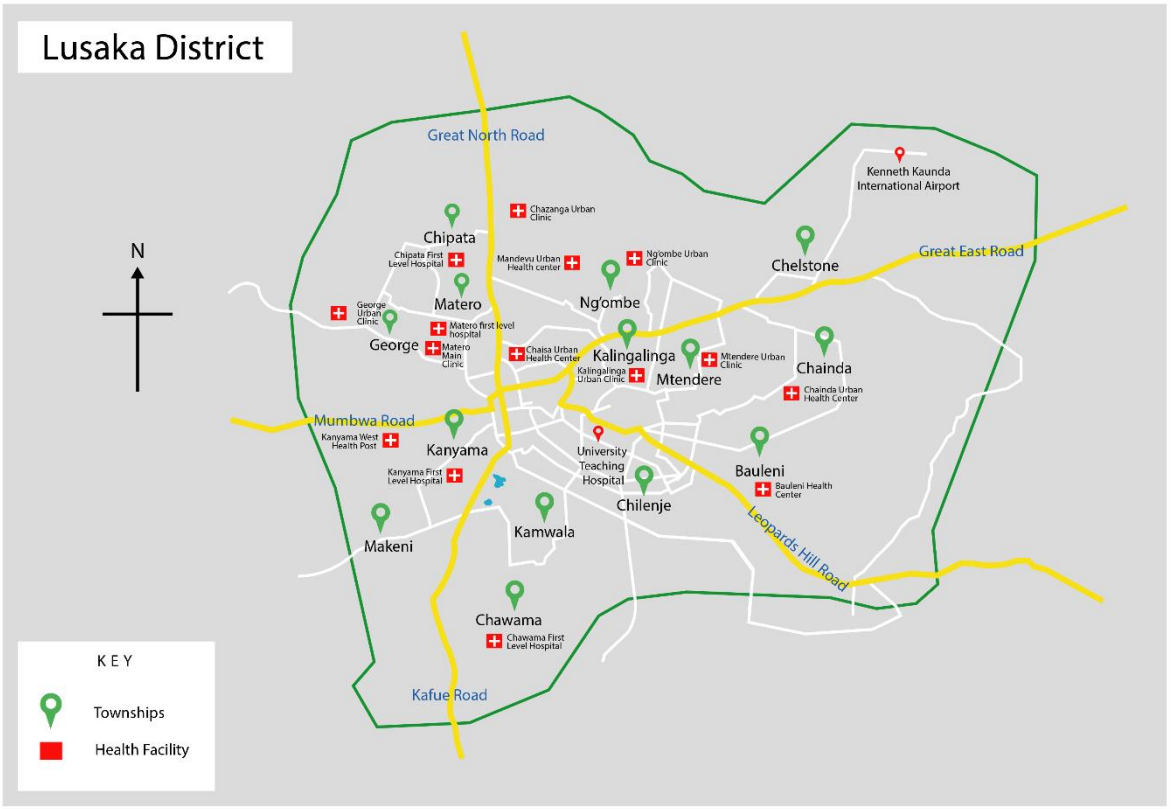

Figure 4.2: Map of Lusaka showing location of health facilities included in the study

4.3.4 Participants

Eligibility criteria

Study population: The study units included all health facilities run by the government with 2010 to 2019 complete data/ records from the Health Management Information Systems (HMIS).

- **Inclusion criteria:** All cases of diarrhea reported to the health district office from the selected health facilities were included in the study.
- **Exclusion criteria:** Health facilities selected that had extensive missing records were excluded from the study. For example, some health facilities that had missing data in years after 2010 were excluded from the study even though they were also found in the areas of interest.

4.3.5 Selection of participants: All the diarrhea records from the selected health facilities run by the government in peri-urban areas were included.

4.3.6 Sampling methods: Purposeful sampling was used as all the diarrhea records from the government facilities were included in this study as the main health care providers in peri-urban areas of Lusaka.

4.3.7 Study and sample size: The study sample was arrived at purposively as all health facilities run by government in peri-urban areas were included in the study. Total enumeration of reported diarrhea cases from the selected government health facilities in peri-urban areas for the period 2010 to 2019 were included in the study.

4.3.8. Study variables

The study included several variables including diarrhea cases; type of diarrhea (non-bloody, bloody diarrhea and cholera), deaths, age group, year, season, population and health facility zones. The detailed explanation of the variables is presented in table 4.1.

Table 4.1: Study variables

Variable	Indicator	Measuring scale
Diarrhea cases	Recorded number of diarrhea cases	Discrete (Count)
Deaths	Recorded number of deaths due to diarrhea	Discrete (Count)
Type of diarrhea	Recorded number of bloody, non-bloody diarrhea and cholera cases	Nominal (Bloody diarrhea, Non-bloody diarrhea, Cholera)
Age group	Recorded number of diarrhea cases within age groups	Nominal (Less than one, One to five years, More than 5 years)
Year	Year	Nominal (2010 to 2019)
Season	Season of the year	Nominal Season 1 - May to August - Cool Dry Season; Season 2 - September to October - Hot Dry Season; Season 3 - November to April - Rainy Season
Population	Health facility catchment population	Discrete (Count)

Variable	Indicator	Measuring scale
Health facility zones	Facility sub - district	Nominal **Chelstone Sub-district** 1. Mtendere Urban Clinic 2. Chainda Urban Health Center 3. Kalingalinga Urban Clinic **Chipata Sub-district** 4. Chipata First Level Hospital 5. Chaisa Urban Health Center 6. Chazanga Urban Clinic 7. Mandevu Urban Health Center 8. Ng'ombe Urban Clinic **Matero Sub-district** 9. Matero first level hospital 10. Matero Main Clinic 11. George Urban Clinic **Kanyama Sub-district** 12. Kanyama First Level Hospital 13. Kanyama West Health Post **Chawama and Chilenje sub-district** 14. Chawama First Level Hospital 15. Bauleni Health Center

4.3.9 Data sources: The study used secondary data from the HMIS Ministry of Health electronic data base. The system collects and records data from all the health facilities in Zambia. Data for the period 2010 to 2019 were included. All the variables presented in table 4.1 were collected from the HMIS database.

4.3.10 Data collection: The instrument that was used to collect data on the trends of diarrhea was the data capture form that was created by Principal Investigator (PI) and checked by the other research team members. The form captured the following data: diarrheal cases for each facility per month and year. Other data including the age groups, the type of diarrhea (bloody or non-bloody, Cholera), deaths and health facility catchment population. Data collection was done by the PI with the help of a research assistant who helped to access the records from the Ministry of Health. A data capture form was used to collect secondary data from the file refer to appendix 4 the form was piloted before use to ensure that it was able to collect the required data.

4.3.11 Bias: There was possibility of misclassification of data i.e., classifying missing data as zero records.

4.3.12 Data management and storage

All the data collected were checked by the PI every day after data collection for completeness and consistency. Data was stored on a computer with a password for security only accessible by the PI and supervisors.

4.3.13 Quantitative variables: All the variables in this study were quantitative in nature and are presented in table 4.1.

4.3.14 Data analysis

Data was entered and cleaned in Ms Excel. Frequencies and proportions were used to summarize diarrhea cases for each health facility per year and season. Cases in the different age groups, deaths, type of diarrhea and deaths. Results are presented in tables; bar charts and trends of diarrheal diseases were also conducted using Ms Excel.

For the inferential analysis the outcome variable that was employed in this study was the number of deaths from non-bloody diarrheal diseases and as such a count data model was used. The Poisson model was not used due to a few excess zeros found in the data; therefore, a model which considers the excess zeros, the zero inflated Poisson model was used. All variables found with p-values less than 0.05 were considered statistically significant. All analyses were performed using Stata software, version 14.0 SE (Stata Corporation, College Station, TX, USA). Note that during the analysis data from Kanyama level one hospital and Kanyama west health facilities were combined as they used to be one facility before they were split. The combination was important for easier and better interpretation of results. Therefore, the study employed 14 facilities during the analysis.

The study results are interpreted in line with the research objectives and the reviewed literature. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was used to report the study. No sensitivity analysis nor controlling for confounding was done.

4.4 Ethical considerations

Ethical approval was obtained from the Faculty of Health Science Research Ethics Committee of the University of Pretoria (REF: 847/2019) and the University of Zambia

Biomedical Research Ethics Committee (UNZABREC) (REF: 808-2020). Permission to obtain and use secondary data was obtained from the Lusaka district health management office Ministry of Health as they are the custodians of the secondary data used and oversee all the health facilities in Lusaka district. The use of secondary data in this study had minimal risk since there was no use of people's names and or identification numbers. Only information that was necessary to answer the research questions was collected and used. After data collection, data was stored on a computer with password for security only accessible to the PI and supervisors.

4.5 Results

4.5.1 Participants

The study included 15 healthcare facilities in peri-urban areas of Lusaka district. The general trends for years and seasons from 2010 to 2019 according to the type of Diarrhea i.e., non-bloody, Bloody and cholera according to years, seasons, age as well as deaths from diarrhea diseases were assessed. Table 4.2 presents the summary of the trends of all the diarrheal cases (non-bloody diarrhea, Bloody diarrhea, and Cholera) cases from 2010 to 2019.

Overall, over the 10-year period, there were 731,237 cases of diarrheal diseases. Of all these cases, non-bloody diarrhea had the highest number of cases (705,362/731,237) representing about 96.5%. This was followed by bloody diarrhea at 1.9% (14,049/731,237) and the rest represented cholera cases. In reference to the number of cases recorded each year, the highest number of cases were recorded in 2016 (125,199 cases) and the lowest number of cases were in 2019 with only 54,276 cases (Table 4.2).

4.5.2 Number of cases for each condition

The diarrheal diseases in this study were grouped in three (3) categories, non-bloody diarrhea, bloody diarrhea, and cholera. Non-bloody diarrhea refers to passage of loose stool which does not contain blood, bloody diarrhea refers to passage of loose stool which contains blood and cholera refers to diarrhea that is caused by Vibrio cholerae.

4.5.2.1 Non-bloody diarrhea

Non-bloody cases were the highest number of cases with 705,362 out of 731,237 total cases**.** In the non-bloody diarrhea, the highest number of cases was found in 2016 with 125,199 cases out of the total 731,237 representing 17.1%. The lowest number of non-

bloody cases was 3.3% and this was recorded in the year 2019 with 54,276/731,237 cases (Table 4.2).

4.5.2.2 Bloody diarrhea

Out of all the diarrheal cases 14,049 bloody diarrhea were recorded in total. It could be seen from Table 4.2 that the highest number of cases was recorded in 2014 with 1,861 cases out of the total 14,049. This represented a 13.2%. The lowest number of cases was recorded in 2019 with only 406 cases (Table 4.2).

4.5.2.3 Cholera

There were 11,826 cases of cholera in the entire period from 2010 to 2019 and of these, the highest number of cases was recorded in 2010 with 6,836 cases. The lowest was recorded in 2014 and 2015 with 0 cases (Table 4.2).

Table 4.2: Diarrheal cases from 2010 to 2019 in all health facilities of peri-urban areas Lusaka district

Year	Non-bloody	Bloody	Cholera	Total
2010	51341	954	6836	59131
2011	52497	1667	144	54308
2012	54443	1736	10	56189
2013	57472	1113	3	58588
2014	66329	1861	0	68190
2015	79222	1790	0	81012
2016	122494	1422	1283	125199
2017	82442	1784	1602	85828
2018	85257	1316	1943	88516
2019	53865	406	5	54276
Total	705362	14049	11826	**731237**

4.5.2.4 Graphical presentation of cases

It can be observed from figure 4.3 that the number of non-bloody diarrhea cases were more than the other two (bloody diarrhea and cholera). This was followed by bloody diarrhea as the line is above the cholera line.

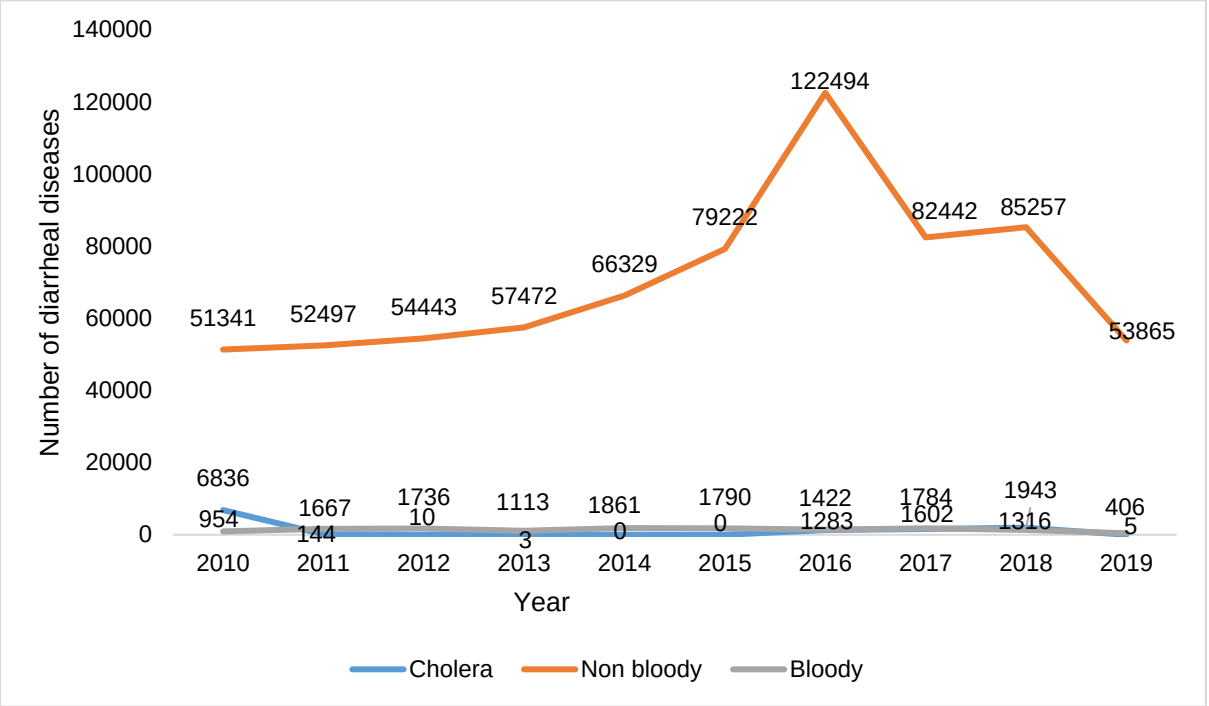

Figure 4.3: Trends of diarrheal diseases from 2010 to 2019 in health facilities of peri-urban areas Lusaka Zambia

4.5.3 Diarrheal Diseases by Seasons

Table 4.3 shows diarrheal cases according to seasons in all the health facilities. Generally, a lot of diarrheal cases were recorded between November and April while the lowest were recorded in the months between September and October.

Table 4.3: Diarrheal cases according to seasons in health facilities of peri-urban areas Lusaka District

Season	Non-bloody	Bloody	Cholera	Total
May-August	312383	5603	185	318171
Nov-April	508448	10793	12720	531961
Sept-October	201271	4109	142	205522
Total	1022102	20505	13047	**1055654**

Figure 4.4 shows the diarrheal diseases cholera, bloody diarrhea, and non-bloody diarrhea in the entire period 2010 to 2019. More cases were recorded in the season November to April (rainy season) as compared to other seasons. For instance, for cholera, 97.49% of all the cholera cases were recorded in between November and April followed by May to August and the least number of cholera cases was recorded between September and October during the period under review.

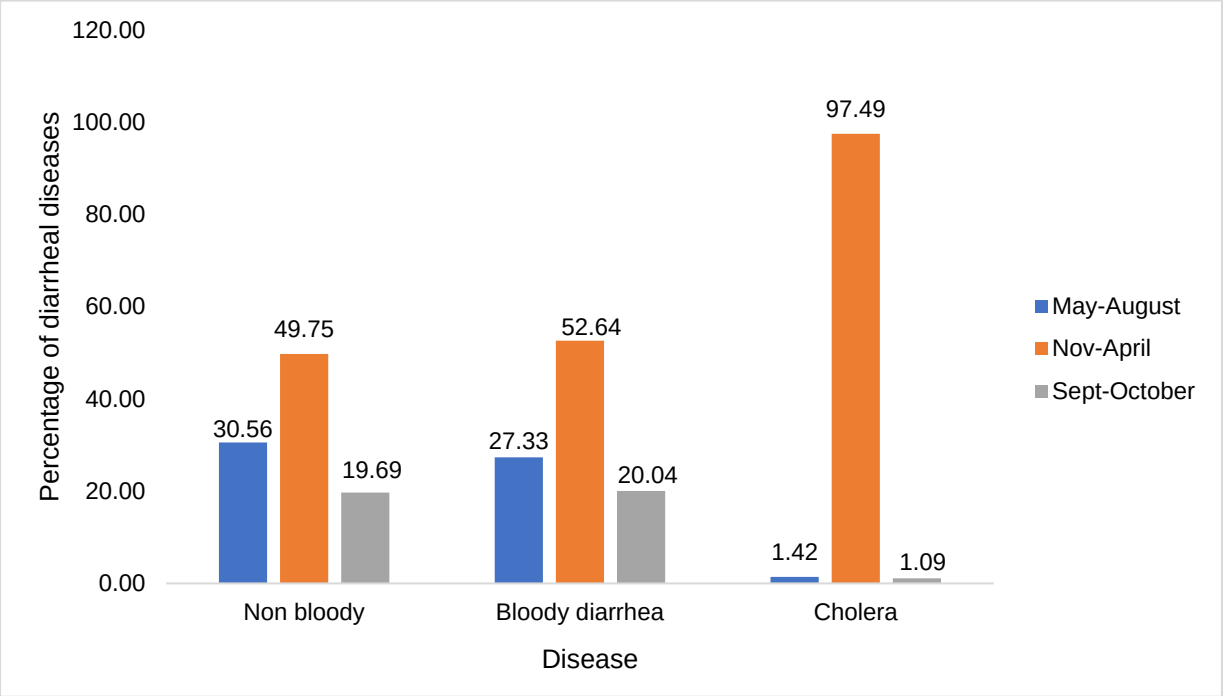

Figure 4.4: Diarrheal diseases disaggregated by season between the years 2010 and 2019 in health facilities of peri-urban areas Lusaka district

4.5.4 Summary of diarrheal diseases in health facilities of peri urban areas Lusaka Zambia

Table 4.4 presents a summary of all diarrheal diseases from 2010 to 2019 according to health facility. The study revealed that Chipata level one hospital had the highest number of diarrheal diseases. This facility recorded a total of 126,108 out of 731,237 this represents a 17. 2% of all the diarrheal diseases. Table 4 also indicate that on average more non-bloody diarrhea cases were recorded followed by bloody cases and fewer cases of cholera were recorded in the facilities. The health facility which had the lowest number of diarrheal diseases was Mtendere with a total of 23,084 cases for the entire period 2010 to 2019.

Table 4.4: Summary of diarrheal diseases in health facilities of peri-urban areas Lusaka district 2010 to 2019

No	Health facility	Diarrheal Disease			Total
		Non-bloody N (%)	Bloody N (%)	Cholera N (%)	
1	Bauleni urban	45590 (6.5)	532 (3.8)	601 (5.1)	46723
2	Chainda urban	27510 (3.9)	1100 (7.8)	43 (0.4)	28653
3	Chaisa urban health	52538 (7.4)	360 (2.6)	19 (0.2)	52917
4	Chawama first level	69243 (9.8)	2073 (14.8)	1133 (9.6)	72449
5	Chazanga urban	38771 (5.5)	222 (1.6)	0 (0)	38993
6	Chipata first level	124112 (17.6)	360 (2.6)	1636 (13.8)	126108
7	George urban	48585 (6.9)	2598 (18.5)	604 (5.1)	51787
8	Kalingalinga urban	61849 (8.8)	386 (2.7)	123 (1.0)	62358
9	Kanyama first level and West (Kanyama)	98890 (14.0)	2311 (16.4)	3499 (29.6)	104700
10	Mandevu urban	32584 (4.6)	274 (2.0)	3 (0.0)	32861
11	Matero first level	20450 (2.9)	1316 (9.4)	3466 (29.3)	25232
12	Matero main urban	22536 (3.2)	697 (5.0)	10 (0.1)	23243
13	Mtenderere urban	21586 (3.1)	1182 (8.4)	316 (2.7)	23084
14	Ng'ombe urban	41118 (5.8)	638 (4.5)	373 (3.2)	42129
	Total	705362	14049	11826	**731237**

4.5.5 Deaths from diarrheal diseases in health facilities of peri-urban areas, Lusaka District

It can be seen from figure 4.5 that more deaths from bloody diarrhea was recorded in Matero level one hospital with 183 deaths, this was followed by Chawama level one hospital with 162 deaths. Eight (8) health facilities i.e., Bauleni, Chainda urban, Chaise urban, Chazanga, George urban, Mandevu urban, Mtendere urban and Ng'ombe urban had no deaths in the entire period.

4.5.5.1 Bloody diarrhea deaths

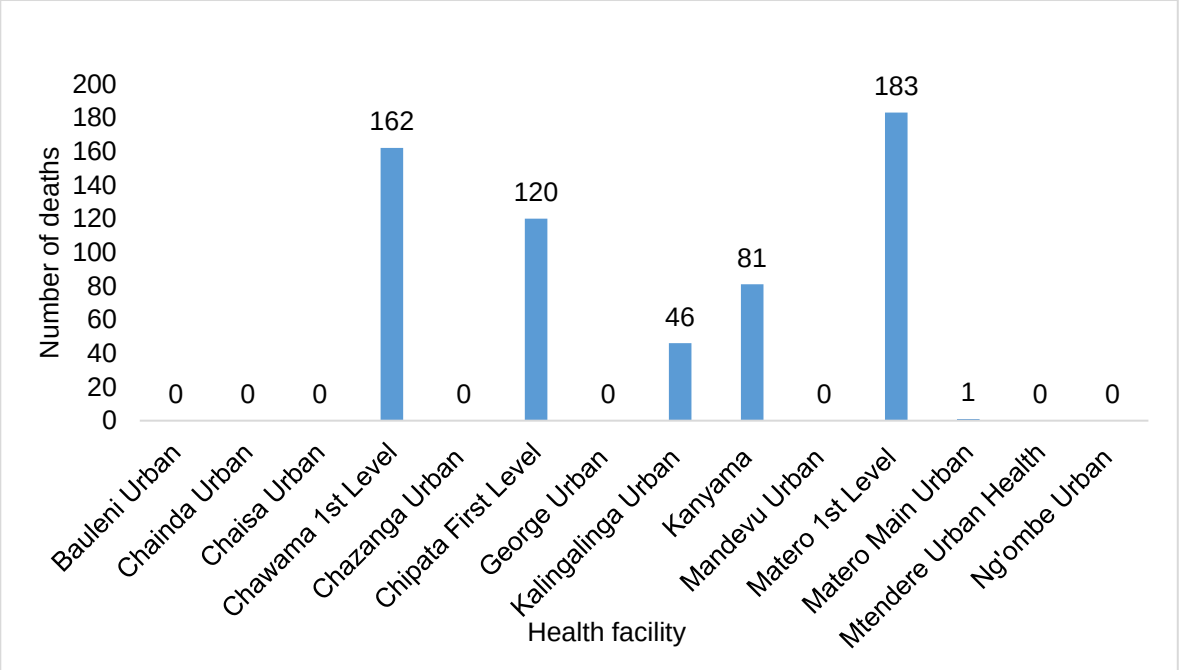

Figure 4.5: Deaths from bloody diarrhea in health facilities of peri-urban areas Lusaka District

4.5.5.2 Non-bloody diarrhea deaths

Figure 4.6 presents non-bloody diarrhea deaths for the period 2010 to 2019. Chawama first level hospital had the highest deaths that was 153, this was followed by Matero first level hospital with 133 deaths. Eight facilities i.e. (Bauleni, Chainda, Chaisa, Chazanga, George, Mandevu, Mtendere and Ng'ombe) recorded zero deaths from non-bloody diarrhea.

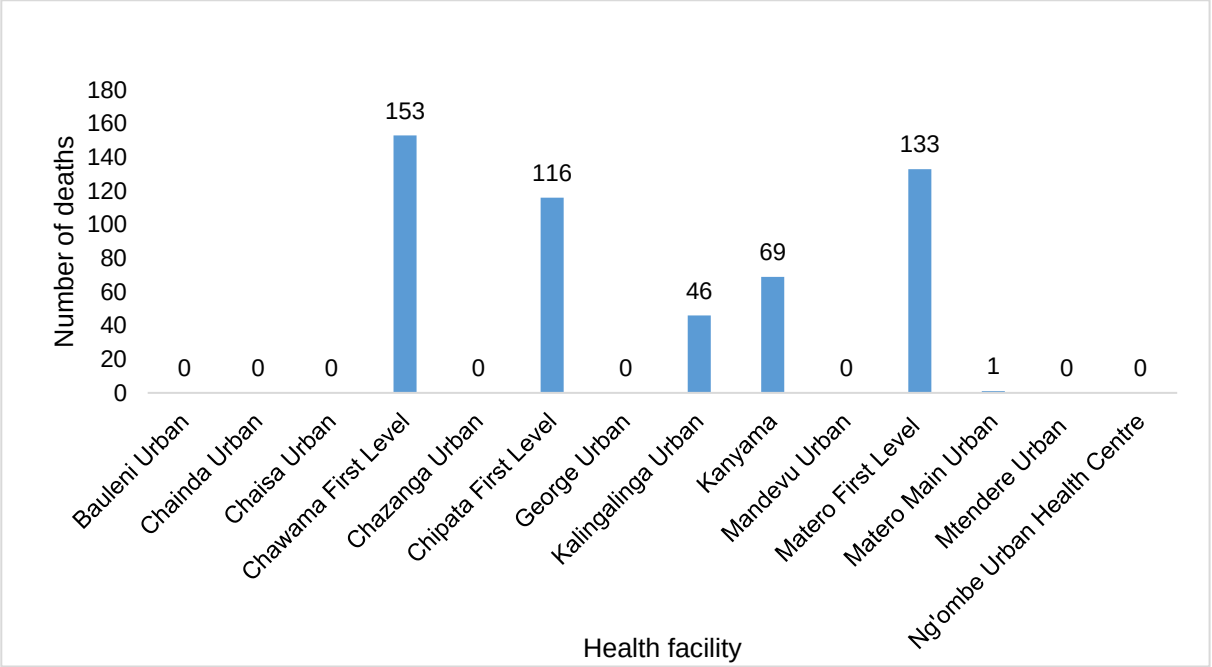

Figure 4.6: Deaths from non-bloody diarrhea in health facilities of peri-urban areas Lusaka district

4.5.5.3 Cholera deaths

Cholera recorded low numbers of deaths with a lot of health facilities recording zero deaths. However, Chawama and Kanyama level one hospitals both recorded 8 deaths each. The highest number of deaths was recorded in Matero level one hospital with 49 deaths in the entire period 2010 to 2019 Figure 4.7.

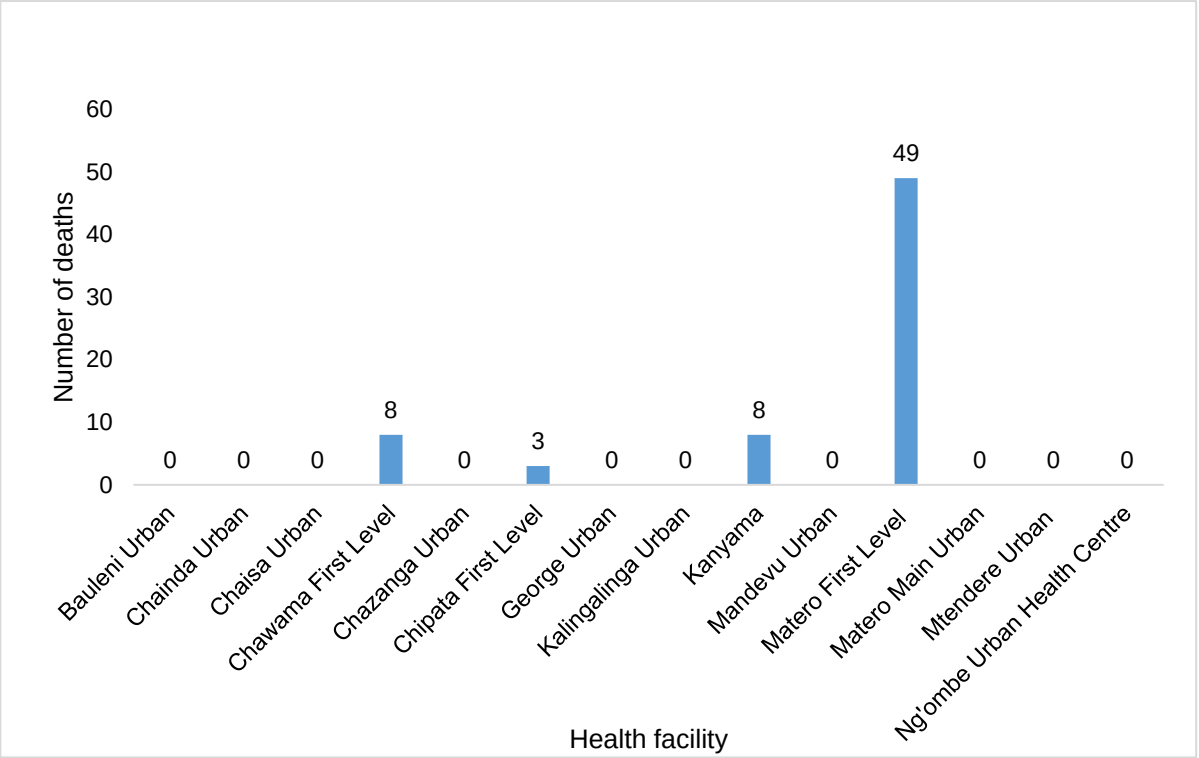

Figure 4.7: Deaths from cholera in health facilities of peri-urban areas Lusaka district

4.5.6 Summary deaths from all diarrheal diseases in health facilities of peri-urban areas Lusaka district Zambia

Figure 4.8 illustrates the summary of the death rate of individuals from the three diarrheal diseases by health facility. For instance, at Kalingalinga urban clinic, of all the three diseases recorded death rate from non-bloody diarrhea was at 50% and death rate from bloody diarrhea was at 50%, whereas death rate from cholera was at 0% indicating that no one died of cholera in Kalingalinga in the period under review.

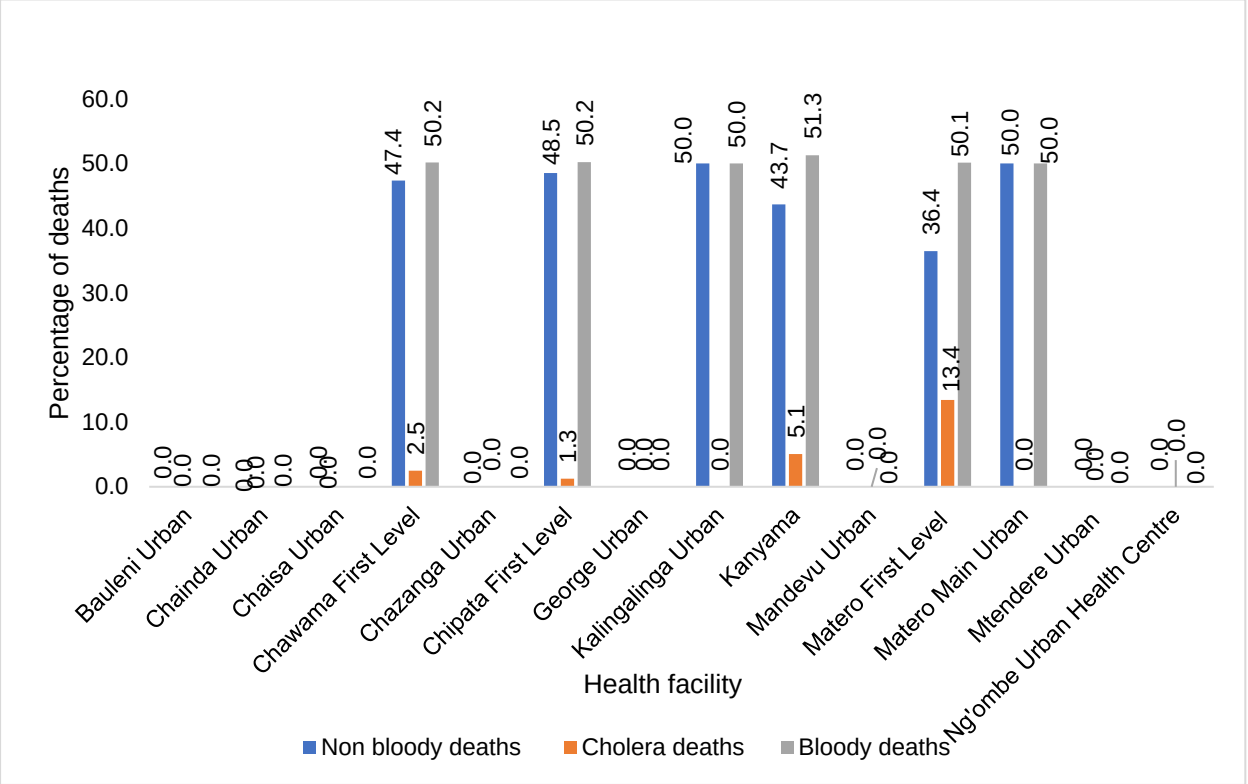

Figure 4.8: Deaths from all the diarrheal diseases in health facilities of peri-urban areas Lusaka district

4.5.7 Comparison of prevalence of diarrheal diseases in under 5 and over 5-year-old in health facilities of Lusaka district

The prevalence of the different diarrhea diseases was compared in children under 5 years to those above 5 years. The calculation of this prevalence was done in comparison with the populations of the children in the years under review. The findings are given in figures 4.9, 4.10 and 4.11.

4.5.7.1 Prevalence of non-bloody diarrhea

Figure 4.9 indicates that the prevalence of non-bloody diarrhea was high in children less than 5 years compared to the population above 5 years. This was uniform across all the years. For instance, in 2016 the prevalence of non-bloody diarrhea in children under five years was 25.4% and the prevalence in those over 5 years was 3.6%.

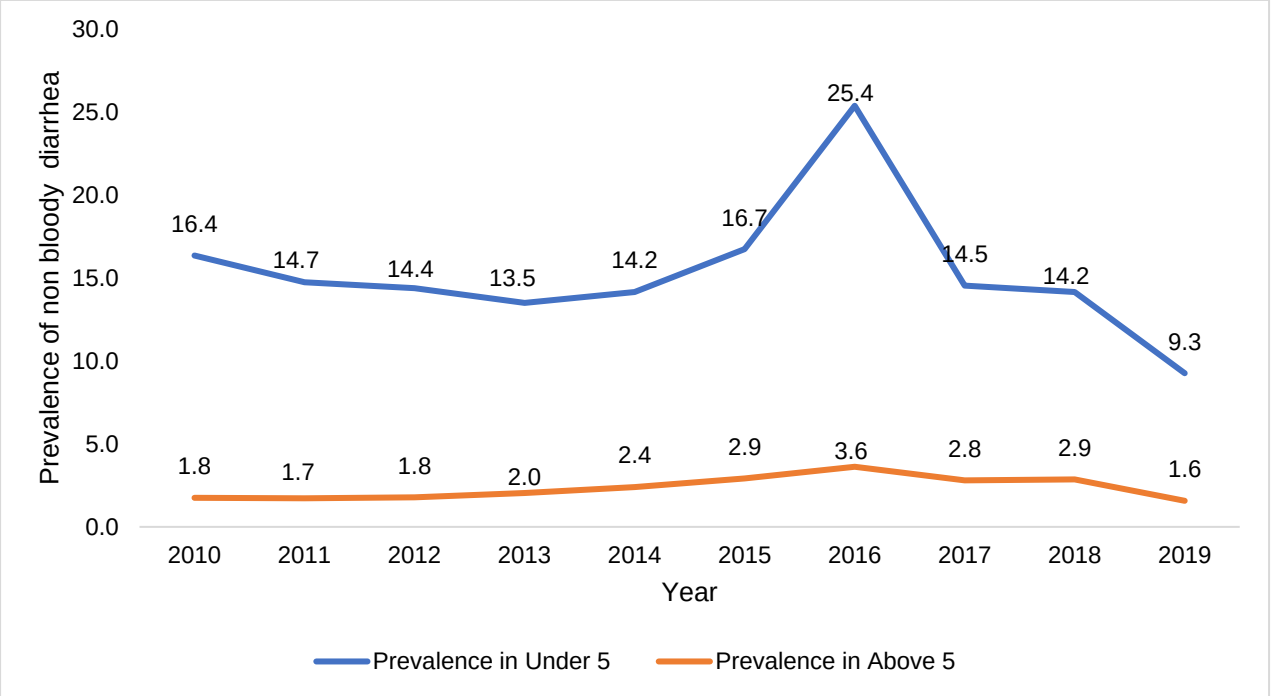

Figure 4.9: Prevalence of non-bloody diarrhea by age group from 2010 to 2019 in health facilities of peri-urban areas Lusaka district

4.5.7.2 Prevalence of bloody diarrhea

For bloody diarrhea, the trend indicates that there was a high prevalence of bloody diarrhea cases in the individuals below 5-year-old as compared to those who were above 5 years. For instance, in 2011, the prevalence of bloody diarrhea in children less than 5 years was 0.29% and the prevalence of those that are above 5 years old was 0.10% figure 4.10.

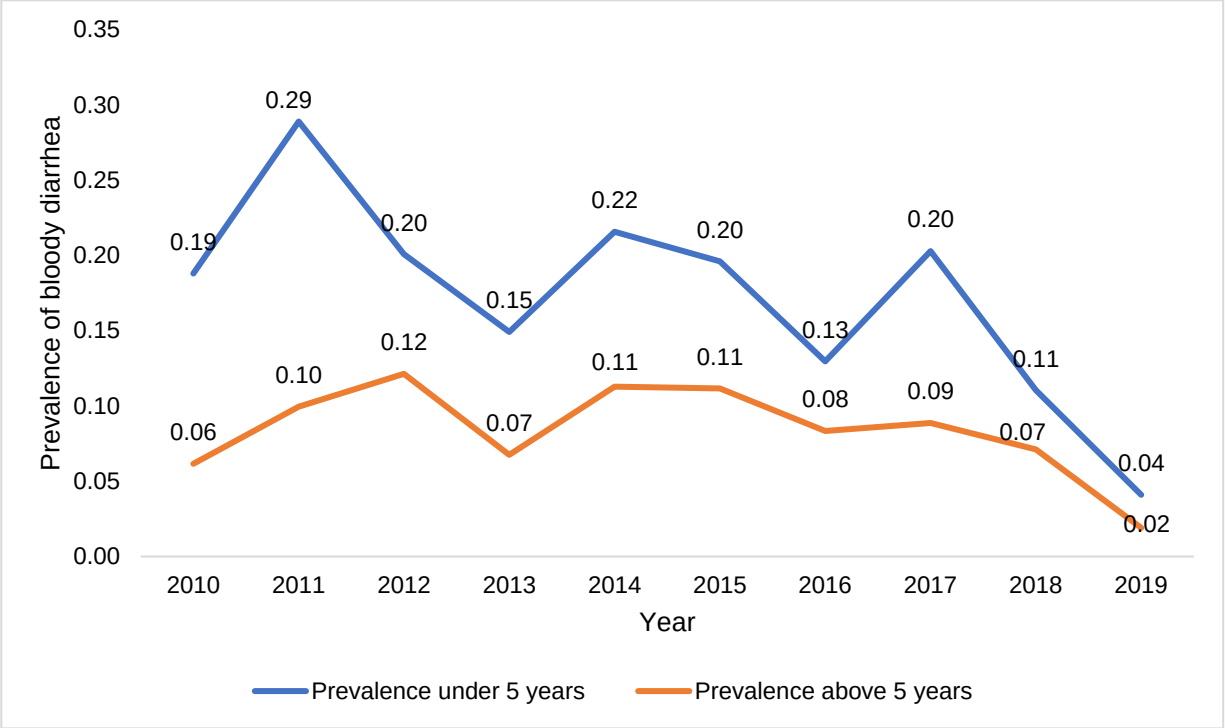

Figure 4.10: Prevalence of bloody diarrhea for the period 2010 to 2019 by age group in health facilities of peri-urban areas Lusaka district

4.5.7.3 Prevalence of cholera

The prevalence of cholera was very similar for both age groups although in some years the prevalence was high in those who were under 5 years compared to those who are older than 5 years. For instance, in 2010 the prevalence of cholera in children younger than 5 years was 0.77% and the prevalence of those who were older than 5 years was 0.58%. Note also that there was zero prevalence of cholera for both age groups in the years 2014 and 2015 figure 4.11.

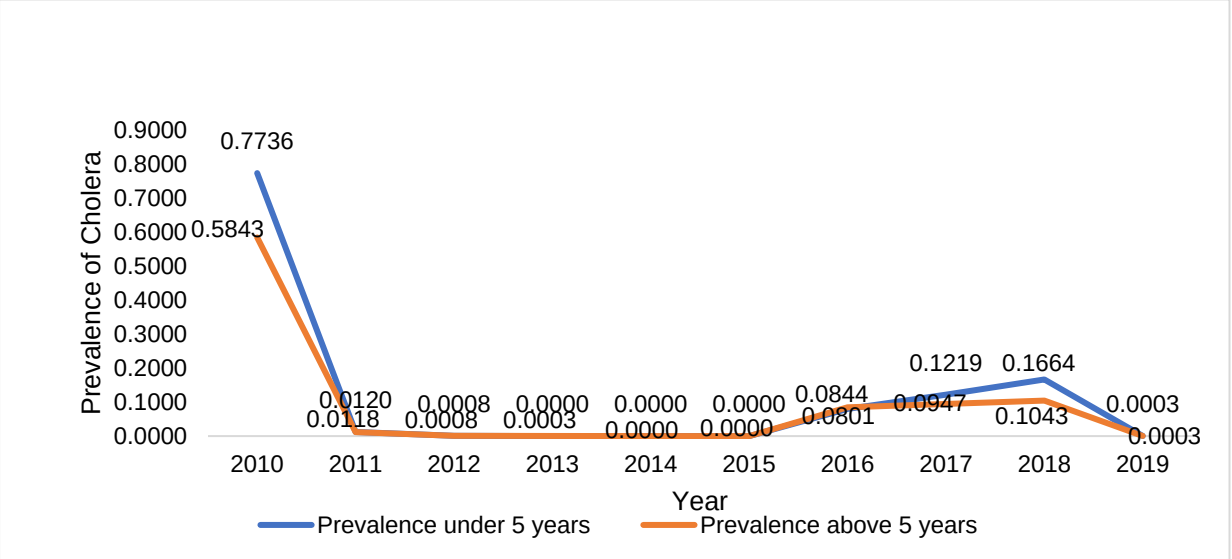

Figure 4.11: Prevalence of cholera for the period 2010 to 2019 disaggregated by age group in health facilities of peri-urban areas Lusaka district

4.5.8 Modeling the number of deaths from non- bloody diarrhea using a zero-inflated Poisson model

The final model with four variables, age of the individual, season, year and health facility were the best predictors of deaths from non-bloody diarrhea. The results indicated that there was a reduced incidence of death if one is between the age of 1 to 4 years compared with those who were less than 1 year (IRR = 0.87, CI:0.61-1.23). However, this finding was not statistically significant, p-value = 0.425. Comparing those who were above the age of 5 to those who were less than 1 year old, the results showed that those above the age of 5 years had an increased incidence of death from non-bloody diarrhea compared to those less than 1 year (IRR =1.79, CI: 1.38, 2.33). This finding was statistically significant, p-value<0.0001.

With regards the effect of season on deaths, the results revealed that one had a reduced incident of death in the month of September to October compared to May to August (IRR = 0.47, CI: 0.60 0.99). This was statistically significant with a p-value = 0.045. Further, other findings regarding season indicated that there was a 28% increase incident of death in the months between November to April compared to the period between May and August (IRR =1.28, CI: 1.05, 1.57) and this was real finding, p-value = 0.017.
The study also assessed the effect of the year on non-bloody deaths. In this regard, it was found that a unit increase in year reduced the incidence of death by 4% (IRR=0.96, CI: 0.93, 0.99). This finding was statistically significant, p-value=0.013. The health facilities were divided into 5 zones/subdistricts depending on the similarities and location. The analysis was then done at zone level. In this analysis it was found that the facilities which were in Chipata sub-district zone had an increased incident of death compared to those in the Chelstone sub-district zone (IRR=1.46, CI: 1.02, 2.09). This was statistically significant with p-value = 0.038. Other significant findings were that the facilities which were in Matero sub-district had an increased incidence of death from non-bloody diarrhea (IRR=1.55, CI: 1.09, 2.21) compared to Chelstone sub-district. This finding was statistically significant, p-value=0.015. Health facilities in Chawama and Chilenje sub-district showed an increased incident of death from non-bloody diarrhea compared to Chelstone sub-districts (IRR=2.09, CI:1.48, 2.94), and this was statistically significant p-value<0.0001.

The final model with four variables, age of the individual, season, year and health facility were the best predictors of deaths from non-bloody diarrhea as presented in table 4.12. The results indicated that there was a reduced incidence of death if one is between the age of 1 to 4 years compared with those who were less than 1 year (IRR = 0.87, CI:0.61-1.23). However, this finding was not statistically significant, p-value = 0.425. Comparing those who were above the age of 5 to those who were less than 1 year old, the results showed that those above the age of 5 years had an increased incidence of death from non-bloody diarrhea compared to those less than 1 year (IRR =1.79, CI: 1.38, 2.33). This finding was statistically significant, p-value<0.0001.

With regards the effect of season on deaths, the results revealed that one had a reduced incident of death in the month of September to October compared to May to August (IRR = 0.47, CI: 0.60 0.99). This was statistically significant with a p-value = 0.045. Further, other findings regarding season indicated that there was a 28% increase incident of

death in the months between November to April compared to the period between May and August (IRR =1.28, CI: 1.05, 1.57) and this was real finding, p-value = 0.017.

Since the data was collected between the year 2010 and 2019 inclusive the effect of the year on non-bloody deaths was also assessed. In this regard, it was found that a unit increase in year reduced the incidence of death by 4% (IRR=0.96, CI: 0.93, 0.99). This finding was statistically significant, p-value=0.013.

The health facilities were divided into 5 zones/subdistricts depending on the similarities and location. The analysis was then done at zone level. In this analysis it was found that the facilities which were in Chipata sub-district zone had an increased incident of death compared to those in the Chelstone sub-district zone (IRR=1.46, CI: 1.02, 2.09). This was statistically significant with p-value = 0.038. Other significant findings were that the facilities which were in Matero sub-district had an increased incidence of death from non-bloody diarrhea (IRR=1.55, CI: 1.09, 2.21) compared to Chelstone sub-district. This finding was statistically significant, p-value=0.015. Health facilities in Chawama and Chilenje sub-district showed an increased incident of death from non-bloody diarrhea compared to Chelstone sub-districts (IRR=2.09, CI:1.48, 2.94), and this was statistically significant p-value<0.0001 (Table 4.5)

Table 4.5: Modelling the number of deaths from non-bloody diarrhea using a zero-inflated Poisson model

	Unadjusted estimates			Adjusted estimates		
Variable	**IRR**	**CI**	**P-value**	**IRR**	**CI**	**P-value**
Age:						
Under 1 year	**REF**			**REF**		
1 to 4 years	0.88	(0.62, 1.25)	0.480	0.87	(0.61, 1.23)	**0.425**
Above 5 years	1.77	(1.37, 2.30)	<0.0001	1.79	(1.38, 2.33)	**<0.0001***
Season:						
May to August	**REF**			**REF**		
September to October	0.75	(0.58, 0.96)	0.023	0.47	(0.60 0.99)	**0.045***
November to April	1.26	(1.03, 1.54)	0.027*	1.28	(1.05, 1.57)	**0.017***
Year	0.96	(0.93, 0.99)	<0.011	0.96	(0.93, 0.99)	**0.013***
Heath facility sub-district:						
Chelstone sub-district	**REF**			**REF**		
Chipata sub-district	1.30	(0.91, 1.86)	0.148	1.46	(1.02, 2.09)	**0.038***
Matero sub-district	1.18	(0.83, 1.66)	0.354	1.55	(1.09, 2.21)	**0.015***

Unadjusted estimates				Adjusted estimates		
Variable	**IRR**	**CI**	**P-value**	**IRR**	**CI**	**P-value**
Kanyama sub-district	0.86	(0.58, 1.27)	0.453	1.09	(0.74, 1.62)	0.663
Chawama and Chilenje sub-district	1.77	(1.26, 2.48)	0.001	2.09	(1.48, 2.94)	**<0.0001***

Key: REF: Reference category, ***statistically significant at 0.05 level; IRR: Incidence Rate Ratio

4.6 Discussion

Overall, the study generally revealed fluctuating trends of diarrhea diseases with the highest number of diseases being in 2016 and the lowest being in year 2019. The common diarrhea diseases were non-bloody diarrhea followed by bloody diarrhea and then cholera. The study also revealed that there were more cases of diarrhea diseases in rainy seasons. Chipata health facility recorded the highest number of cases and Mtendere the lowest cases. Highest number of diarrhea deaths were caused by bloody diarrhea. Diarrheal diseases were common in the population under the age of 5 years. The study also found that age of the individuals, season, year and facility zone or sub district were the best predictors of deaths from non-bloody diarrhea.

The data revealed that the cases of diarrhea diseases gradually increased from 2010 to 2016 with the highest cases being recorded in 2016. However, the cases started to decline with 2019 recording the lowest number of diarrhea diseases. These results indicate that the number of diarrhea diseases have generally reduced. These results are in line with other assessments at global scale[26,27] and other specific places such as India, Ghana, Democratic Republic of Congo and Brazil from 1990 to 2019.[7-9,28] The reasons for the reduction might be due to introduction of different interventions to mitigate diarrheal diseases such as provision of improved water supply, sanitation facilities and hygiene, vaccination for waterborne diarrhea diseases including cholera and rotavirus, household water treatment and so on.[1,2,5]

The common diarrheal diseases reported in this study were non-bloody followed by bloody diarrhea and then cholera. Cases of non-bloody diarrhea are possibly high due to the numerous causative agents of non-bloody that are not usually detected by routine diagnostic laboratory tests.[29,30] While bloody diarrhea is commonly caused by specific microorganism including (*Escherichia coli* O157:H7, shigella, campylobacter, nontyphoid salmonella, and Shiga toxin–producing *E. coli*[29,31,32] and cholera is caused specifically by Vibrio Cholerae.[33,34]

This study also found that diarrhea diseases were most common in the rainy season compared to other seasons. These findings are in line with other studies conducted in different countries for example studies conducted in Bangladesh review high cholera and other diarrheal cases in rainy season and another prediction study revealed the same in Iran.[35,36] The reason behind the high number of cases in the rainy or hot season is due to increased replication of the cholera causative agent in hot conditions.[36,37] In addition, there is contamination of underground water sources by sanitary facilities and other runoff during the rainy season especially in communities that use water from unprotected sources.[38,39] Literature from Zambia also revealed the same. A report on cholera for the years 2017 to 2018 in Lusaka showed the highest number of cases in the rainy season with a reduction after the implementation of different interventions including provision of emergency safe water, vaccines, burying of shallow wells and so on.[40] Another study on trends of dysentery (bloody diarrhea) also revealed more cases in rainy seasons of period 2016 to 2018 than the other seasons in Zambia.[16]

In terms of diarrhea diseases by age group, the study revealed more cases of diarrheal diseases among children under five years compared to those above five years old. These findings are in line with literature by WHO, a review conducted in sub-Saharan Africa and other countries.[1,2,41-43] The reason for this age group being more at risk is due to their immune system not being fully developed to fight diseases. This age group is also explorative in nature touching and eating or putting whatever they pick up in the mouth.[30] Further the poor health and nutrition state of under-five children are some of the contributors to the high incidences in this age group.[41,44]

In terms of death, it was noted that some facilities did not record any deaths from non-bloody, bloody diarrhea and cholera during the study period. However, Matero first level hospital recorded the highest number of bloody diarrhea and cholera deaths. Followed by Kanyama and Chawama first level hospitals. The highest number of deaths at the first level hospitals might be attributed to these facilities being the referral hospital for the other facilities in Lusaka district. In addition, Matero and Kanyama as well as Chawama were cholera isolation and treatment centers during the cholera outbreaks[45] these health facilities were also found with the highest overall number of diarrhea cases. In terms of the causes of deaths bloody diarrhea caused the highest number of deaths followed by non-bloody and then cholera which represented the lowest number of deaths. Literature shows that Bloody diarrhea last longer and associated with high complication and deaths compared to non-bloody diarrhea.[46] In terms of cholera the low

number of deaths might be attributed to it mostly being seasonal and not occurring every year.

This study found that age of the individual, season, year and health facility were the best predictors of deaths from non-bloody diarrhea. These results are in line with other studies already presented in this section. Those above the age of 5 years had an increased incidence of death from non-bloody diarrhea compared to those less than 1 year the results were statistically significant. The study also found reduced incidents of death in the (hot dry season) compared to cool dry season. There was also an increase of 28% increase incident of deaths in the rainy seasons compared to cool dry season. The current study found that the unit increase in the year reduced the incidence of deaths from non-bloody diarrhea by 4%. The deaths are probably declining as the number of cases also reduced for the study period as revealed in this study. In terms of deaths by sub district or zones this study found that some zones had increased incident of deaths due to non-bloody diarrhea compared to others. This finding calls for intensified provision of interventions in these zones with increased incident of deaths including Chipata, Matero and Chawama.

4.7 Limitations

Secondary data is prone to misclassification i.e., the mis-categorization of the cases as zero when the recording was not just done. Limited variables were included in this study as they were the ones available in the data search. However, the variables included were able to give some valuable information on diarrhea diseases in the study areas. Not all the diarrhea cases are reported to the health facilities. The cases might be higher in the population than recorded. This study has however given an approximation of what exist in the community in terms of diarrhea diseases as the health facilities included are the main facilities in the targeted communities. The number of months for the three seasons used in the analysis were different with rainy seasons having more months compared to the other seasons this might have contributed to more cases being recorded in this season compared to the other season. However, the results can still be valid since the months that are in each season have generally got the same characteristics that influences disease occurrence.

4.8 Generalization

The results of this study can be generalized to other peri-urban areas in Zambia and similar settings.

4.9 Conclusions

In summary there was a general decline in trends of diarrheal diseases in health facilities of peri-urban areas of Lusaka district from 2010 to 2019. Non-bloody diarrhea was the most common cause of morbidity and bloody diarrhea main cause of mortality. The diseases were generally highest during the rainy season with the under-five children reporting the highest. First level hospitals recorded highest number of cases and deaths compared to other facilities. The results of this study call for implementation of interventions to mitigate the risk of diarrheal diseases. The interventions must be implemented after conducting intervention needs assessment for each facility catchment area for best outcomes.

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CHAPTER 5: DEVELOPMENT AND VALIDATION OF THE FRAMEWORK

5.1 Introduction

This chapter presents the development of the draft framework for mitigating the risk of waterborne diarrheal diseases and the validation of the framework.

5.2. Development of the draft framework

People in peri-urban areas are exposed to diarrheal diseases that are caused by a variety of waterborne diarrhea pathogens. There are various interventions that have been implemented to curb the diseases, however the diseases are still prevalent and causing deaths world over especially in developing countries.[1] The author conducted research to determine whether there are frameworks that are available to mitigate the risk of waterborne diarrhea diseases. However, none were found that specifically addressed the issue of mitigating the risk of waterborne diarrhea diseases in peri-urban areas in general and or specifically in Lusaka district Zambia.

The review of available framework as well as other methods were used to create the draft framework. This chapter presents brief findings of the various methods that were used to create the draft framework for mitigating the risk of waterborne diarrhea diseases. The following was done to create the draft framework:

1. Identification of interventions for mitigating the risk of diarrhea diseases through a systematic literature review - Chapter 3.2, the review has been published available at: https://systematicreviewsjournal.biomedcentral.com/articles/10.1186/s13643-022-01947-y.

2. Determining the trends of diarrheal diseases in peri-urban areas to determine the problem of waterborne diarrhea diseases in peri-urban of Lusaka district - Chapter 4.
3. Review of frameworks for mitigating the risk of waterborne diarrheal diseases. This review was the basis of the draft framework through a scoping review – Chapter 3.3, the scoping review has been published available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0278184.
4. To get information specifically for the peri-urban areas of Lusaka district, additional information was collected through secondary data and interviews with experts. Literature review was also used to strengthen some of the components of the framework.

The following is a summary of the findings of the objectives mentioned.

- **Systematic review on interventions**

Results of the systematic literature review (refer to chapter 3.2) revealed different interventions available for mitigating the risk of waterborne diarrheal diseases including vaccines for rotavirus disease (Monovalent, Pentavalent and Lanzhou lamb vaccine); enhanced water filtration for preventing Cryptosporidiosis, Vi polysaccharide for typhoid; cholera 2 dose vaccines, water supply, water treatment and safe storage, household disinfection and hygiene promotion for controlling cholera outbreaks. These results helped to identify the interventions to include in the developed framework.[2]

- **Longitudinal study on trends of diarrheal diseases**

The study on trends of diarrheal diseases (refer to chapter 4) found a decline in trends of diarrheal disease in Lusaka district in the period 2010 to 2019 under review. Non-bloody and bloody diarrhea were the major contributors to morbidity and mortality, respectively. The diseases were highest in the rainy season and among children under the age of five. In addition, the high-risk areas of diarrheal diseases in Lusaka district Zambia for intervention implementation in the district were identified.

- **Scoping review of frameworks**

Five frameworks were identified through the scoping literature review (refer to chapter 3.3). These frameworks include Hygiene Improvement Framework (HIF), Community Led Total Sanitation (CLTS), Global Action Plan for Pneumonia and Diarrhea (GAPPD), Participatory Hygiene and Sanitation Transformation (PHAST) and Sanitation and Family Education (SAFE). The frameworks were used as a basis for the development of the draft framework presented later in this chapter after assessing the strengths and weaknesses of the frameworks.[3]

This chapter will revisit chapter 3.3 on how the identified frameworks were identified and used to develop the draft framework.

5.3 Review and selection of the frameworks

A literature search was conducted to determine the frameworks available to mitigate the risk of waterborne diarrheal diseases. Several databases including PubMed, Scopus, Web of Science in addition to google scholar, google free search and organization

websites were searched as presented in chapter 3.3. The full searchers for the databases are presented in table 5.1.

Table 5.1: Complete search strategy PubMed, Scopus and Web of Science

Data Base/ Search Date	Search Terms	Search Limit	Results
PubMed			
13th April 2021	Waterborne framework	Free search	147
13th April 2021	Waterborne Model	Free search	1319
31st August 2021	"diarrh*"[Title/Abstract]	Title/abstract	116544
1			
2	(prevent*[Title/Abstract]) OR (Control*[Title/Abstract])	Title/abstract	5,314,648
3	"Framework"[Title/Abstract] OR "Model"[Title/Abstract]		2,521,755
1 + 2 + 3	"diarrh*"[Title/Abstract] AND ("prevent*"[Title/Abstract] OR "control*"[Title/Abstract]) AND ("Framework"[Title/Abstract] OR "Model"[Title/Abstract])	Title/abstract	2,761
Total			**4227**
Scopus			
22nd April 2021	TITLE-ABS-KEY (waterborne AND framework): waterborne framework	article title, abstract, keywords	290
22nd April 2021	TITLE-ABS-KEY (waterborne AND model) waterborne model	article title, abstract, keywords	1,988
2nd August 2021	TITLE (diarrh*)	Title	36810
1			
2nd August 2021	TITLE (framework OR model)	Title	2423298
2			
2nd August 2021	(TITLE (diarrh*)) AND (TITLE		
1 + 2	(framework OR model))		363
Total			**2641**
Web of Science			
22nd April 2021	Waterborne framework (Waterborne framework)	Topic	224
22nd April 2021	Waterborne model	Topic: title, abstract, author keyword, and Keywords PLUS	1889

Data Base/ Search Date	Search Terms	Search Limit	Results
2nd August 2021	Diarrh* (Title)		30,971
1			
2	Framework OR Model (Title)		2,803,212
3	1 and 2		462
Total			**2575**
Grand total			**9443**

After the search, no framework was found that addressed waterborne diarrhea diseases. Thus, frameworks that looked at general diarrhea diseases were used as a basis for the framework. A total of five (5) frameworks were found that met the inclusion criteria including Hygiene Improvement Framework (HIF),[4] Community Led Total Sanitation (CLTS),[5] Global Action Plan for Pneumonia and Diarrhea (GAPPD),[6] Participatory Hygiene and Sanitation Transformation (PHAST),[7] and Sanitation and Family Education (SAFE).[8] The Inclusion and exclusion of the framework are presented in table 5.2. The details of the selected frameworks are presented under chapter 3.3.

Table 5.2: Inclusion and exclusion criteria

Inclusion criteria
• mitigating the risk of diarrhea • frameworks addressing either diarrhea prevention • combination of prevention and control/treatment of waterborne diarrhea/diarrhea diseases; latest version • known reliable source
Exclusion criteria
• concentrated fully on clinical aspects treatment of diarrhea diseases only, • no reliable source • no proper framework (studies reporting interventions only); mathematical models. • frameworks that looked at mitigating the risk of diarrhea diseases in animals • did not have access to the full text documents

A Strength Weakness Opportunity Threat analysis was done on the five (5) frameworks that were found. Criterion of assessment of the frameworks was done using the standard that was made in consultation with literature. The resources that were used to obtain the standards for frameworks evaluation were that of center of disease control and prevention (CDC) framework for prevention or control of communicable diseases[9] and national framework for control of communicable diseases, Australia.[10] The two

resources were used as they gave general components of frameworks. They were also closely related to waterborne diarrhea diseases as they were developed to deal with general communicable diseases of which waterborne diarrhea diseases are a part of. In addition to the two frameworks some of the components were derived by the author. The components of the criteria that were used to assess the frameworks are presented in table 5.3 and their sources.

The components that were used for framework assessment included: Problem identification through epidemiological and laboratory testing;[9,10] Risk identification and quantification (authors derived); Identification of interventions;[9,10] Integrated approach of intervention (hardware, software and enabling);[9] Interventions target multiple groups in community (authors derived); Implementation of interventions and delivery methods;[9] Financing, resource mobilization and infrastructure;[9,10] Human resource;[10] Implementation of interventions/program within existing structures (authors, derived); Multiple Stakeholders' involvement;[9,10] Community involvement;[9,10] Monitoring – follow up;[9,10] Evaluation - measures of success[9,10] Improved information system and means of record keeping electronic means;[9,10] Means of sustainability (authors derived); Focuses on waterborne diarrhea diseases (authors derived) and Policies and laws development and or improvement[9,10] In addition, two components were included at the development of the framework level. That is assessment of the interventions and selection and adoption of the interventions in prototype communities.[9]

Table 5.3: Criteria, sources, scores, and definition of components that were used to assess the frameworks for mitigating the risk of diarrhea diseases

	Criterion and sources	Score	Definition
1	Problem identification[9,10]	1	Include identification of problem using epidemiological and laboratory surveillance
		0.5	Include only epidemiological surveillance or laboratory surveillance but not both
		0	No problem identification component
2	Risk identification and quantification (authors)	1	Has a component of risk identification and quantification
		0.5	Included only risk identification or quantification
		0	No element of risk identification and quantification
3	Identification of interventions[9,10]	1	Identification of intervention
		0	No identification of interventions
4		1	Include at least hardware and software interventions

	Criterion and sources	Score	Definition
	Integrated approach[9]	0	Includes either the software or hardware intervention(s) only
5	Interventions target multiple groups (authors)	1	Intervention targets multiple groups in the community
		0	Interventions only targets one group in the community e.g., children under 5 years only
6	Implementation and Delivery of interventions[9]	1	Has component of implementation and delivery of intervention
		0	No component of implementation and intervention delivery
7	Means of financing and or resource mobilization[9,10]	1	Has a component of means of financing or resource mobilization
		0	No component of financing and or and resource mobilization
8	Human resources[10]	1	Component of required human resources in the program
		0	No component of human resources required in the program
9	Implementation of interventions/program within existing structures (authors)	1	Intervention or programs implemented within existing structures
		0.5	Not clear whether the program is implemented within existing structures but there is a component of implementation
		0	No component on whether the program or intervention implementation
10	Multiple Stakeholders' involvement[9,10]	1	Involvement of different stakeholders in diarrhea mitigation activities or program
		0.5	Not too clear whether multiple stakeholders are involved in the program or activities
		0	No multiple stakeholder's involvement
11	Community involvement[9,10]	1	Community involvement in the whole process of the process
		0.5	Not clear whether there is community participation or not
		0	No component of community involvement
12	Monitoring - follow-up[9,10]	1	Component of Monitoring available
		0.5	Not clear of monitoring component
		0	Monitoring component not available
13	Evaluation - measure of success[9,10]	1	Evaluation component available
		0.5	Not clear of availability of evaluation
		0	No Evaluation component
14	Electronic means of Data collection, storage and transferring[9,10] (authors)	1	Availability of electronic means of data collection, storage and transferring
		0	No means of electronic data collection, storage and transferring

	Criterion and sources	Score	Definition
15	Means of sustainability (authors)	1	Has a component of sustainability and means of sustainability explained
		0.5	Has a component of sustainability but means of sustainability not clearly explained
		0	No component of sustainability available
16	Focuses on waterborne diarrhea diseases (authors)	1	Framework focuses on waterborne diarrhea diseases
		0	Framework does not focus on waterborne diarrheal diseases
17	Laws and policy development and improvement on intervention[9,10]	1	Component of laws and policy development or improvement
		0	No component of laws and policy development or improvement

Note: Authors - These are the components that were derived by the authors.

Multiple stakeholder involvement: Program involving different government department or institutions, private sectors Non-Governmental Organizations and international communities etc.

5.4 Strengths and weaknesses of the identified frameworks

In all consulted frameworks, no framework or approach looked at waterborne diarrhea diseases. The strengths of all the identified frameworks were having a component of community involvement, monitoring and evaluation, human resources and implementation and delivery of intervention. The main weakness of the frameworks involved data collection, storage and transfer using electronic means and focusing on general diarrhea instead of waterborne diarrhea diseases.

All the frameworks assessed had a component of problem identification, but none had comprehensive problem identification that involved both epidemiological assessment and laboratory tests to determine the cause of diarrheal diseases, which is vital to decide on the specific prevention and treatment aspect of the different waterborne diarrhea diseases. In term of risk factors identification and quantification and intervention identification majority (four) frameworks i.e., CLTS, PHAST, SAFE and GAPPD had these components. Intervention identification is vital to know what exactly should be done or worked on based on the risks identified. Only two frameworks i.e., HIF and GAPPD had the component of integrated approach i.e., using multiple interventions to prevent diarrhea diseases. Integrated approach is important in control of diarrheal diseases as it is transmitted through different mean which needs to the controlled in a holistic approach to get the required outcomes or effectiveness. More than half of the frameworks i.e. SAFE, PHAST and CLTS had diarrhea interventions that target multiple

groups in the community. Targeting different groups in the population increases the number of people that are reached and ensures that people of different classes, age and other characteristics are reached. Most of the diarrhea target children only when even the adults are affected by the diseases.

All the frameworks addressed implementation and delivery of interventions, human resource, community involvement, monitoring and evaluation of the interventions. These components are important to choose the right type of intervention delivery to increase reach and update of the interventions. Availability of human resource is vital to ensure that the program objectives are met. Community involvement is also essential to increase ownership important for sustainability of health programs. Monitoring and evaluation are also vital to ensure that everything is working well and to check for the effectiveness of the program or interventions. This helps to change strategies if need be to the implementation of the programs. In terms of financing and resource mobilization, frameworks HIF, PHAST and GAPPD had this component. Means of financing and resource mobilization for the projects is vital to ensure that the objectives of the programs are meant, programs with proper financing can succeed than those that are poorly financed. Only two frameworks HIF and GAPPD had the component of implementing the interventions in already existing programs or structures and CLTS had this component though not clearly presented and the rest did not have. Implementing of interventions in already existing programs is important to ensure sustainability and efficient use of resources. Most of the frameworks (4) had an element of multiple stakeholders' involvement in the process with one not too clear of involvement of different stakeholder. Multiple stakeholder involvement in diarrhea prevention is important as it requires different stakeholders including but not limited to government, private sectors, and international communities etc. None of the frameworks had a component of data collection, keeping and transfer through electronic means. It is important to stress that data management using electronic means is important to ensure easy data collection, storage and transfer to the various offices for decision making. In terms of sustainability three frameworks i.e., HIF, CLTS and GAPPD had this component while two frameworks did not have a clear means of sustainability. Sustainability of interventions or programs for diarrhea diseases is important to deal with the problem. Without sustainability programs are a waste of resources diarrhea interventions must be continuous to prevent reoccurrence of the diseases. Lastly, less than half of the frameworks two (2) HIF and GAPPD had components of laws and policy

development and improvement. Laws and policies are important for ensuring compliance to standards vital for disease mitigation.

Out of the 17 total scores for each framework using the criteria in table 5.3, none of the frameworks got a final score of 100%. The best framework was GAPPD with a total score of 12.5 and the least scoring framework was SAFE with a total score of 9.5 out of 17 refer to table 5.4.

Table 5.4: Scores of the Selected Frameworks

	Criteria /Component	Framework and Score					Total
		HIF	CLTS	PHAST	GAPPD	SAFE	
1	Problem Identification	Z(0.5)	Z(0.5)	Z(0.5)	Z(0.5)	Z(0.5)	2.5
2	Risk identification and quantification	Z(0.5)	Y(1)	Y(1)	Y (1)	Y(1)	4.5
3	Identification of interventions	N(0)	Y(1)	Y(1)	Y(1)	Y(1)	4
4	Interventions integrated approach	Y(1)	N(O)	N(0)	Y(1)	N(0)	2
5	Interventions target multiple groups	N (0)	Y(1)	Y(1)	N(0)	Y(1)	3
6	Implementation and delivery of interventions	Y (1)	Y(1)	Y(1)	Y(1)	Y(1)	5
7	Financing and or resource mobilization	Y(1)	N(0)	Y(1)	Y(1)	N(0)	3
8	Human resources	1	1	1	1	1	5
9	Implementation of interventions/program within existing structures	Y(1)	Z(0.5)	N(0)	Y(1)	N(0)	2.5
10	Multiple stakeholders' involvement	Y(1)	Y(1)	Y(1)	Y(1)	Z(0.5)	4.5
11	Community involvement	Y(1)	Y(1)	Y(1)	Y(1)	Y(1)	5
12	Monitoring – follow up	Y(1)	Y(1)	Y(1)	Y(1)	Y(1)	5
13	Evaluation - measures of success	Y(1)	Y(1)	Y(1)	Y(1)	Y(1)	5
14	Electronic means of Data collection, storage and transferring	N(0)	N(0)	N(0)	Z(0)	N(0)	0
15	Means of sustainability	Y(1)	Y(1)	Z(0.5)	Y(1)	Z(0.5)	4
16	Focuses on waterborne diarrhea diseases	N(0)	N(0)	N(0)	N(0)	N(0)	0
17	Laws and policy development and improvement on intervention	Y(1)	N(0)	N(0)	Y(1)	N(0)	2
	Total	**12**	**10**	**11**	**12.5**	**9.5**	

Literature identifies several aspects that are important for diseases prevention frameworks including:

N= Not available = 0; Y= available =1; Z= Available but not too clear or adequate = 0.5

After reviewing the frameworks and establishing their strengths and weaknesses, a draft framework was developed**.**

5.5 Draft framework for mitigating the risk of waterborne diarrheal diseases

The framework developed under this study was generated for mitigating the risks of waterborne diarrhea diseases in peri urban areas of Lusaka district. Peri-urban are areas that are not serviced with limited access to water and sanitation systems and other services. Majority of the people in these areas do not have access to safely managed water and sanitation facilities. This is in addition to poor hygiene practices. For example, some people in these areas use shallow wells and pit latrines for water supply and excreta disposal, respectively.[11,12] This framework can be adapted to areas with similar characteristics. The draft framework has several components including problem identification, identification and quantifying of risk factors, identification of appropriate intervention, assessment of intervention, selection and adoption of relevant interventions, implementation, monitoring and evaluation and means of sustainability for the implemented interventions. This framework also proposes ten other components to support the system. To ensure effectiveness, the framework must be continuous, and implemented in stages from the first to the last stage. Figure 5.1 shows the summary of the draft developed framework.

5.5.1 Problem identification

The first phase of the framework involves identification of the problem i.e. the burden of waterborne diarrheal diseases. Surveillance methods including but not limited to health facilities and community survey, laboratory analysis to determine the causative pathogens for diarrhea diseases and literature review are methods that can be used to identify the problem. This stage involves collection of information about waterborne diarrhea diseases and affected people by determining the cases or burden of diseases and the trends of diseases. Other information to be collected include demographics, behavioral - personal, social economic and environmental data such as age, sex, locations/landmarks), income, level of education, and so on of the affected people**.** Data of cases and related factors should be collected from both health facilities and community through community surveys to obtain comprehensive information. Community surveys are important to acquire information from people who do not report

to the health facility when they have diarrhea diseases. This stage is also vital to identify diseases high risk areas to ensure targeted interventions. Validated tools must be used to obtain data using the various methods from the community and health facilities. In the development of this framework, the methods that were used to identify the problem included literature review and health facility data on diarrheal diseases for trends.

5.5.2 Identification and quantifying of risk factors

The second phase of the framework involves identification and quantification of the risk factors of waterborne diarrheal diseases. Risk factors refers to determinants that are associated with an increased risk of waterborne diarrhea diseases including personal - demographic, social - economic and environmental factors. Multiple strategies to identify the risk factors of waterborne diarrhea diseases must be used using validated tools. Literature view, scoping reviews and community surveys data from health facilities were used to determine the risk factors of waterborne diarrheal disease in the development of this framework. A comprehensive assessment should be applied to determine the risk factors of waterborne diarrhea diseases because of multiple risk factors associated with diarrhea diseases.[13-15] Risk factors must be collected at community levels as well as the health facilities to get information from people who do not report to the health facilities. When identifying risk factors the assessments should focus on water supply, sanitation, and hygiene (hand washing) as these are the major risk factors of waterborne diarrhea diseases according to literature and these are essential to cut the fecal oral transmission route of waterborne diarrhea diseases.[16]

5.5.3 Identification of interventions

The third phase of the framework involves identification of interventions for waterborne diarrhea diseases. This phase involves identification of evidence-based interventions that have been published in literature from scientific studies. The interventions must be based on the risks that have been identified in the second phase of the framework. In the development of this framework, interventions were identified through the systematic literature review of studies, scoping review, and other general literature. This framework proposes integrated approach in terms of interventions since diarrhea has different risk factors. The interventions that were identified through the systematic literature review, scoping review of frameworks as well as general literature review include: water and sanitation (solid and liquid waste management), food safety, hygiene facilities, vaccinations, exclusive breastfeeding, treatment, enforcements, hygiene promotion

behavior change Chapter 3. These interventions can also be classified into two i.e., Hardware and software interventions. “Hardware” include (water and sanitation facilities: Toilets, sewers, drainage, hand washing/drying facilities, soap, anal cleaning material, taps) and “software” includes (hygiene and or sanitation promotion activities such as handwashing promotion, water protection, safe excreta disposal other software activities include policy development, training, monitoring and evaluation and everything that allow a program, project or interventions to take place in addition to other intervention such as food safety, immunization etc.[16,2]

Even though comprehensive interventions are required, this framework will focus on priority areas that are lacking in terms of water, sanitation, and hand hygiene and other risks as assessed during the risk identification phase.[8] While each of these interventions mentioned is effective on its own, in combination, they can deliver even greater results. The framework proposes mandatory long-term provision of toilets and water supply as these are fundamental requirement for mitigation of waterborne diarrhea diseases before implementation of the other interventions. The framework also recommends hygiene promotion as the first step to ensure behavioral change before provision of hardware interventions without knowledge and or behavioral change the provided facilities will not result to any health benefits.[4]

To facilitate decision on the type of water and sanitation facilities to be provided, the Joint Monitoring Program (JMP) ladders must be applied and other relevant local and or international standards. The facilities must also be chosen considering the geological and topological conditions of the area.[4] WASH authorities, community members and other stakeholders must discuss and agree on the interventions prior to their implementation. Community meetings must also be arranged to determine what is required to come up with facilities and whether the communities are willing to contribute to the construction of the facilities, as any type of contribution they can provide is important to ensure ownership.

5.5.4. Assessment of interventions in prototype communities

The fourth phase of the framework involves assessment of the interventions to mitigate the risk of waterborne diarrheal diseases in a prototype community in this case peri-urban area of Lusaka district Zambia. Epidemiological methods must be used to ascertain the interventions that have been implemented and currently being implemented in the area. To achieve this, in-depth interview with WASH stakeholders

or experts must be done as well as discussions with the community members. This will provide information about the interventions and perceptions of the stakeholders of the interventions in terms of how the interventions were implemented and being implemented with focus on the type of intervention, the target groups, equity in provision of interventions, methods of delivery, points of delivery and generally what they think about the interventions. This information is vital to decide on the types of interventions that can work and not work or need some modification in terms of implementation in specific communities. In the development of this framework the methods that were used during this stage included interviews and or discussions with WASH experts/stakeholders and use of community survey secondary data.

5.5.5 Selection and adoption of interventions

The fifth stage of the framework involves selection and adoption of the interventions for mitigating the risk of diarrhea diseases. This selection is based on the risks identified in phase two, the interventions identified through literature phase three and the assessment of interventions under phase four. Issues of acceptability and appropriateness of the interventions must be checked here. Evidence based literature and experts' knowledge are critical at this stage to identify specific interventions. This phase also involves checking the advantages and disadvantages of the selected interventions. To achieve this, interviews with WASH experts and discussions with the community members are vital. The main aim of involving the experts is that they approve with the interventions. The community must also be included to ensure that the interventions proposed are accepted. After these meetings, the interventions must be decided on and adopted. To collect information on this phase interviews with WASH experts/stakeholders and literature review were used.

5.5.6 Intervention implementation, monitoring, and evaluation

Once the intervention(s) have been selected and adopted, the implementation of the interventions must be done. Implementation should consist of coming up with an implementation team and action plan with clearly outlined activities, persons responsible for each activity, required resources, dates and expected results. Monitoring the implementation of the interventions must be done to check the progress of the implementation. Monitoring must be planned on inception of intervention implementation. Monitoring must be conducted over a pre-determined period. Evaluation of the interventions must then be done to determine the impact or outcome

of the interventions. The impact of the interventions must be checked to see whether the cases of waterborne diarrhea diseases increase or not after the interventions are implemented. This can be done by comparing the cases of waterborne diarrheal diseases before and after the program in a specific area. Indicators to measure the interventions effects must be made. These should be done in two groups the input indicator(s) for the intervention as well as the output indicator for the waterborne diarrhea diseases. Examples of input indicators include interventions that have been selected adopted and implemented as found phase five. The output indictors are the burden of waterborne diarrhea diseases this can be measured using different measures such as prevalence or incidences (morbidity) and mortality etc. It is important to note that a sustainability plan must be put in place, how exactly the interventions will be sustained to avoid reoccurrence of diseases.

5.5.7 System support

The framework proposes 10 system support factors that can help to achieve the framework objectives. These factors were identified in literature during the scoping literature review as well through general literature review. The factors include: Intersectoral participations; government will; human and financial resources and resource mobilization; policies and laws; strengthening collection and recording of data through electronic means; adapting the elements to emerging problems and new solutions; working within available structures: horizontal approach of programming; institutional strengthening; provision of laboratory facilities for testing and development or strengthening of a national preparedness program for waterborne diarrheal diseases.

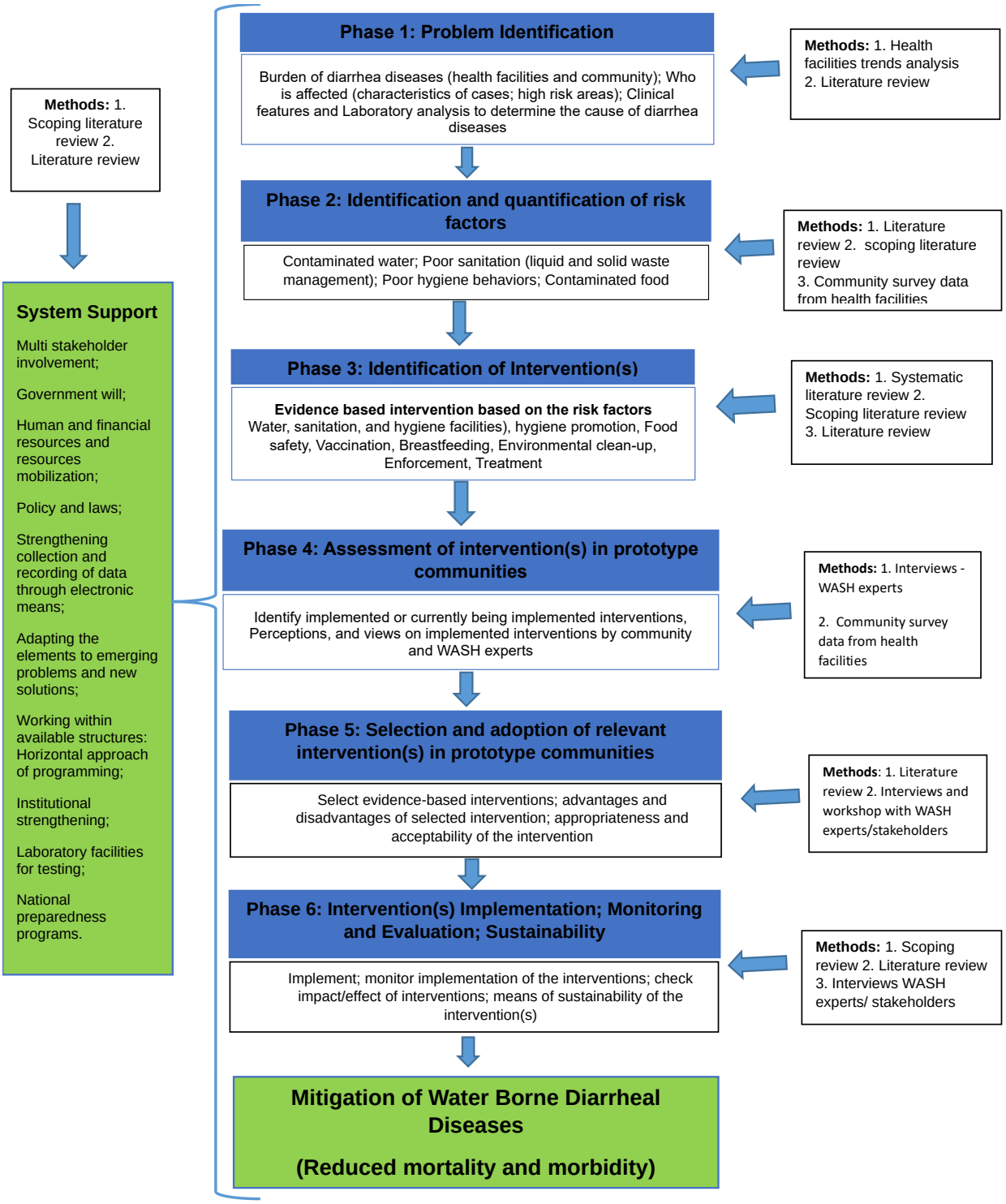

Figure 5.1: Draft framework for mitigating the risk of waterborne diarrheal diseases

5.6 Validation of the draft framework

The validation of the draff framework was conducted in Lusaka district and it involved several stakeholders including the health care workers from the Ministry of Health (sub-district leaders), Environmental Health Technicians (EHTs) in charge of coordinating community health programs, Local Government EHTs and Environmental Health Officers (EHOs), Water and Sanitation Utility Company (Lusaka Water Supply and Sanitation Company) personnel, academicians and other stakeholders from Non-Governmental Organizations**.** The purpose of the validation process was to check the applicability and acceptability of the developed framework through the expertise as well as the experiences of the various stakeholders.

5.6.1 Settling for framework validation

The framework was validated in Lusaka district. The location of the peri-urban areas that were of interest included the following sub-districts Kanyama, Chipata, Chelstone, Matero, Chilenje and Chawama. A workshop that included people from various institutions who operate in the stated areas was conducted. The validation workshop was conducted by first the Principal Investigator presenting focusing on the background of the framework and how exactly the draft framework was developed. This was followed by a question-and-answer session. The team was then given an opportunity to critic the draft framework and provide their thoughts on the stages of the framework. The stakeholders who did not attend the workshop, including some key personnel from the Ministry of Health and Local Government head offices were given the draft framework to give feedback. Academicians from the University of Zambia and other institutions were also given the framework to give their input.

5.6.2 Results of validation of the framework

The process of framework validation introduced vital information about the developed framework. The team that conducted the validation of the framework indicated that all the phases of the framework were important but had suggestions of the information that was relevant to include in each phase of the framework.

The following were issues that came up during the validation of the framework for each phase.

5.6.2.1 Problem identification

a. There was suggestion of the framework including community neighborhood health committees in the problem identification stage as well as in the whole process of planning and implementation for acceptability. This is because this committee consists of community health workers, publicity secretary and community members from specific communities.
b. The team also emphasized on having laboratories in each sub-district for determining the causative agent of diarrheal diseases. In addition, the provision of portable laboratories for easy assessing the quality of water from the different water sources was recommended.
c. The identification of cases was also emphasized through active means at the health facilities and event based through the neighborhood health committees. To this effect, there was a suggestion of training of the neighborhood health committees to enhance their participation in reporting and identification of cases.

d. The team also suggested the need to have person or personnel at each health facility employed to record data on waterborne diarrhea diseases. This is because some cases are not recorded as the routine collection of data was said to be ineffective. The suggestion was to improve the physical registers that are available at facility level as the current tool that is used i.e the smart care application records very limited variables and the surveillance officers are usually very overwhelmed with data entry**.**

5.6.2.2 Identification and quantification of risk factors

The team recommended community diagnosis to be enforced in each area. This assessment should be done yearly or biannual to establish the state of water, sanitation hygiene and other health related problems in the community. This should be coupled with monthly routine assessment of the community status. The main hinderance to the assessment of the community was the availability of resources to conduct the assessments. The team also suggested coming up with a standard tool for community diagnosis that can be used in Zambia as this could help to get uniform information for decision making. The community diagnosis tool must also be flexible to be tailored to the needs of the various communities.

5.6.2.3 Identification of interventions

a. The team recommended engagement of the community in identification of the interventions for acceptability - this should be based on the risks that are identified. The PHAST approach was recommended by the team members as a tool that could be useful in identification of risk factors and interventions.
b. Health promotion was said to be the main tool at this stage to ensure acceptability of the interventions identified.

5.6.2.4 Assessment of interventions in prototype communities

- No comment was given on this stage. The team agreed that this was a good phase to enhance acceptability of the interventions.

5.6.2.5 Selection and adoption of relevant interventions in prototype communities

a. The team proposed interventions selection based on the specific sub-district needs and engagement of the community in the process.
a. The team stated that majority of the population from the study areas obtained water from water kiosks - Lusaka water and sewage company i.e., water utility, boreholes, protected and shallow wells and one compound had a stream as a source of water. In terms of sanitation, a variety of sanitation services were available including pit latrines, ventilated improved pit latrines and some were connected to the Lusaka water and sewerage system. Flushable toilets and open defecation were also mentioned. Solid waste management was mentioned as one of the problems in all the sub-districts with only a small population subscribed to the solid waste management services. Poor drainage was also cited as one of the problems in the areas.
b. Based on the problems identified, several recommendations were given during the workshop to help deal with the problems in these areas including:
    - Provision of toilets for each household or shared latrines preferably waterborne toilets squatting type with watertight pits in these areas.
    - The use of shared latrine was recommended for some areas that have small space for each household to have latrines.
    - Ground water contamination can also be avoided if few toilets are constructed.
    - Implementing of the Lusaka water sanitation project which aimed to provide toilets to the community with watertight pits was recommend by

the participants. Even though some people in some sub-districts that implemented these latrines were not using the facilities due to several reasons such as the cost of desludging. In addition to some people failing to pay the subsidized K2500 approximately 140 US dollars cost of construction of the toilets.

- Servicing the areas with water and sewerage systems were possible if there is enough space for laying sewers in the areas was also recommended.
- Coming up with a proper plan for solid waste management at subsided costs and if possible, hiding the cost in other services such as rent, electricity and water was proposed. The team also emphasized on ensuring that the local authority or council provide licenses to waste collection companies with capacity to manage the waste i.e., proper vehicles and other requirements. Recycling of waste was also recommended.
- The community neighborhood health committees were proposed to enforce proper waste management for effectiveness of the service. The general community must be at look out for any community members disposing waste indiscriminately.
- There was emphasis on behavioral change or mind set change to be the core part in implementation of these solutions.
- Political will was also mentioned as some of the participants indicated that it was vital for success of the interventions.
- Enforcement of available water, sanitation and hygiene policy or standards was also recommended, and penalties given to individuals who do not follow standards.
- A proposal of involving the Landlords to be responsible for making sure that their tenants subscribed to waste management and other essential WASH services in the areas was emphasized.
- There was proposal of the drainage systems being worked on in the communities to avoid flooding as this was one of the main causes of water contamination in the communities especially for those people using unprotected wells.
- The other solutions that were proposed included discouraging or banning use of pit latrines and shallow wells, ensuring a continuous supply of

water to avoid people using well water and burying all the shallow wells in the areas.

- Provision of hygiene programs in public places such as markets, schools, religious groups was also recommended.
- Giving awards to those abiding to WASH standards, policies was also mentioned.
- Use of PHAST approach was emphasized to promote hygiene behavior change. I.e., communities deciding of what type of interventions they need based on the risk that they identify.

5.6.2.6 Intervention implementation, monitoring and evaluation, sustainability

The team suggested strong community neighborhood health committees/ community involvement as a key in the sustainability of the interventions, periodic monitoring, and evaluating the interventions and fresher training for sustainability of the program.

5.6.2.7 System support

a. **Multistakeholder involvement**

The following stakeholders were proposed to be involved in the mitigation of waterborne diarrheal diseases program: local business companies, religious leaders or institutions, councilors, and members of parliament, ministries (health, local government, water and sanitation and other WASH related ministries), the police and other defense institution for enforcement of the laws, Ministry of Education to help in behavioral change by teaching people at young ages on WASH issues, Zambia Environmental Management Agency(ZEMA), Water Resources Management Authority(WARMA) and market leaders, NGOs related to WASH etc.

b. **Government or political will**

Involving councilors and members of parliament in the implementation of the intervention program to ensure political will was recommended by the participants.

c. **Policy and laws**

The participants recommend for water, sanitation, hygiene laws to be enforced and those that do not exist made.

d. Strengthening collection, recording and transmission of data should be enhanced.
e. Working within existing structures was commended i.e., involving the available people at the health facilities and neighborhood health committees to implement the program in the community instead of bringing new people who do not have much information of the community.
f. In terms of institutional strengthening, the proposal by the team was for each sub-district to have a laboratory for use to isolate the causative agents of waterborne diarrheal diseases.
g. The team proposed pandemic preparedness programs to be implemented at sub-district levels. This should involve risk assessment done through provision of portable testing kits for different waterborne diarrheal diseases and environmental samples for easy detection of pandemics. The assessment should be ongoing not only during the rainy season to prevent occurrence of pandemics. Support must also be offered to the officers in charge of WASH to ensure that they have the necessary materials to execute their duties for the preparedness. Vaccines for rotavirus, cholera and other diarrheal diseases must always be available as part of the preparedness or prevention plan.

5.6.2.8 Other suggestions from stakeholders who individually reviewed the framework

a. Proposed inclusion of people with disabilities to assess how they are affected by waterborne diarrheal diseases and collection of spatial data under problem identification.
b. Proposed inclusion of an exit plan for initial external funding if available to help in ensuring sustainability of the interventions.
c. Proposed community driven programs to ensure acceptability and sustainability.

5.7 Conclusions

After the validation, all the concerns of the participants were put into consideration and a final validated framework was developed. This final framework is presented in chapter 6.

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CHAPTER 6: DISCUSSION AND PRESENTATION OF THE FINAL FRAMEWORK

6.1 Components of the final framework

This study has developed a framework for mitigating the risk of waterborne diarrhea diseases. The developed framework has six (6) main steps and support factors including problem identification, identification and quantifying of risk factors, identification of interventions, assessment of interventions in prototype communities, Selection and adoption of interventions, Intervention Implementation, monitoring, and evaluation and System support as presented in figure 6.1.

6.1.1 Problem identification

This phase involves identification of the problem of waterborne diarrheal diseases from both community and health facilities to obtain a comprehensive burden of the diseases. Community data can be collected by the neighborhood health committees (consisting of community health workers, secretary and community members) in case of Lusaka district or any community structures available. Data obtained in the community must be collected by the members of the health committee who should also encourage community members to report cases. The collected data must be transferred to the health facilities through electronic means preferably by phones or other similar gadgets. Training and refresher training must be done to teach the community neighborhood committees on case identification and reporting of cases. Data from the health facilities must also be collected when patients report at the facilities with diarrheal diseases.

All the data collected from both the community and at the health facilities must be recorded in an electronic database available. If such a database is not available, one must be developed. For Lusaka district, the existing smart care database must be used. However, it must be expanded to include more variables and have a person or people available to enter data in the system. The methods to be used in this phase to collect data include laboratory analysis to determine the causative pathogens for diarrhea diseases, community and or health facility surveys and literature review.

Laboratories must be provided at each health facility or at least one laboratory per subdistrict or similar structure to avoid taking samples to the main laboratory at the University Teaching Hospital (main hospital in Lusaka district) to avoid delay in getting the results. In addition, portable laboratories must be provided for easy assessment of the quality of water in the different water sources and or other media. Health facilities and community surveys must involve collection of information about waterborne

diarrheal disease and affected people by determining the cases or burden of diseases and the trends of diseases. Other data to be collected include demographics, behavioral, personal, social economic, environmental data (including spatial data) and so on of the affected people**.** In addition, it is important to assess the problem among people with disabilities. Community surveys are important to obtain information from people who do not report to the health facility when they have diarrhea diseases. High risk areas must also be determined during this phase to ensure targeted interventions. Literature review is also important at this stage to have information of the findings of other people or institutions doing similar studies in the area for comparison.

6.1.2 Identification and quantifying of risk factors

Identification and quantification of the risk factors of waterborne diarrheal diseases is the second phase of the framework. Risk factors refers to determinants that are associated with an increased risk of waterborne diarrhea diseases including personal - demographic, social - economic and environmental factors. Multiple strategies to identify the risk factors of waterborne diarrhea diseases must be done in the community using a standardized community diagnosis tool (incorporating both qualitative and quantitative methods such as observations and questions). These assessments must be conducted yearly or biannually, and follow-up routine inspections must be done monthly. Other methods that can be used include environmental monitoring of water quality in the community from the natural water sources, if available, and borehole wells and other water sources. Updates on the discovered risk factors must also be done through literature review. All the risk factors must be checked to ensure that a comprehensive assessment is done since the diseases have multiple risk factors. Risk factors including water supply, sanitation (liquid and solid waste management), and hygiene (hand washing) as these are the major risk factors of waterborne diarrhea diseases. In addition to community diagnosis, the risk factors must also be collected at health facilities from the people who report at the facilities. Resources must be made available to conduct the community assessment for risk factors this should be planned. The community must be involved in risk identification through the neighborhood health committees to ensure that they identify the risk factors for them to know what exactly the cause of the diseases might be in their communities.

6.1.3 Identification of interventions

Identification of evidence-based interventions for waterborne diarrheal diseases must be done by checking scientific literature. Other methods including interviews or discussion with WASH experts/stakeholders, which must also be done to identify the appropriate interventions. The community through the community neighborhood health committees or other community structures must also be involved at this stage to ensure acceptability of the interventions and they should also give information of their contributions towards the chosen interventions to ensure ownership and sustainability. The interventions must be based on the risks factors that have been identified in the second phase of the framework. This framework proposes an integrated approach in terms of interventions both hardware and software interventions must be considered since waterborne diarrhea diseases have different risk factors including water and sanitation (solid and liquid waste management), food safety, hygiene facilities, vaccinations, exclusive breastfeeding, treatment, enforcements, hygiene promotion behavior change etc. as found in Chapter 3 of this thesis. Interventions must also target different age groups in the population as all age groups are affected by waterborne diarrheal diseases, as found in Chapter 4.

The framework proposes mandatory long-term provision of toilets and water supply as these are fundamental requirements for mitigation of waterborne diarrhea diseases. The validation workshop also revealed that the main problems that are in the community are poor sanitation (lack of proper toilets, poor solid waste management, poor drainage) and lack of safe and adequate water supply. Hygiene education and promotion activities must be conducted before implementing the hardware interventions to ensure behavioral change through PHAST approach. Local standards as well as other international WASH standards such as the Joint Monitoring Program must be used to ensure that the appropriate facilities are provided, and the facilities must be adopted to the local conditions of the area i.e., the geological and topography since literature has indicated that Lusaka underground water is contaminated latrines with watertight pits must be made like the ones provided by the Lusaka water and sewerage company millennium development project. In terms of water protected water sources must be provided such as boreholes or serviced pipe water supply from the Lusaka water and sewerage company and household water treatment must be encouraged.

6.1.4 Assessment of interventions in prototype communities

Assessment of the interventions to mitigate the risk of waterborne diarrhea diseases in a prototype community in this case peri-urban area of Lusaka district Zambia must be done. This must involve discussion with community members and interviews with WASH experts or stakeholders. This must be done to ascertain the interventions that have been implemented and currently being implemented in the area(s). Information about the interventions and perceptions of the stakeholders of the interventions must also be collected. Particularly, information of how the interventions were implemented and or being implemented with focus on the type of intervention, the target groups, equity in provision of interventions, methods of delivery, points of delivery and generally what they think about the interventions must be collected. This information is vital to decide on the types of interventions that can work and not work or need some modification in terms of implementation in specific communities. The validation team agreed that this phase was good for enhancing acceptability of the interventions.

6.1.5 Selection and adoption of interventions

Selection and adoption of the interventions must be based on the needs of the community to ensure acceptability of the intervention and experts' knowledge to ensure appropriateness of the intervention to the specific areas. Discussions with community members and or Interviews with WASH experts/stakeholders must be done to get information for this phase. Evidence based literature is also critical at this stage to identify specific interventions. Selection and adoption of interventions must be based on the risks identified in phase two, the interventions identified phase three and the assessment of intervention phase four. This phase also involves checking the merits and demerits of the selected interventions from both the experts and community. Once the merits and demerits have been discussed and all parties agree the selection and adoption of the intervention(s) must be done.

For Lusaka district the validation team proposed selection of interventions based on the needs of the different sub-districts. Several WASH problems were mentioned during the validation workshop in form of poor provision of water and sanitation services. Based on the identified issues the team proposed several interventions appropriate for the communities including provision of latrines preferably watertight pits to avoid contamination of ground water and individual household latrines. Shared latrines were also proposed in areas with inadequate spaces for individual household latrines. The

team recommended the promotion of Lusaka water sanitation project watertight toilets which costed 2500 Zambian Kwacha equal to about 140 United States dollars. The team also proposed servicing the areas with water and sewerage systems in areas with enough space and coming up with a proper waste management system subsidized for the local people, done through hiding costs in services such as rent, electricity and water. The engagement of the landlords or house owners in the process of waste management was critical for success. The team also proposed the council or local authorities giving licenses to companies with capacity to manage waste after strict scrutiny. The framework particularly recommends recycling of waste as an important measure. A proposal to involve the community neighborhood health committees to enforce proper waste management for effectiveness was also emphasized and encouraging the general community being at look out for any community members disposing waste indiscriminately.

Other issues proposed as important aspects for success of interventions were behavioral or mind set change using the PHAST approach, political will and enforcement involving penalties and rewards for good WASH practices. The team also recommended working on the drainage systems in the community to avoid flooding as this was one of the main causes of water contamination of unprotected water sources in the communities. Discouraging use of pit latrines, ensuring a continuous supply of water to avoid people using well water and burying all the shallow wells in the areas were also proposed. Provision of hygiene promotion programs in public places such as markets, schools, religious groups is also important.

6.1.6 Intervention implementation, monitoring, and evaluation

This phase involves implementation, monitoring and evaluation of the interventions that are selected and adopted. Implementation involves establishing the implementation team and implementation action plan consisting of the activities, persons responsible for each activity, required resources, dates and expected results of the program. Monitoring the implementation of the interventions must be done to check the progress of the implementation which should be planned on inception of intervention implementation. Monitoring must be conducted over a pre-determined period deemed to be appropriate for a particular program or intervention. Evaluation of the interventions must then be done to determine the impact or outcome of the interventions. The impact of the interventions must be checked to see whether the cases of waterborne diarrhea diseases increase or not after the interventions are implemented. This can be done by

comparing the cases of diarrhea diseases before and after the program in the specific areas. Indicators to measure the interventions effects must be made. These should be in two groups including the input indicator(s) for the intervention as well as the output indicator for the waterborne diarrhea diseases. Examples of input indicators include interventions that have been selected adopted and implemented as found in phase five. The output indictors are the burden of waterborne diarrhea diseases this can be measured using different measures such as prevalence or incidences (morbidity) and mortality etc. It is important to note that a sustainability plan must be put in place, how exactly the interventions will be sustained to avoid reoccurrence of diseases. During the validation process, a suggestion was made to involve community neighborhood committees or community members in the implementation, monitoring and evaluation and ensuring sustainability of the programs. Refresher training for the community members should also be done on the sustainability of the program. An exit plan for external funding of the interventions must be developed to help ensure sustainability of the interventions. The methods to use in this phase include literature review, interviews with experts and discussion with community members on the best way of implementation, evaluation and sustainability of the programs or interventions.

6.1.7 System support

The framework proposes 10 system support factors that can help to achieve the framework objectives. The factors include intersectoral participations; government will; human and financial resources and resource mobilization; policies and laws; strengthening collection and recording of data through electronic means; adapting the elements to emerging problems and new solutions; working within available structures: horizontal approach of programming; institutional strengthening; provision of laboratory facilities for testing and development or strengthening of a national preparedness program for waterborne diarrheal diseases.

6.1.7.1 Multistakeholder involvement

A number of stakeholders are important in the mitigation of waterborne diarrheal diseases program. During the validation workshop the following stakeholders were recommended as important to mitigate the risk of waterborne diarrheal diseases in Lusaka district these include: local business companies, religious leaders or institutions, councilors, and members of parliament, ministries (health, local government, water and sanitation and other WASH related ministries), the police and

other defense institution for enforcement of the laws, Ministry of Education to assist in behavioral change by teaching people at young ages on WASH issues, Zambia Environmental Management Agency (ZEMA), Water Resources Management Authority (WARMA) and market leaders, NGOs related to WASH etc. The stakeholders should be identified according to the community and their involvement in WASH programs this means that they can be unique according to the setting. In addition, the programs must be community driven.

6.1.7.2 Government or political will

Government or political will should be dependent on the political structures in each setting. In the case of Lusaka district, involving councilor(s) and member(s) of parliament in the implementation of the intervention program was recommended during the workshop to ensure support from the government.

6.1.7.3 Human and financial resources and resource mobilization: Human and financial resources for the program or framework should be planned to ensure that there are people in charge of the program. These should be people from within the health system including neighborhood health committee or similar structures in the community. Financial resources must also be planned for before the implementation of the framework or intervention(s) preferably from the government and other institutions. The community should also contribute human and financial resources towards the implementation of the framework i.e., provision of land or material or manpower to build water and sanitary facilities and involvement in hygiene promotion activities etc.

6.1.7.4 Policy and laws: The participants in the workshop recommend water, sanitation, hygiene laws to be enforced and revised where applicable and those that do not exist made. A review to assess the available laws and policies and their gaps for improvement is important at this stage.

6.1.7.5 Strengthening collection, recording and transmission of data: Strengthening collection, recording and transfer of data on waterborne diarrheal diseases should be enhanced by providing electronic means at the health facilities as well as the community. All data collected from the community and at the health facility must be transferred to the central database for decision making.

6.1.7.6 Adapting the elements to emerging problems and new solutions: The solution to the problems of waterborne diarrhea diseases should be adapted to new existing issues through conducting literature review for new WASH solutions.

6.1.7.7 Working within existing structures: The framework proposes running this framework within the existing structures. This should be done by involving the available people at the health facilities and neighborhood health committee or any available community structures. These should implement the program in the community instead of bringing new people who do not have much information about the community needs.

6.1.7.8 Institutional strengthening: The framework proposes more manpower in charge of all programs related to waterborne diarrheal diseases and more funding related to WASH preventive programs or interventions.

6.1.7.9 Laboratory facilities: The framework proposes the development of analytical capacity in terms of constructing capable laboratory infrastructure in all the subdistricts for testing of causative agents of diarrheal diseases in stool samples as well as in water and other media in the communities.

6.1.7.10 National preparedness programs: National preparedness programs should be implemented at sub-district levels or any existing community levels of health service delivery. This should involve risk assessment done through provision of portable testing kits for different waterborne diarrheal diseases and environmental samples for easy detection of pandemics. The assessment must be ongoing not only during the rainy season to ensure prevention of the pandemics. Support should also be offered to the officers in charge of WASH to ensure that they have the necessary materials to execute their duties for the preparedness. Vaccine for rotavirus and cholera and other diarrheal diseases must always be available as part of the preparedness or prevention plan.

6.2 Conclusions

A framework for identifying interventions for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia has finally been developed and presented in Figure 6.1.

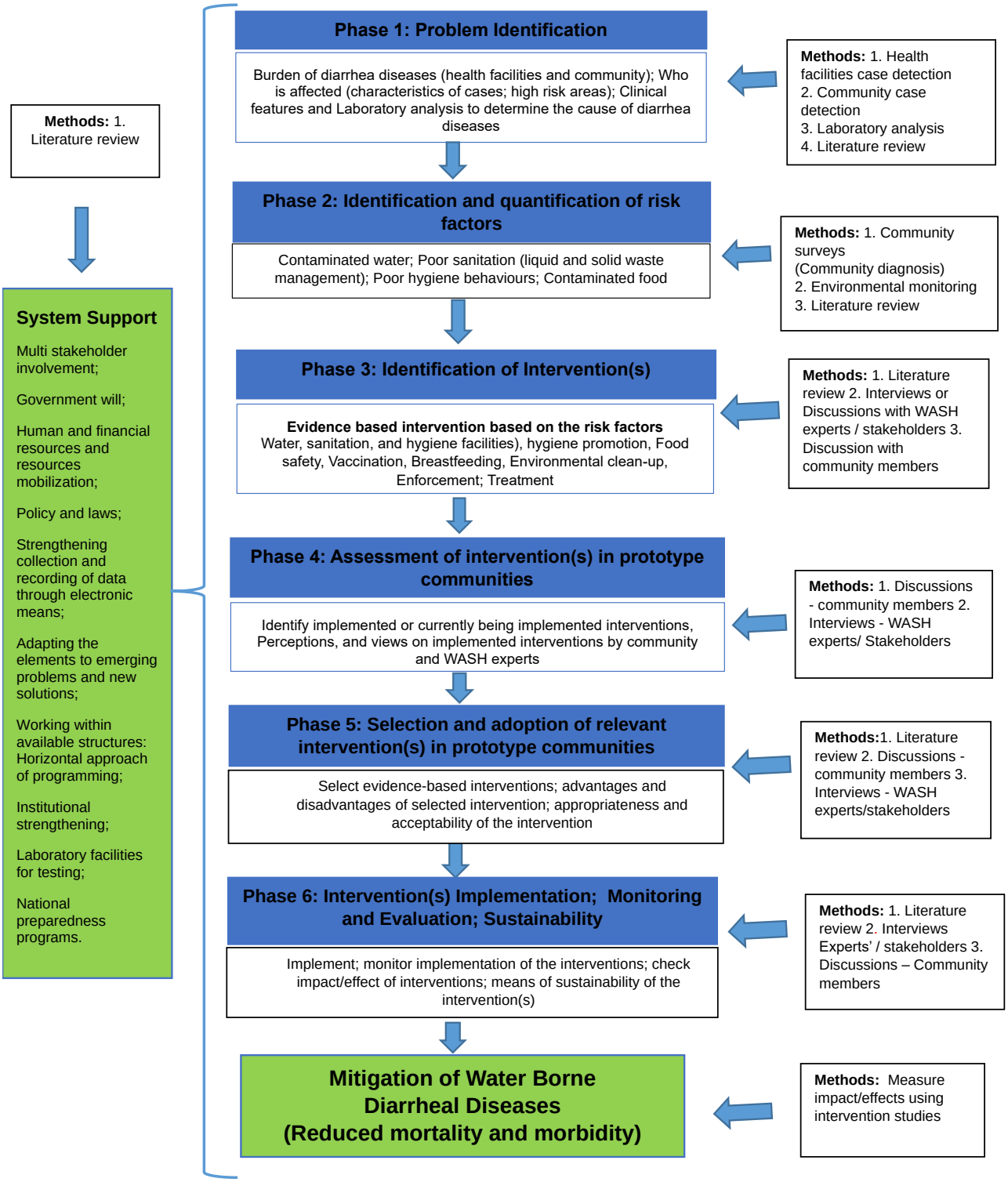


Figure 6.1: Final framework for mitigating the risk of waterborne diarrhea diseases.

CHAPTER 7: GENERAL CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The aim of the study was to develop a framework for identifying interventions for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district. This was achieved through conducting a systematic literature review on interventions available for mitigating the risk of waterborne diarrheal diseases, assessing the trends of waterborne diarrheal diseases, review of frameworks for mitigating the risks of diarrheal diseases, development of the draft framework for mitigating the risk of waterborne diarrheal diseases, validation of the draft framework and development of the final framework.

The first specific objective was to conduct a systematic review on interventions for mitigating the risk of waterborne diarrheal diseases in developing and developed countries. To achieve this objective a systematic review was conducted where data was obtained from different databases world over. A total of 56 studies were identified and included in the review. These studies reported the following interventions, vaccines for rotavirus disease (Monovalent, Pentavalent and Lanzhou lamb vaccine); enhanced water filtration for preventing Cryptosporidiosis, Vi polysaccharide for typhoid; cholera 2 dose vaccines, water supply, water treatment and safe storage, household disinfection and hygiene promotion for controlling cholera outbreaks. This review has been published in BMC systematic reviews and presented in chapter three of this thesis.

The second specific objective sought to investigate diarrheal diseases trends over a period of 10 years (2010 to 2019) in peri-urban areas of Lusaka district, Zambia. To attain this objective a longitudinal study of secondary data from the HMIS was conducted in 15 health facilities of peri-urban areas of Lusaka district for the period 2010 to 2019. The study revealed a general reduction in the trend of diarrhea diseases in the study areas. Non-bloody diarrhea presented the highest number of diarrheal cases followed by bloody diarrhea then cholera. Year 2016 had the highest number of cases and 2019 recorded the lowest cases with most cases being in the rainy season. Bloody diarrhea was the main cause of deaths followed by non-bloody then cholera. The diseases were highest in children under the age of five. Age, year, season and facility zone or sub-district were found as best predictors of deaths due to non-bloody diarrhea. This study has been submitted for publication and presented in chapter 4 of

the thesis.

The third specific objective identified gaps in existing frameworks for mitigating the risk of waterborne diarrheal diseases. This was achieved through conducting a scoping review of frameworks for mitigating waterborne diarrheal diseases through review of different databases world over. A total of five (5) frameworks were identified and included in the review including the hygiene improvement framework, community led total sanitation, global action plan for pneumonia and diarrhea, participatory hygiene and sanitation transformation, and sanitation and family education. A SWOT analysis was conducted on these frameworks. The scoping review has been published in PLoS One journal and presented in chapter three of this thesis.

The fourth objective was to develop a draft framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district Zambia. The draft framework was made from the five (5) frameworks that were identified in the scoping review and two other standards frameworks as presented in chapter 5.

The fifth specific objective aimed to validate the draft framework. The draft framework developed was validated through a workshop and reviews by health workers, WASH experts and academicians in Lusaka district Zambia. The inputs of the stakeholders were used to develop the final framework.

The last specific objective was to develop a refined framework for use by health authorities. In this regard, the final framework was developed which included the input from the stakeholders during the validation. The main components of the final frameworks include problem identification, identification and quantifying of risk factors, identification of interventions, assessment of interventions in prototype communities, selection and adoption of interventions, intervention implementation, monitoring, and evaluation and system support factors. The final framework is presented in chapter 6.

7.2 Recommendations

7.2.1 Recommendations based on the results and implementation of the developed framework

1. Based on the results of the reviews which indicate that most of the countries with high burden of waterborne diarrhea diseases are in developing countries; these diseases can affect different age groups and different interventions are available for mitigating the risk of waterborne diarrheal diseases. Interventions of waterborne diarrheal diseases must target developing countries like Zambia with high burden of diarrheal diseases. The interventions must also target different age groups in the communities and integrated approach is also recommended.
2. Based on the results of the trends analysis which revealed different burdens of diarrheal diseases in the different areas of Lusaka district. Interventions must be concentrated on sub-districts with high burden of diarrheal diseases.
3. The developed framework is recommended to be used by health authorities including but not limited to Ministry of Health and Local Government and other WASH institutions to help in mitigating the risk of waterborne diarrheal diseases. To the author's knowledge, this is the first framework that has been made to help in the mitigation of waterborne diarrheal diseases in peri-urban areas of Lusaka district or similar settings.
4. The developed framework must be implemented in the areas of the sub-district of Lusaka to help mitigate the risk of waterborne diarrheal diseases. The interventions that must be implemented must be specific to the sub-district needs.
5. Continuous development and validation of the framework by more stakeholders is important for success of the developed framework. Therefore, the author is ready to receive feedback from other stakeholders for improvement of the framework.
6. Training and dissemination of the framework to health workers and other WASH stakeholders on the use of the framework is also significant to ensure the success of the framework.

7.2.2 Recommendations for future studies

1. Studies for assessing the trends of diarrheal diseases must be done to incorporate both secondary and primary data from both the health facilities and community to assess the factual magnitude of the problem of waterborne

diarrheal diseases in the peri-urban areas of Lusaka district Zambia. This should also include stool laboratory tests to determine the causative agents of the different diarrheal diseases.

2. A comprehensive study should also be done to determine interventions that have been implemented in Lusaka district using both secondary and primary data collection methods to obtain a comprehensive idea of what exists or has been implemented in the specific subdistrict. Similar studies must be done in other developing countries as the systematic review on waterborne diarrheal diseases conducted in this study revealed very few studies from developing countries.

7.3 Dissemination of the framework

Several approaches were used to disseminate findings of the research. First findings of reviews on interventions and frameworks for mitigating waterborne diarrheal diseases presented in chapter three have been published in peer review journals. The framework was presented at the validation workshop in Lusaka district. This resulted into dissemination of the framework to the various stakeholders including officials from the Ministry of Local Government, health, water and sewerage company and academics. Findings of chapters 4, 5 and 6 will be published in peer review journals. Publication of findings in journals allows facilitate access of the results to a wider audience. In addition, the findings of this study will be disseminated to a wider community of WASH stakeholders and other line ministries in Zambia and international community through presentations.

APPENDICES

Appendix 1: Ethical approval

Appendix 1.1: Ethics approval letter South Africa

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0278 Approved for use through August 31, 2023.

Faculty of Health Sciences **Research Ethics Committee**

19 January 2023

Approval Certificate
Annual Renewal

Dear Ms CD Meki,

Ethics Reference No.: 847/2019 – Line 3
Title: Framework for Mitigating the Risk of Waterborne Diarrheal Diseases in Peri-Urban Areas of Lusaka District Zambia

The **Annual Renewal** as supported by documents received between 2023-01-05 and 2023-01-18 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2023-01-18 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2024-01-19.
- Please remember to use your protocol number (847/2019) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
Deputy Chairperson *of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Research Ethics Committee
Room 4-60, Level 4, Tswelopele Building
University of Pretoria, Private Bag x323
Gezina 0031, South Africa
Tel +27 (0)12 356 3084
Email: deepeka.behari@up.ac.za
www.up.ac.za

Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

Appendix 1.2: Ethics approval letter Zambia

UNIVERSITY OF ZAMBIA
BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: 260-1-256067
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
Federal Assurance No. FWA00000338

Ridgeway Campus
P.O. Box 50110
Lusaka, Zambia
E-mail: unzarec@unza.zm
IRB00001131 of IORG0000774

30th April 2020.

Your **REF. No. 808-2020**.

Ms. Chisala Deborah Meki,
University of Pretoria,
Pretoria.

Dear Ms. Meki,

RE: "FRAMEWORK FOR MITIGATING THE RISK OF WATERBORNE DIARRHEAL DISEASES IN PERI-URBAN AREAS OF LUSAKA DISTRICT ZAMBIA" (REF. NO. 808-2020)

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee on 30th April, 2020. The proposal is **approved**. The approval is based on the following documents that were submitted for review:

a) **Study proposal**
b) **Questionnaires**
c) **Participant Consent Form**

APPROVAL NUMBER : REF. 808-2020

This number should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE : 30th April 2020**
- **TYPE OF APPROVAL : Standard**
- **EXPIRATION DATE OF APPROVAL : 29th April 2021**
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the UNZABREC Offices should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING**: All SAEs and any other serious challenges/problems having to do with participant welfare, participant safety and study integrity must be reported to UNZABREC within 3 working days using standard forms obtainable from UNZABREC.
- **MODIFICATIONS**: Prior UNZABREC approval using standard forms obtainable from the UNZABREC Offices is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report must be submitted to the UNZABREC using standard forms obtainable from the UNZABREC Offices.

- **NHRA:** You are advised to obtain final study clearance and approval to conduct research in Zambia from the National Health Research Authority (NHRA) before commencing the research project.
- **QUESTIONS**: Please contact the UNZABREC on Telephone No.256067 or by e-mail on unzarec@unza.zm.
- **OTHER**: Please be reminded to send in copies of your research findings/results for our records. You're also required to submit electronic copies of your publications in peer-reviewed journals that may emanate from this study. Use the online portal: unza.rhinno.net for further submissions.

Yours sincerely,

Sody Mweetwa Munsaka, BSc., MSc., PhD
CHAIRPERSON
Tel: +260977925304
E-mail: s.munsaka@unza.zm

Appendix 2: Letter from the Ministry of Health

P. O. Box 50827
Lusaka
Tel: +260-211-235554
Fax: +260-211- 236429

In reply please quote:

No:.....

REPUBLIC OF ZAMBIA

MINISTRY OF HEALTH
LUSAKA DISTRICT HEALTH OFFICE

16th December, 2019

Chisala D. Meki (Ms)
University of Pretoria
Faculty of Health Sciences
School of Health Systems and Public Health
PRETORIA, SOUTH AFRICA

Dear Ms. Meki,

RE: AUTHORITY TO CONDUCT RESEARCH IN LUSAKA DISTRICT

We are in receipt of your letter over the above subject.

Please be informed that Lusaka District Health Office has no objection for you to conduct research entitled **"Frame Work for Mitigating the Risk of Waterborne Diarrheal Diseases in Peri-urban areas of Lusaka District".**

Kindly ensure that your findings are shared with the health facility and District Health Office and that the normal operations of the facility are not disrupted.

By copy of this letter, the Medical Superintendents for Matero and Kanyama First Level Hospitals is kindly requested to facilitate accordingly.

Yours sincerely,

Dr. Richard Mwila
SENIOR CLINICAL CARE OFFICER
For/DISTRICT HEALTH DIRECTOR

C.C: The Medical Superintendent – Matero First Level Hospital, **LUSAKA**
C.C: The Medical Superintendent – Kanyama First Level Hospital, **LUSAKA**
C.C: Dr. Esper J. Ncube, Supervisor - University of Pretoria, **SOUTH AFRICA**

Appendices 3: Consent form and information sheets

Appendix 3.1: Informed consent form - workshop

University of Pretoria Faculty of Health Sciences School of Health Systems and Public Health

We are inviting you to participate in research, titled **"Framework for Mitigating the Risk of Waterborne Diarrhoeal Diseases in Peri-urban Areas of Lusaka District Zambia**"

Name of Principal Investigator: Chisala Deborah Meki
Name of Organization: University of Pretoria
Name of Sponsor: National Research Foundation (NRF)

This Informed Consent Form has two sections:

• Section 1: Information Sheet outlining information about the study to share with you
• Section 2: Certificate of Consent for signatures or thumb prints if you choose to participate in this study. A copy of the Informed Consent Form will be given to you.

Section 1: Information Sheet

Introduction: I am Chisala D. Meki, studying a Doctor of Philosophy in Public Health at the University of Pretoria. I am conducting research on developing a framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district. The diarrheal diseases are very common in Zambia particularly in the peri-urban areas. I will provide you with information and invite you to participate in this research. You do not have to decide at this moment whether you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research. This consent form may contain words that you may not understand. Please ask me to stop as we go through the information and I will take time to explain further. If you have questions later, you can ask me at any time.

Purpose of the research: Many people suffer from waterborne diarrheal diseases in communities of Lusaka district. We want to find ways to stop this from happening. We

believe that you can help us by telling us your opinion about the framework that has been created to prevent the diseases in peri-urban areas of Lusaka district. Your views will be used to modify and hence improve the framework.

Type of Research Intervention: This research will involve your participation in a workshop that will take about 5 to 8 hours.

Participant Selection: You are being invited to take part in this research because we feel that your experience and expertise can contribute towards validating the developed framework.

Voluntary Participation: Your participation in this research study is voluntary. You can choose to participate or not. If you choose not to participate nothing will change. The choice that you make will have no bearing on your job or on any work-related evaluations or reports. You may change your mind later and stop participating even if you agreed earlier.

Procedures: We are asking you to help us validate the developed framework on Mitigating the Risk of waterborne diarrheal diseases in the area. We are inviting you to take part in this research project. If you accept, you will be asked to discuss the draft framework in groups with other group members.

You will take part in a group discussion with 5 to 8 other persons. This discussion will be guided by myself or another moderator. We will present the framework and thereafter, me or the group moderator will start the discussion to make sure that you are comfortable. We can also answer questions about the research that you might have. Then we will ask you questions about the created framework and give you time to share your knowledge and what you think about it.

We will not ask you to share personal beliefs, practices or stories and you do not have to share any knowledge that you are not comfortable sharing. The workshop will take place at the University of Zambia School of Public Health and no one else but the people who take part in the workshop and guide or myself will be present during this discussion. The entire discussion will be recorded, but no-one will be identified by name. You can ask to pause the recording at any time. The recorded information will

be kept in a secure office under lock and key. The information recorded is confidential, and no one else except the principal investigator will have access and later will be destroyed after transcription.

Duration: The workshop will be held once and will take about 6 to 8 hours.

Risks: We do not see any significant risks related to participation in this study. However, if there is a risk that you may share some personal or confidential information by chance, or that you may feel uncomfortable talking about some of the topics. You do not have to answer any question or take part in the discussion if you feel the question(s) are too personal or if talking about them makes you uncomfortable. However, we do not wish for this to happen.

Benefits: The study will not have direct benefit to you, but your participation is likely to help us find out more about how to mitigate the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka Zambia.

Reimbursements: You will not be provided any incentive to take part in the research. However, we will refund travel expenses and provide some refreshments.

Confidentiality: The research may draw attention, if you participate you may be asked questions by other people. We will not be sharing information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will be presented by a number on it instead of your name. Only the researchers will know what your number is, and we will secure that information.

We will ask you and others in the group not to talk to people outside the group about what was said in the group. We will, in other words, ask each one of you to keep what was said in the workshop confidential. You should know, however, that we cannot stop or prevent participants who were in the workshop from sharing things that should be confidential.

Sharing the Results: Nothing that you tell us today will be shared with anybody outside the research team, and nothing will be attributed to you by name. The

knowledge that we get from this research will be shared with you and your institution before it is made widely available to the public. Each participant will receive a summary of the results. We will also disseminate the results through meetings and publishing in Journals so that other interested people may learn from the research and share at other foras such as conferences.

Right to Refuse or Withdraw: You do not have to take part in this research if you do not wish to do so and choosing to participate will not affect your job or job-related evaluations in any way. You may stop participating in the discussion at any time that you wish without your job being affected. I will give you an opportunity at the end of the discussion to review your remarks, and you can ask to modify or remove portions of those, if you do not agree with my notes or if I did not understand you correctly.

Who to contact: If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact the following: [Chisala D. Meki, University of Zambia, School of Public Health Box 50110 Lusaka; Telephone number: +2609666526445; e-mail: cdmeki@gmail.com]
This proposal has been reviewed and approved by University of Zambia and University of Pretoria research ethics committees, which are committees whose task it is to make sure that research participants are protected from harm. If you wish to find out more about the research committees, contact ____)

You can ask me any more questions about any part of the research study, if you wish to.

Do you have any questions?

Section 2: Certificate of Consent

I have been invited to participate in research about development of a framework for mitigating the risk of waterborne diarrhoea diseases in peri-urban areas of Lusaka district. I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Print Name of Participant_____

Signature of Participant _____

Date _____

Day/month/year

If illiterate

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness_____ Thumb print of participant

Signature of witness _____ Date _____

Day/month/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands all the processes of the study. I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been forced into giving consent, and the consent has been given freely and voluntarily.

A copy of this Informed Consent Form (ICF) has been provided to the participant.

Print Name of Researcher/person taking the consent_____

Signature of Researcher /person taking the consent_____

Date _____

Day/month/year

Appendix: 3.2 Informed consent form - review

University of Pretoria Faculty of Health Sciences School of Health Systems and Public Health

We are inviting you to participate in research, titled **"Framework for Mitigating the risk of Waterborne Diarrhoeal Diseases in Peri-urban Areas of Lusaka District Zambia**"

Name of Principal Investigator: Chisala Deborah Meki
Name of Organization: University of Pretoria
Name of Sponsor: National Research Foundation (NRF)

This Informed Consent Form has two sections:

• Information Sheet to share information about the study with you

• Certificate of Consent for signatures or thumb prints if you choose to participate in this study. You will be given a copy of the full Informed Consent Form.

Section 1: Information Sheet

Introduction: I am Chisala D. Meki, studying a Doctor of Philosophy in Public Health at the University of Pretoria. I am conducting research on developing a framework for mitigating the risk of waterborne diarrheal diseases in peri-urban areas of Lusaka district. The diarrheal diseases are very common in Zambia particularly in the peri-urban areas. I will provide you with information and invite you to participate in this research. You do not have to decide at this moment whether you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research. This consent form may contain words that you may not understand. Please ask if you have any questions.

Purpose of the research: Many people suffer from water borne diarrheal diseases in communities of Lusaka district. We want to find ways to reduce and or possibly stop this from happening. We believe that you can help us by telling us your opinion about the framework that has been created to mitigate the risk of the diseases in peri-urban areas of Lusaka district. Your views will be used to modify the framework for improving

it.

Type of Research Intervention: This research will involve your participation in reviewing the developed draft framework.

Participant Selection: You are being invited to take part in this research because we feel that your experience and expertise can contribute to validating the draft framework.

Voluntary Participation: The choice that you make will have no bearing on your job or on any work-related evaluations or reports. You may change your mind later and stop participating even if you agreed earlier.

Procedures: We are asking you to help us validate the developed framework on Mitigating the Risk of waterborne diarrheal diseases in the area. If you accept, you will participate in reading and giving feedback on the draft framework. The information recorded is confidential, and no one else except the research team will have access to the feedback as you will have to send it directly to the principal investigator. The information recorded is confidential, and no one else except the principal investigator will have access to the tapes. The tapes will be destroyed after the transcription is completed.

Duration: The feedback of the review will be required after two weeks. But you can still get some more time if required.

Risks: We do not envision any significant risks related to participation in this study. However, there is a risk that you may share some personal or confidential information by chance, or that you may feel uncomfortable talking about some of the topics. However, we do not wish for this to happen. You do not have to answer any question or take part in the interview/review if you feel the question(s) are too personal or if talking about them makes you uncomfortable.

Benefits: The study will not have direct benefit to you, but your participation is likely to help us find out more about how to mitigate the risk of waterborne diarrheal diseases.

Reimbursements: You will not be provided any incentive to take part in the research.

Confidentiality: The research being done can draw attention and if you participate you may be asked questions by other people. We will not be sharing information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is, and we will lock that information up.

Sharing the Results: Nothing that you tell us will be shared with anybody outside the research team, and nothing will be attributed to you by name. The knowledge that we get from this research will be shared with you and your institution before it is made widely available to the public. You will receive a summary of the results. We will publish results in Journals so that other interested people may learn from the research and share at foras such as conferences.

Right to Refuse or Withdraw: You do not have to take part in this research if you do not wish to do so and choosing to participate will not affect your job or job-related evaluations in any way. You may stop participating in the discussion or review at any time that you wish without your job being affected. You can ask questions if some information is not clear.

Who to contact: If you wish to ask any questions, you may contact the following: [Chisala D. Meki, University of Zambia, School of Public Health P.O. Box 50110 Lusaka; Telephone number: +2609666526445; e-mail: cdmeki@gmail.com]
This proposal has been reviewed and approved by University of Zambia and University of Pretoria research ethics committees, which are committees whose task it is to make sure that research participants are protected from harm. If you wish to find out more about the research committees, contact: Research ethics committee, University of Pretoria , Private Bag x323 , Gezina 0031, Pretoria, South Africa , Tell +27 0123563084 Email: deepeka.behari@up.ac.za

You can ask me any more questions about any part of the research study, if you wish to.

Section 2: Certificate of Consent

I have been invited to participate in research about development of a framework for mitigating the risk of waterborne diarrhoea diseases in peri-urban areas of Lusaka district. I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Print Name of Participant_____

Signature of Participant _____

Date _____

Day/month/year

If illiterate

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness_____ Thumb print of participant

Signature of witness _____ Date _____

Day/month/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands all the processes of the study. I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been forced into giving consent, and the consent has been given freely and voluntarily.

A copy of this Informed Consent Form (ICF) has been provided to the participant.

Print Name of Researcher/person taking the consent_____

Signature of Researcher /person taking the consent_____

Date _____

Day/month/year

Appendix 4: Data capture form

Name of facility/number:

Year:

Variable	month												Total
	J	F	M	A	M	J	Jy	Ag	S	O	N	D	
Number of Cases													
Number of Deaths													
First report cases													
Severity of diarrhea													
Type of diarrhea (bloody/non bloody Cholera)													
cases/age group													
Health facility catchment population													

KEY: J: January, F: February, M: March, A: April, M: May, J: June, Jy:July, Ag: August, S:September O:October N:November D:December

Appendix 5: Discussion guide for validation workshop and review

University of Pretoria

Faculty of Health Sciences

School of Health Systems and Public Health

Opening

- Introduction of researchers and the research
- Making the respondents feel free and relaxed
- Create rapport

Main Body

- Ask questions about the created framework

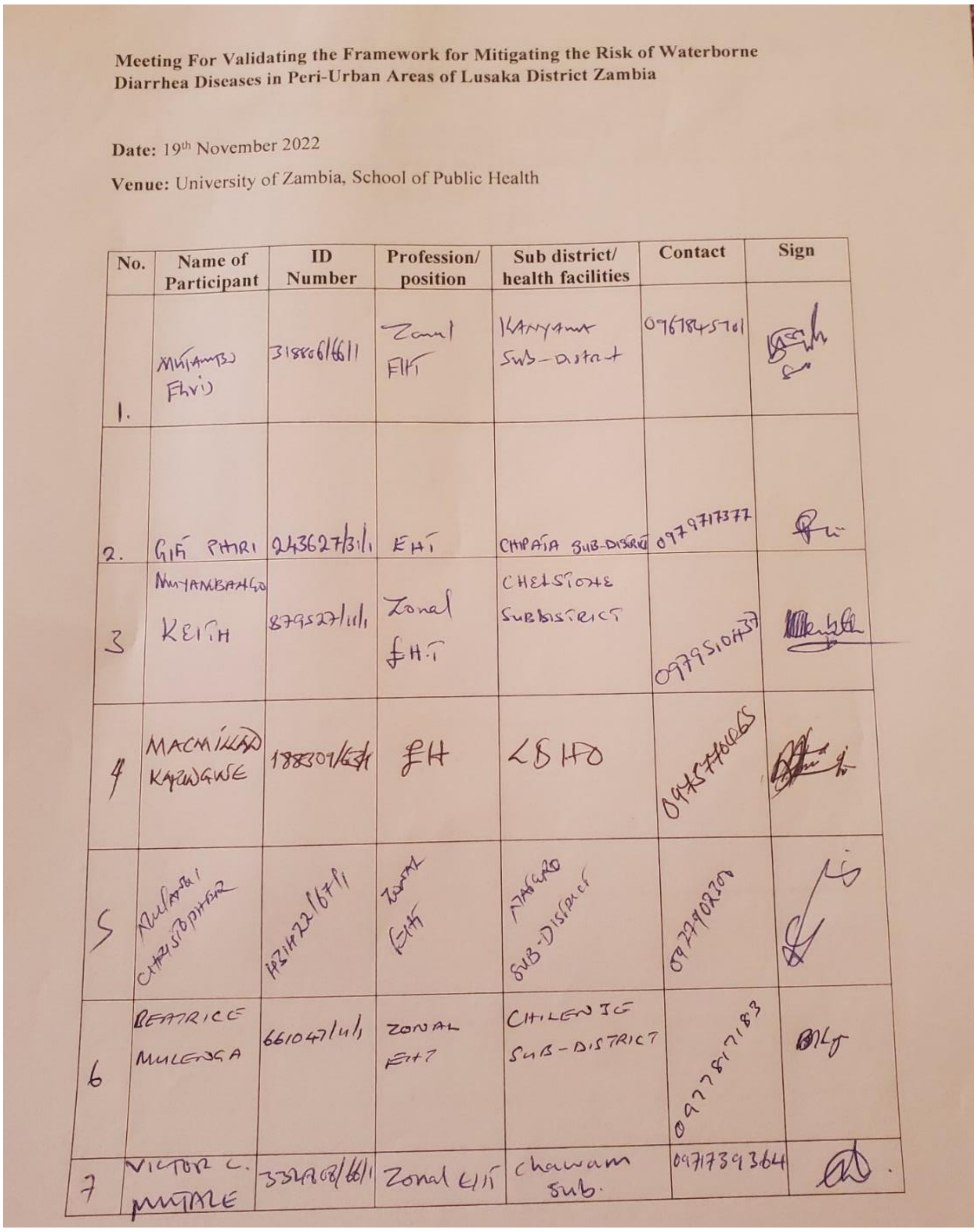
Example: what do you think about the draft framework do you think it can work or not in Peri-urban areas of Lusaka district?

How can the frame be improved?

Conclusion

- Thank the respondents and ask if they have any questions

Appendix 6: Workshop attendance register

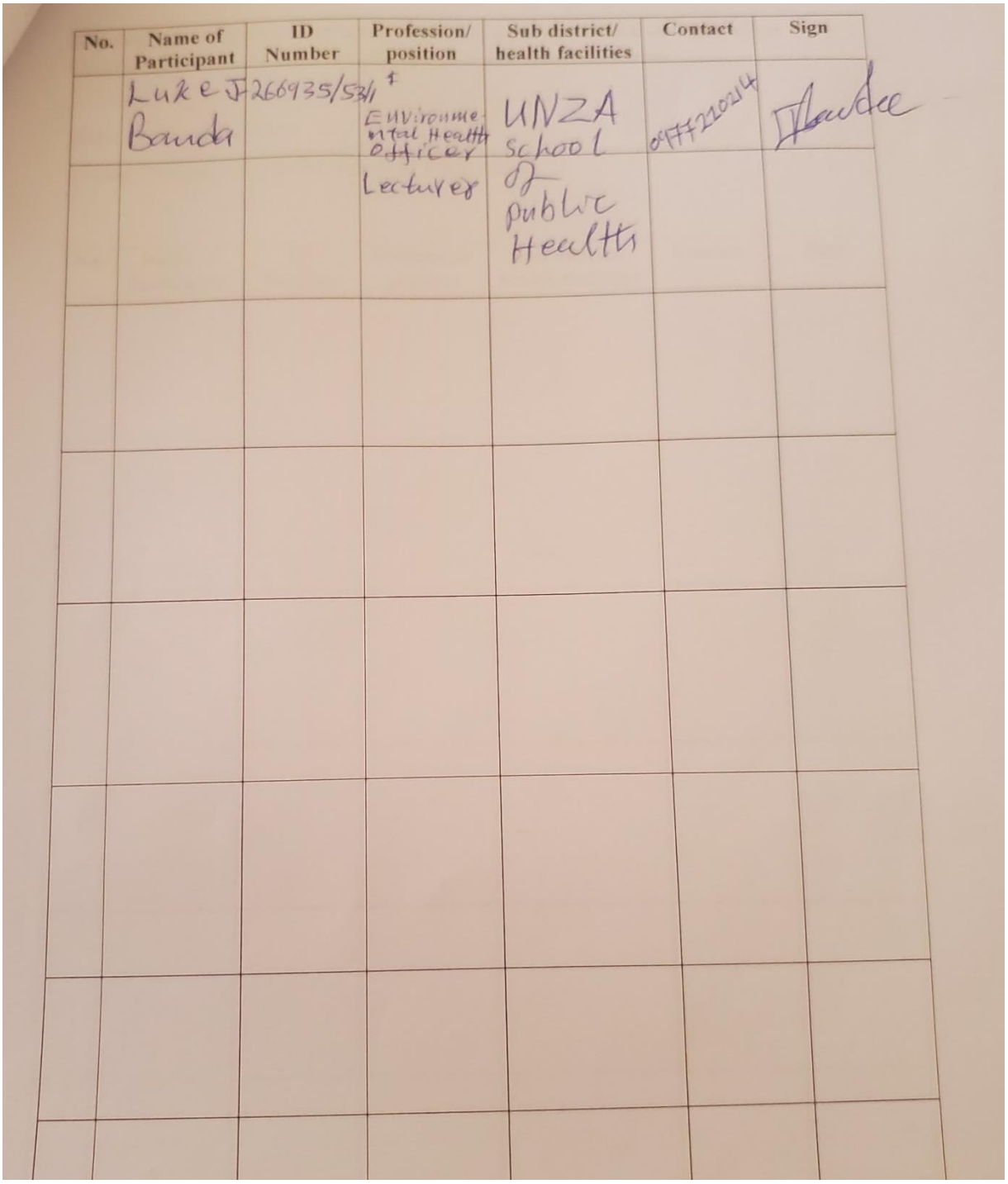


Meeting For Validating the Framework for Mitigating the Risk of Waterborne Diarrhea Diseases in Peri-Urban Areas of Lusaka District Zambia

Date: 19th November 2022

Venue: University of Zambia, School of Public Health

No.	Name of Participant	ID Number	Profession/ position	Sub district/ health facilities	Contact	Sign
1.	Mutambo Elvis	318866/66/1	Zonal EHT	Kanyama Sub-district	0967845761	[illegible]
2.	Gift Phiri	243627/31/1	EHT	Chipata Sub-District	0979717377	[illegible]
3	Nyambaabo Keith	879527/11/1	Zonal EHT	Chelstone Subdistrict	0979510437	[illegible]
4	Macmillan Kapungwe	188309/43/1	EH	LDHO	0975710065	[illegible]
5	Ruwapa Christopher	421422/67/1	Zonal EHT	Matero Sub-District	0972740270	[illegible]
6	Beatrice Mulenga	661047/41/1	Zonal EHT	Chilenje Sub-District	0977817183	[illegible]
7	Victor C. Mutale	332908/66/1	Zonal EHT	Chawama Sub.	0971739364	[illegible]



No.	Name of Participant	ID Number	Profession/ position	Sub district/ health facilities	Contact	Sign
	Luke J Banda	266935/53/1	Environmental Health Officer / Lecturer	UNZA School of Public Health	0977220214	

Appendix 7: Search strategy for review of interventions to mitigate risk of waterborne diarrheal diseases

Database and Date Last Searched	Search Terms/Phrases	Limiters	Results
CINAHL			
02/08/2020	“waterborne disease” OR “waterborne infection” OR “waterborne illness” OR “waterborne outbreak” OR" waterborne sickness” (Free search)	Published Date: 20090101-20201231	91
02/08/2020	(MH "Cholera/PC") MH (Major Headings) PC (prevention/control)	Published Date: 20090101-20201231	266
02/08/2020	(MH "Rotavirus Infections/PC")	Published Date: 20090101-20201231	520
02/08/2020	Reovirus* (Free search)	Published Date: 20090101-20201231	53
02/08/2020	(MH "Escherichia Coli Infections/PC")	Published Date: 20090101-20201231	176
02/08/2020	(MH "Enterovirus Infections/PC")	Published Date: 20090101-20201231	46
02/08/2020	(MH "Caliciviridae Infections/PC")	Published Date: 20090101-20201231	172
02/08/2020	Astrovirus* (Free search)	Published Date: 20090101-20201231	66
02/08/2020	(MH "Adenoviruses")	Published Date: 20090101-20201231	23
02/08/2020	(MH "Giardiasis/PC")	Published Date: 20090101-20201231	16
02/08/2020	Cyclosporia* Free search	Published Date: 20090101-20201231	31
02/08/2020	(MH “Dysentery, Bacillary/PC”)	Published Date: 20090101-20201231	31
02/08/2020	(MH “Dysentery/PC”)	Published Date: 20090101-20201231	12
02/08/2020	(MH "Cryptosporidiosis/PC")	Published Date: 20090101-20201231	27

Database and Date Last Searched	Search Terms/Phrases	Limiters	Results
02/08/2020	(MH "Yersinia Infections/PC")	Published Date: 20090101-20201231	3 started 2011
02/08/2020	(MH "Shigella")	Published Date: 20090101-20201231	316
02/08/2020	(MH "Typhoid/PC")	Published Date: 20090101-20201231	201
02/08/2020	(MH "Campylobacter Infections/PC")	Published Date: 20090101-20201231	33
02/08/2020	(MH "Amebiasis/PC")	Published Date: 20090101-20201231	13
Total			**2096**
Scopus			
03/08/2020	TITLE-ABS-KEY (waterborne) SEARCH #1	NONE	15,418
03/08/2020	disease* OR infect* OR illness* OR outbreak* OR sickness* TITLE-ABS-KEY (disease* OR infect* OR illness* OR outbreak* OR sickness*) #2	NONE	11,078,068
03/08/2020	#1 AND #2 (TITLE-ABS-KEY (waterborne)) AND (TITLE-ABS-KEY (disease* OR infect* OR illness* OR outbreak* OR sickness*))	Published date: 2009 -2020	3,241
03/08/2020	TITLE-ABS-KEY (cholera OR rotavirus* OR reovirus* OR shigell* OR enterovirus* OR calicivir* OR norovirus* OR astrovirus* OR adenovirus* OR giard* OR cyclosporia* OR dysenter* OR cryptosporid* OR yersin* OR salmonell* OR typhoid* OR campylobacter* OR amoebia*) #1	NONE	391,463
03/08/2020	Intervention*(TITLE-ABS-KEY) #2	NONE	1,449,978
03/08/2020	(TITLE-ABS-KEY (cholera OR rotavirus* OR reovirus* OR shigell* OR enterovirus* OR calicivir* OR norovirus* OR astrovirus* OR adenovirus* OR giard* OR cyclosporia* OR dysenter* OR cryptosporid* OR yersin* OR salmonell* OR typhoid* OR	Published Date: 2009 to 2020	3,993

Database and Date Last Searched	Search Terms/Phrases	Limiters	Results
	campylobacter* OR amoebia*)) AND (TITLE-ABS-KEY (intervention*)) #1 AND #2		
Total			**7234**
Pubmed			
02/08/2020	Waterborne [Title/Abstract] #1	2009-2020	7,292
02/08/2020	"disease*"[Title/Abstract] OR "infect*"[Title/Abstract] OR "illness*"[Title/Abstract] OR "sickness*"[Title/Abstract] OR "outbreak*"[Title/Abstract] #2	2009 to 2020	5,398,395
02/08/2020	"Waterborne"[Title/Abstract] AND ((((("disease*"[Title/Abstract] OR "infect*"[Title/Abstract]) OR "illness*"[Title/Abstract]) OR "sickness*"[Title/Abstract]) OR "outbreak*"[Title/Abstract]) #1 AND #2	2009-2020	2,285
02/08/2020	"waterborne diseases/prevention and control"[MeSH Terms]	2009 to 2020	43 started in 2014
02/08/2020	"Cholera/prevention and control"[Mesh]	2009 TO 2020	637
02/08/2020	"Rotavirus infections/prevention and control"[Mesh]	2009-2020	1,363
02/08/2020	" Reoviridae Infections/prevention and control"[Mesh]	2009-2020	1,650
02/08/2020	"Escherichia coli Infections/prevention and control"[Mesh]		917
02/08/2020	"Enterovirus infections/prevention and control"[Mesh]	2009-2020	2,359
02/08/2020	"Caliciviridae Infections/prevention and control"[Mesh]	2009-2020	323
02/08/2020	"Mamastrovirus"[Mesh]	2009 -2020	259
02/08/2020	"Adenoviridae Infections/prevention and control"[Mesh]	2009-2020	124
02/08/2020	"Giardiasis/prevention and control"[Mesh]	2009-2020	61
02/08/2020	"Cyclosporiasis/prevention and control"[Mesh]	2009-2020	2
02/08/2020	"Dysentery/prevention and control"[Mesh]	2009-2020	196
31/07/2020 02/08/2020	"Dysentery, Amebic/prevention and control"[Mesh]	2009-2020	9
31/07/2020	"Dysentery, Bacillary/prevention and control"[Mesh]	2009-2020	144
31/07/2020	"Cryptosporidiosis/prevention and control"[Mesh]	2009-2020	133

Database and Date Last Searched	Search Terms/Phrases	Limiters	Results
31/07/2020	"Yersinia Infections/prevention and control"[Mesh]	2009-2020	319
31/07/2020	"Salmonella infections/prevention and control"[Mesh]	2009-2020	1,352
31/07/2020	"Typhoid fever/prevention and control"[Mesh]	2009-2020	314
31/07/2020	"Campylobacter Infections/prevention and control"[Mesh]	2009-2020	185
Total			**12675**
Web of science core collection			
03/08/2020	Waterborne #1	NONE	12,793
03/08/2020	disease* OR infect* OR illness* OR outbreak* OR sickness* #2	NONE	5,874,468
03/08/2020	#1 AND #2	2009-2020	2815
03/08/2020	TOPIC: (cholera OR rotavirus* OR reovirus* OR shigell* OR enterovirus* OR calicivir* OR norovirus* OR astrovirus* OR adenovirus* OR giard* OR cyclosporia* OR dysenter* OR cryptosporid* OR yersin* OR salmonell* OR typhoid* OR campylobacter* OR amoebia*) #1	NONE	289,176
03/08/2020	TOPIC: (intervention*) #2	NONE	1,175,146
03/08/2020	#1 AND #2	2009-2020	3,433
Total			**6248**
Cochrane library			
01/08/2020	Waterborne AND (disease* OR infect* OR illness* sickness* OR outbreak*) Title and Abstract[tiab]	2009-2020	27
01/08/2020	"Waterborne Diseases/prevention and control"[Mesh]	2014 to 2020	0
01/08/2020	"Cholera/prevention and control"[Mesh]		47
01/08/2020	"Rotavirus infections/prevention and control"[Mesh]	2009-2020	96
01/08/2020	" Reoviridae Infections/prevention and control"[Mesh]	2009-2020	96
01/08/2020	"Escherichia coli Infections/prevention and control"[Mesh]	2009-2020	26
01/08/2020	"Enterovirus infections/prevention and control"[Mesh]	2009-2020	150
01/08/2020	"Caliciviridae Infections/prevention and control"[Mesh]	2009-2020	13

Database and Date Last Searched	Search Terms/Phrases	Limiters	Results
01/08/2020	“Mamastrovirus”[Mesh]	2009-2020	
01/08/2020	“Adenoviridae Infections/prevention and control”[Mesh]	2009-2020	3
01/08/2020	“Giardiasis/prevention and control”[Mesh]	2009 TO 2020	3
01/08/2020	“Cyclosporiasis/prevention and control”[Mesh]	2009 TO 2020	0
01/08/2020	“Dysentery/prevention and control”[Mesh]		9
01/08/2020	“Cryptosporidiosis/prevention and control”[Mesh]	2009-2020	2
01/08/2020	“Yersinia Infections/prevention and control”[Mesh]	2009-2020	2
01/08/2020	“Salmonella infections/prevention and control”[Mesh]	2009-2020	24
01/08/2020	“Campylobacter Infections/prevention and control”[Mesh]	2009-2020	22
Total			**520**
Grand Total			**28773**

Appendix 8: Characteristics of studies included in the systematic review

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
1	Association Between Pentavalent Rotavirus Vaccine and Severe Rotavirus Diarrhoea Among Children in Nicaragua	Patel et al. 2009 [54]	Nicaragua	Lower middle income	Rotavirus diarrhoea	Hospitals	Case control
2	Case-control Study of the Effectiveness of Vaccination with Pentavalent Rotavirus Vaccine in Nicaragua	Mast et al. 2011 [52]	Nicaragua	Lower middle income	Severe wild-type rotavirus gastroenteritis	Hospitals	Case control
3	Impact of rotavirus vaccination on hospitalizations for rotavirus diarrhoea: The IVANHOE study	Gagneur et al. 2011 [53]	France	High income	Rotavirus diarrhoea	Hospitals	Cohort
4	Effectiveness of Pentavalent Rotavirus Vaccine Against Severe Disease	Staat et al.2011 [55]	USA	High income	Rotavirus acute gastroenteritis	Hospital/ medical centre	Surveillance and case control
5	Impact and Effectiveness of RotaTeq Vaccine Based on 3 Years of Surveillance Following Introduction of a Rotavirus Immunization Program in Finland	Vesikari et al. 2013 [50]	USA	High income	Rotavirus acute gastroenteritis	Hospitals	Surveillance and case-control
6	Impact of Rotavirus Vaccine on Premature Infants	Roué et al. 2014 [56]	France	High income	Rotavirus diarrhoea	Hospital	Surveillance
7	Real-World Effectiveness of Pentavalent Rotavirus Vaccine Among Bedouin and Jewish Children in Southern Israel	Leshem et al. 2016 [51]	Israel	High income	Rotavirus Acute Gastroenteritis	Hospital	Surveillance and Case-control
8	Effectiveness of rotavirus pentavalent vaccine under a universal immunization programme in Israel, 2011 to 2015: a case-control study	Muhsen et al. 2018 [48]	Israel	High income	Rotavirus gastroenteritis	Hospitals	Surveillance

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
9	Impact and effectiveness of pentavalent rotavirus vaccine in children <5 years of age in Burkina Faso	Bonkoungou et al. 2018 [49]	Burkina Faso	Low income	Rota virus acute gastroenteritis	Hospitals	Case control
10	Effectiveness of Lanzhou lamb rotavirus (LLR) vaccine in preventing gastroenteritis among children younger than 5 years of age	Li et al. 2019 [72]	China	Upper middle income	Rota virus diarrhoea	Hospitals	Case control
11	Effectiveness of the Lanzhou lamb rotavirus vaccine against gastroenteritis among children	Fu et al. 2012 [73]	China	Upper middle income	Rotavirus gastroenteritis	Hospital	Case control
12	Effectiveness of Rotavirus Vaccine in Preventing Hospitalization due to Rotavirus Gastroenteritis in Young Children in Connecticut, USA	Desai et al. 2010 [65]	USA	High income	Rotavirus gastroenteritis,	Hospital	Case control
13	Reduction in Paediatric Rotavirus-related Hospitalizations After Universal Rotavirus Vaccination in Belgium	Raes et al. 2011 [70]	Belgium	High income	Rota virus disease	Hospitals	Retrospective database
14	Effectiveness of rotavirus vaccines in preventing cases and hospitalizations due to rotavirus gastroenteritis in Navarre, Spain	Castilla et al. 2012 [64]	Spain	High income	Rotavirus gastroenteritis	Health Care Facilities	Case control
15	Effectiveness of Pentavalent and Monovalent Rotavirus Vaccines in Concurrent Use Among US Children <5 Years of Age, 2009–2011	Payne et al. 2013 [63]	USA	High income	Rota virus acute gastroenteritis	Hospitals and medical Centres	Surveillance
16	Effectiveness of Monovalent and Pentavalent Rotavirus Vaccine	Cortese et al. 2013 [71]	USA	High income	Rotavirus disease	Hospitals	Surveillance and case control
17	Effectiveness of 2 Rotavirus Vaccines Against Rotavirus Disease in Taiwanese Infants	Chang et al. 2014 [62]	Taiwan	High income	Severe rota virus acute gastroenteritis	Hospitals	Surveillance and case control

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
18	Case Control Study of Rotavirus Vaccine Effectiveness in Portugal During 6 Years of Private Market Use	Marlow et al. 2015 [61]	Portugal	High income	Rotavirus acute gastroenteritis	Hospital	Case control
19	Long-term Consistency in Rotavirus Vaccine Protection: RV5 and RV1 Vaccine Effectiveness in US Children, 2012–2013	Payne et al. 2015 [68]	USA	High income	Rota virus acute gastroenteritis	Medical facilities Centre	Surveillance
20	Association between mixed rotavirus vaccination types of infants and rotavirus acute gastroenteritis	Mohammed et al. 2015 [69]	USA	High income	Rotavirus acute gastroenteritis	Hospitals	Case control
21	Rotavirus vaccine effectiveness in Hong Kong children	Yeung et al. 2916 [58]	Hong Kong, China	Upper middle income	Acute rotavirus gastroenteritis	Hospitals	Case control
22	Sustained Effectiveness of Monovalent and Pentavalent Rotavirus Vaccines in Children	Immergluck et al. 2016 [59]	USA	High income	Rotavirus disease	Hospitals	Surveillance and case control
23	Effectiveness of Monovalent and Pentavalent Rotavirus Vaccines in Guatemala	Gastañaduy et al. 2016 [60]	Guatemala	Upper middle income	Rotavirus diarrhoea	Hospitals	Surveillance and case control
24	Rotavirus Genotypes and Vaccine Effectiveness from a Sentinel, Hospital-Based, Surveillance Study for Three Consecutive Rotavirus Seasons in Lebanon	Ali et al. 2016 [67]	Lebanon	Upper middle income	Rotavirus Gastroenteritis	Medical centres	Surveillance
25	Effectiveness of rotavirus vaccines against hospitalisations in Japan	Yoshiyuki et al. 2017 [57]	Japan	High income	Rotavirus acute gastroenteritis	Hospital	Case control
26	Effectiveness and impact of rotavirus vaccines in Saudi Arabia: A single hospital-based study	Zaki et al. 2017 [14]	Saudi Arabia	High income	Rotavirus gastroenteritis	Hospital	Retrospective analysis
27	Effectiveness of monovalent and pentavalent rotavirus vaccines in Japanese children	Araki et al. 2018 [66]	Japan	High income	Rota virus gastroenteritis	Medical facilities	Surveillance and case control
28	Effectiveness of the Monovalent G1P (8) Human Rotavirus Vaccine Against	Justino et al. 2011 [40]	Brazil	Upper middle income	Severe Rotavirus Gastroenteritis	Hospitals	Case control

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
	Hospitalization for Severe G2P (4) Rotavirus Gastroenteritis in Bele´m, Brazil						
29	Effectiveness of rotavirus vaccination in prevention of hospital admissions for rotavirus gastroenteritis among young children in Belgium: case-control study	Braeckman et al. 2012 [39]	Belgium	High income	Rotavirus gastroenteritis	Hospital	Case control
30	Effectiveness of monovalent rotavirus vaccine in Bolivia: case-control study	Patel et al. 2013 [38]	Bolivia	Lower middle income	Rota virus	Hospital	Case control
31	Effectiveness of the monovalent rotavirus vaccine in Colombia: A case-control study	Cotes-Cantillo et al. 2014 [45]	Colombia	Upper middle income	Rotvirus diarrhoea	Health centres	Case control
32	Effectiveness of rotavirus vaccine against hospitalized rotavirus diarrhoea: A case–control study	Ichihara et al. 2014 [36]	Brazil	Upper middle income	Rotavirus diarrhoea	Hospital	Case control
33	Effectiveness of monovalent human rotavirus vaccine against admission to hospital for acute rotavirus diarrhoea in South African children: a case-control study	Groome et al. 2014 [37]	South Africa	Upper middle income	Acute Rotavirus diarrhoea	Hospitals	Case control
34	Effectiveness of a monovalent rotavirus vaccine in infants in Malawi after programmatic roll-out: an observational and case-control study	Bar-Zeev et al. 2015 [35]	Malawi	Low income	Rotavirus gastroenteritis	Hospital	Surveillance and case control
35	Effectiveness of monovalent rotavirus vaccine in a high-income, predominant use setting	Doll et al. 2015 [43]	Canada	High income	Rotavirus diarrhoea	Hospital	Time series analysis and case control
36	Effect of Monovalent Rotavirus Vaccine on Rotavirus Disease Burden and Circulating Rotavirus Strains Among Children in Morocco	Benhafid et al. 2015 [44]	Morocco	Lower middle income	Rotavirus diseases	Hospitals	Surveillance

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
37	Impact and Effectiveness of Monovalent Rotavirus Vaccine in Armenian Children	Sahakyan et al. 2016 [31]	Armenian	Upper middle income	Rotavirus gastroenteritis	Hospitals	Surveillance and case control
38	Impact of Rotavirus Vaccine Introduction and Vaccine Effectiveness in the Republic of Moldova	Gheorghita et al. 2016 [32]	Moldova	Lower middle income	Rotavirus diseases	Hospitals	Surveillance and case control
39	Effectiveness of Monovalent Rotavirus Vaccine After Programmatic Implementation in Botswana: A Multisite Prospective Case-Control Study	Gastañaduy et al. 2016 [60]	Botswana	Upper middle income	Rotavirus diarrhoea	Hospitals	Case control
40	Population Impact and Effectiveness of Monovalent Rotavirus Vaccination in Urban Malawian Children 3 Years After Vaccine Introduction: Ecological and Case-Control Analyses	Bar-Zeev et al. 2016 [34]	Malawi	Low income	Rotavirus diarrhoea	Hospital	Surveillance and case control
41	A Preliminary Assessment of Rotavirus Vaccine Effectiveness in Zambia	Beres et al. 2016 [41]	Zambia	Lower middle income	Rotavirus diarrhoea	Public health facilities	Case control
42	Effectiveness of a live oral human rotavirus vaccine after programmatic introduction in Bangladesh: A cluster-randomized trial	Zaman et al. 2017 [30]	Bangladesh	Lower middle income	Acute rotavirus diarrhoea	Village health care facilities	Cluster-Randomized Controlled Trial
43	Impact of rotavirus vaccination on rotavirus hospitalisation rates among a resource-limited rural population in Mbita, Western Kenya	Wandera et al. 2018 [28]	Kenya	Lower middle income	Rotavirus gastroenteritis	Hospital	Surveillance
44	Rotavirus gastroenteritis hospitalization rates and correlation with rotavirus vaccination coverage in Sicily	Restivo et al. 2018 [47]	Italy	High income	Rotavirus gastroenteritis	Hospitals	Retrospective observational
45	Sustained impact of rotavirus vaccine on rotavirus hospitalisations in Lusaka, Zambia, 2009–2016	Mpabalwani et al. 2018 [29]	Zambia	Lower middle income	Rotavirus acute Gastroenteritis	Hospital	Surveillance

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
46	Detection of rotavirus before and after monovalent rotavirus vaccine introduction and vaccine effectiveness among children in mainland Tanzania	Jani et al. 2018 [42]	Tanzania	Lower middle income	Rotavirus Diarrhoea	Hospital and medical centres	Surveillance
47	Monovalent Rotavirus Vaccine Effectiveness Against Rotavirus Hospitalizations Among Children in Zimbabwe	Mujuru et al. 2019 [26]	Zimbabwe	Lower middle income	Rotavirus acute diarrhoea	Hospitals	Surveillance and case control
48	Rotavirus Epidemiology and Monovalent Rotavirus Vaccine Effectiveness in Australia: 2010–2017	Maguire et al. 2019 [27]	Australia	High income	Rotavirus diarrhoea	Notification Centre	Case control
49	Rotavirus prevalence and seasonal distribution post vaccine introduction in Nairobi county Kenya	Gikonyo et al. 2019 [46]	Kenya	Lower middle income	Rotavirus diarrhoea	Hospitals	Case study
50	Description of the targeted water supply and hygiene response strategy implemented during the cholera outbreak of 2017–2018 in Kinshasa, DRC	Bompangue et al. 2020 [74]	Democratic Republic of Congo (DRC)	Low income	Cholera	Community, Health Zones	Preliminary community trial
51	Impact of Vi vaccination on spatial patterns of typhoid fever in the slums of Kolkata, India	Ali et al. 2011 [51]	India	Lower middle income	Typhoid fever	Community slum area (cluster) group of households	Cluster randomised Effectiveness trial
52	Reduction in cryptosporidiosis associated with introduction of enhanced filtration of drinking water at Loch Katrine, Scotland	Pollock et al. 2014 [79]	Scotland	High income	Cryptosporidiosis	Community - households	Cohort
53	Effectiveness of an oral cholera vaccine in Zanzibar: findings from a mass vaccination campaign and observational cohort study	Khatib et al. 2012 [78]	Zanzibar, Tanzania	Lower middle income	Cholera	Public and private treatment facilities/ households	Cohort

No	Title	Author and Year	Country	Economy	Disease(s)	Setting	Study Design
54	Effectiveness of an oral cholera vaccine campaign to prevent clinically significant cholera in Odisha State, India	Wierzba et al. 2015 [76]	India	Lower middle income	Cholera	Health care facilities	Case control and cohort
55	Long-term effectiveness of one and two doses of a killed, bivalent, whole-cell oral cholera vaccine in Haiti: an extended case-control study	Franke et al. 2018 [77]	Haiti	Low income	Cholera	Cholera treatment center/ household/ health facility/ household	Case control
56	Use of Vibrio cholera Vaccine in an Outbreak in Guinea	Luquero et al. 2014 [75]	Guinea	Low income	Cholera	Health Centres	Case control

Appendix 9: Objectives, participants, interventions and results of the studies included in the systematic review

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
1	Patel et al. [54]	The association between Pentavalent rotavirus vaccine (RV5) vaccination and rotavirus diarrhoea requiring overnight admission or intravenous hydration in Nicaragua	Cases: Children with acute diarrhoea requiring hydration with laboratory-confirmed rotavirus (n=285),	Neighbourhood controls: children eligible to receive RV5 (n=840) Hospital controls: children eligible to receive RV5 (n=690)	RV5; None	Three doses of RV5: Lower risk of rotavirus diarrhoea requiring overnight admission or intravenous hydration (OR 0.54; 95% CI 0.36, 0.82). Of the 285 rotavirus cases, 191 (67%) were severe and 54 (19%) were very severe. RV5 vaccinations lowered the risk of severe (OR 0.42; 95% CI 0.26, 0.70) and very severe rotavirus diarrhoea (OR 0.23; 95% CI 0.08, 0.61). Vaccine effectiveness: 3 doses of RV5: Hospitalisation: 46% (95% CI 18, 64); Severe rotavirus diarrhoea: 58% (95% CI 30, 74) Very severe rotavirus diarrhoea: 77% (95% CI 39, 92)
2	Mast et al. [52]	To evaluate the public health impact of routine universal vaccination with RV5 in Nicaragua	Children younger than five who hospitalized with acute gastroenteritis (n=502) Vaccine effectiveness: Children, older than six weeks, positive for rotavirus, eligible to have received	Hospital controls (n=1894) Community controls (n=1685) Vaccine effectiveness: Hospital controls (n=792) Community controls (n=851)	RV5; None	Vaccine effectiveness: 3 doses of RV5: Severe rotavirus disease: 87% (95% CI 74, 93) for community controls 64% (95% CI 44, 78) for hospital controls 76% (95% CI 63, 84) when the groups were combined

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
			one dose of vaccine (n=300).			
3	Gagneur et al. [53]	Trends in hospitalizations for rotavirus diarrhoea in infants younger than 2 years old before and after implementing a rotavirus vaccination campaign in France	Infants younger than 2 years with diarrhoea: with a positive rotavirus stool specimen (n=4798, of whom 4684 received at least one dose of RV5)	Surveillance study	RV5; None	Hospitalizations reduced by a factor of 2.04 (1.56, 2.66) during the last epidemic season (2008/2009) Relative risk for hospitalizations for rotavirus diarrhoea dropped by 98% (95% CI 83, 100)
4	Staat et al., [55]	Vaccine effectiveness of complete and partial vaccination with the RV5 to prevent acute rotavirus gastroenteritis (AGE) hospitalizations and emergency department visits during the first 3 rotavirus seasons after vaccine introduction in the USA	Children older than 52 days. Children positive for rotavirus (n=184)	Children rotavirus-negative but with AGE (n=613) Children with Acute Respiratory Infection (ARI) (n=675)	RV5; None	Vaccine effectiveness vs AGE controls: 1 dose of RV5: 74% (95% CI 37, 90) 2 doses of RV5: 88% (95% CI 66, 96) 3 doses of RV5: 87% (95% CI 71, 94) Vaccine effectiveness vs ARI controls: 1 dose RV5: 73% (95% CI 43, 88) 2 doses of RV5: 88% (95% CI 68, 95) 3 doses of RV5: 85% (95% CI 72, 91)
5	Vesikari et al. [50]	To establish the influence of RV5 vaccination and genotype on AGE cases requiring hospitalization in children from Finland	Children younger than 16 admitted for AGE Rotavirus positive (n=127)	Children admitted for AGE but rotavirus negative (n=73)	RV5; None	Vaccine effectiveness: 3 doses of RV5 Hospitalization: 92.1% (95% CI 50, 98.7). Hospitalizations for rotavirus AGE decreased by 78% in the post-vaccination period (2009–2012) compared to the pre-vaccination (2001–2006) period. Most cases occurred in children under 5 years

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
			Cases vaccine effectiveness analysis (n=7)			
6	Roué et al. [56]	To establish the influence of RV5 vaccination on AGE requiring hospitalization in preterm infants enrolled in the IVANHOE study and to establish vaccine coverage and safety in this population in France	Children younger than 3 years old, born prematurely (before 37 weeks) (n=217)	Cohort study	RV5; None	Of the 217 infants, 41.9% received all three doses of the RV5 vaccine Vaccine safety in premature infants is the same as for term infants. In the vaccinated group, hospitalisations reduced by a factor of 2.6 (95% CI 1.3, 5.2) during the first two epidemic seasons following vaccine introduction and by a factor of 11 (95% CI 3.5, 34.8) during the third season
7	Leshem et al. [51]	Vaccine effectiveness of RV5 vaccination in preventing rotavirus-associated Emergency Department (ED) visits and hospitalizations. To describe age, dose, ethnicity, and strain-specific vaccine effectiveness in Israel	Surveillance study: children younger than five years old Vaccine effectiveness: children older than six months Cases: children hospitalized or visiting the ED with AGE and rotavirus positive (n=185)	Children admitted for AGE but rotavirus negative (n=330)	RV5; None	Vaccine effectiveness: 3 doses of RV5: 63% (95% CI 38, 78) Age 6-11 months: 64% (95% CI 21, 84) 12-23 months: 71% (95% CI 39, 86) Hospitalization: 59% (95% CI 23,78) ED visit: 67% (95% CI 11, 88)
8	Muhsen et al. [48]	Effectiveness of the RV5 universal vaccination programme in preventing rotavirus	Children (0 to 59 months) hospitalized due to diarrhoea. Cases: children at least 2	Children admitted for AGE but rotavirus negative (n=628)	RV5; None	Vaccine effectiveness: 3 doses of RV5 Age 6-59 months: 77% (95% CI 49, 90) 6-23 months: 86% (95% CI 65, 94)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		AGE hospitalization between 2011 and 2015 in Israel, a high-income country	months of age and rotavirus positive (n=98)			Incomplete schedule: Age 6-59 months: 72% (95% CI 28, 89) 6-23 months: 75% (95% CI 30, 91) Genotypes G1P [8]:79% (95% CI 45,92) RVGE: 69% (95% CI 11,89)
9	Bonkoungou et al. [49]	Effectiveness of the RV5 vaccine in Burkina Faso	Children younger than 5 (n=1043) Cases: children at least 6 months old, eligible to have received rotavirus vaccine, rotavirus positive (n=227)	Same age as cases and rotavirus negative (n=761)	RV5; None	Reduced hospital admissions positive for rotavirus: 2014: 36% (154/422), 2015: 22% (71/323), 2016: 20% (61/298) Reduced hospital admissions of infants with rotavirus 2014: 38% (94/250), 2015: 21% (32/153), 2016: 17% (26/149) Vaccine effectiveness: 3 doses of RV5: Age: 6-11months: 58% (95% CI 10, 81) Older than 12 months: 19% (95% CI 78, 63)
10	Li et al. [72]	Vaccine effectiveness of the Lamb Rotavirus (LLR) vaccine to prevent laboratory-confirmed gastroenteritis in children 2–59 months of age in China	Children 2 to 59 months old Cases: rotavirus positive (n=598)	Same aged children: rotavirus negative (n=1766)	LLR vaccine; None	Vaccine effectiveness: 1 dose of LLR vs. no vaccine: 34.9% (95% CI 5.3, 55.3) Severe gastroenteritis: 87.7% (95% CI 32.7, 97.8) Age: 2-35 months: 36.2% (95% CI 4.7, 57.3) Genotype G9: 40.8% (95% CI 7.8, 61.9) Compared to unvaccinated children, vaccinated children were less likely to have watery stool (OR = 0.42) and have diarrhoea longer than 5 days (OR = 0.47)
11	Fu et al. [73]	Effectiveness of the LLR prevent rotavirus gastroenteritis in children 2–35 months of age	Children 2–35 months old with watery vomiting and watery diarrhoea. Cases: rotavirus positive (n=3130)	Randomly selected children aged 2–35 months without gastroenteritis (n=3607)	LLR vaccine; None	Vaccine effectiveness: 1 dose of LLR: Age:9–11 months old: 44.3% (95% CI 28.4, 56.7) 12-17 months old: 52.8% (95% CI 40.8, 62.3) 18-35 months old: 51.8% (95% CI 11.6, 73.8)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
12	Desai et al. [65]	Effectiveness of rotavirus vaccines in preventing hospitalization due to rotavirus in children 8 weeks to 3 years of age	Children 8 weeks to 3 years old Cases: children hospitalised for AGE, rotavirus positive (n=42)	Controls: age matched; rotavirus negative Hospital controls (n=80) Community controls (n=73)	RV1 & RV5; None	Vaccine effectiveness: At least 1 dose Cases vs. hospitalized controls: 94.3% (95% CI 55.4, 99.3; p=0.006) Cases vs. community controls: 96.9% (59.4, 99.8; p=0.008) Partial vaccination: Cases vs. hospitalized controls: 93.2% (41.4, 99.2) Cases vs. community controls: 93.8% (23, 99.5) Full vaccination: Cases vs. hospitalized controls: 96.3% (28.9, 99.8) Cases vs. community controls 99.1% (78.1, 99.9)
13	Raes et al. [70]	Effect of rotavirus vaccines on rotavirus-hospitalizations in children younger than 5 years old before and after the introduction of generalized vaccination in Belgium	Children less than or equal to 5 years old, hospitalised, rotavirus positive In Pre-vaccination (June 2004–May 2006) and postvaccination (June 2007–May 2009) periods	None	RV1 & RV5; None	Rotavirus hospitalizations declined among children 2 to 24 months from 716 (pre-vaccine) to 249 (post-vaccine). Hospitalizations declined by 65% (95% CI 62, 69) in the first year. Hospitalizations further decreased by 140 (80%, 95% CI 77, 83) in the second year post vaccination. Age Younger than 2 months: 1st year post-vaccine: hospitalizations declined by 50% (95% CI 36, 64) 2nd year post-vaccine: hospitalizations declined by 64% (95% CI 49, 76) Older than 24 months: 1st year post-vaccine: hospitalizations declined by 20% (95% CI 14, 28) 2nd year post-vaccine: hospitalizations declined by 64% (95% CI 56, 72)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
14	Castilla et al. [64]	Effectiveness of rotavirus vaccination in children 3–59 months old in preventing rotavirus AGE and hospital admissions	Children 3–59 months seeking medical care for AGE Cases: rotavirus positive (n=756)	Children seeking medical care for AGE but rotavirus negative (n=6036)	RV1 & RV2; None	Vaccine effectiveness At least one dose: Age 3-59 months: 78% (95% CI 70, 84) RV1: 76% (95% CI, 63, 85) RV5: 80% (95% CI 69, 87) Complete vaccination vs. not vaccinated: 78% (95% CI 68, 85) 2 doses of RV1: 75% (95% CI 60, 85) 3 doses of RV5: 81% (95% CI 68, 89) Age >24 months: 61%; 95% CI 0, 84) Age <24 months: 80%; 95% CI 70, 86). Preventing hospitalizations: 83% (95% CI 65, 93) Preventing outpatient cases: 75% (95% CI: 62, 83)
15	Payne et al. [63]	To assess RV5 and RV1 vaccine effectiveness in preventing rotavirus AGE hospitalization and emergency department (ED) visits among US children <5 years of age over 2 consecutive rotavirus seasons in USA	Children younger than 5 years old with AGE. Either hospitalised or in the ED Cases: rotavirus positive (n=359)	Children with AGE, rotavirus negative (n=1811)	RV1 & RV5; None	Vaccine effectiveness 3 doses of RV5: 84% (95% CI 78, 88) 2 doses of RV1: 70% (95% CI 39, 86)
16	Cortese et al. [71]	Vaccine effectiveness of the 2-dose RV1 and 3-doses RV5 series against rotavirus disease resulting in hospitalization, emergency	Children older than 8 months presenting to the hospital with AGE Cases: rotavirus positive (n=165)	Children older than 8 months presenting to the hospital with AGE, rotavirus negative (n=428) Community controls (n=5489)	RV1 & RV2; None	Vaccine effectiveness Age >8 months RV1: 91% (95% CI 80, 95) RV5 92% (95% CI 75, 97) Age 12-23 months RV1: 91% (95% CI 75, 96) Genotypes

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		department or inpatient care USA				RV1_G2P 94% (95% CI 78, 98) RV1_G1P 89% (95% CI 70, 96).
17	Chang et al. [62]	Vaccine effectiveness of RV1 and RV5 against rotavirus AGE resulting in hospitalization among children in Taiwan	Children 8–35 months hospitalized with AGE; Cases: rotavirus positive (n=184)	Hospital controls: non-AGE, rotavirus negative (n=909) AGE, rotavirus negative (n=904)	RV & RV5; None	Vaccine effectiveness 2 doses of RV1: vs. RV-negative AGE: 90.4% (95% CI 70.3, 98.1) vs. RV-negative non-AGE: 92.5% (95% CI 77.1, 98.5) 3 doses of RV5: vs. RV-negative AGE: 96.8% (95% CI 82.3, 100) vs. RV-negative non-AGE: 97.1% (95% CI 84, 100)
18	Marlow et al. [61]	Vaccine effectiveness in Coimbra: a low vaccine coverage setting Portugal	Children 8 weeks ≤36 months, with AGE Cases: rotavirus positive (n=542)	Children 8 weeks ≤36 months, with AGE Cases: rotavirus negative (n=1099)	RV1 & RV5; None	Vaccine effectiveness At least 1 dose of either RV1 or RV5 against AGE: 83.7% (95% CI 73.9, 89.8) against hospital admission: 96.1% (95% CI 83.8, 99.1) Full course of either RV1 or RV5 against attendance: 83% (95% CI 71.8, 89.7) against admission: 97.5% (95% CI 81.4, 99.7)
19	Payne et al. [68]	Vaccine effectiveness of RV5 and RV1 in preventing rotavirus AGE hospitalization and emergency department (ED) visits among US children during 2 rotavirus seasons (2012 and 2013)	Children younger than 8 years Cases: rotavirus positive, RV5 (n=402), RV1 (n=100)	Children younger than 8 years, rotavirus negative, RV5 (n=2559), RV1 (n=804)	RV5 & RV1; None	Vaccine effectiveness 3 doses of RV5: 80% (95% CI 74, 84) 2 doses of RV1: 80% (95% CI 68, 88)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
20	Mohammed et al. [69]	Vaccine effectiveness of RV1 and RV5: incomplete, complete and mixed regimens against rotavirus infection, association with severity of disease USA	Children born after March 1, 2009, presenting with AGE Cases: rotavirus positive (n=215)	Children born after March 1, 2009, presenting with AGE Cases: rotavirus negative (n=493)	RV1 & RV5; None	Children >12 months: more likely to have rotavirus Severity score >11, twice as likely to be rotavirus positive. Prior rotavirus vaccination decreased the mean Vesikari score, p < 0.0001. Complete vaccination with either RV1 or RV5, protected (OR: 0.21, 95% CI 0.14, 0.31, p < 0.0001)
21	Yeung et al.[58]	Vaccine effectiveness of RV1 and RV1 in preventing rotavirus AGE in Hong Kong, China	Children, 1 month to 5 years, Cases: rotavirus positive within 48 hours of hospitalisation (n=126)	Children, 1 month to 5 years, rotavirus negative (n=278)	RV1 & RV5; None	Vaccine effectiveness At least 1 dose of either vaccine: 92% (95% CI 75, 98). Age matched: 96% (95% CI 72, 100) Age and admission date matched: 89% (95% CI 51, 97)
22	Immergluck et al. [59]	Vaccine effectiveness of the RV1 and RV5 vaccines USA	Children, ≥8 months, presenting to the ED with AGE Cases: rotavirus positive (n=98)	Children, ≥8 months, presenting to the ED with AGE Cases: rotavirus negative (n=175)	RV1 & RV5; None	Vaccine effectiveness Age 8-23 months 2 doses of RV1: 84% (95% CI 38, 96) 3 doses of RV5: 80% (95% CI 27, 95) Age >24 months 2 doses of RV1: 82% (95% CI 41, 95) among 3 doses of RV5: 87% (95% CI 22, 98)
23	Gastañaduy et al. [60]	Vaccine effectiveness of RV1 and RV5 against rotavirus diarrhoea requiring emergency department (ED) care or hospitalization in Guatemala	Vaccine eligible children (born after June 2009), presenting to the ED or hospital with AGE Cases: rotavirus positive (n=213)	Two control groups: children, non-AGE, rotavirus negative (n=657) Children with AGE, rotavirus negative (n=334)	RV1 & RV5; None	Vaccine effectiveness 2 to 3 doses of either RV1 or RV5 vs. hospital controls: 74% (95% CI 58, 84) vs. test-negative controls: 52% (95% CI 26, 69) Vaccine effectiveness was similar across age groups and vaccine type

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
24	Ali et al. [67]	Surveillance study: Rotavirus infections in a Lebanese paediatric population, younger than five years	Children, <5 years, admitted for AGE Cases: rotavirus positive (n=428)	Children, <5 years, admitted for AGE Cases: rotavirus negative (n=986)	RV1 & RV5; None	Median duration of hospitalization was 4 days. RV negative subjects were more likely to be RV vaccinated (21%) compared to the RV positive subjects (11.3%) (P<0.001), vaccine breakthrough rate of 18.8%. RV1: RV5 (7.8:1) Vaccine effectiveness RV1 and RV5: 68.4% (95% CI 49.6, 80.2)
25	Yoshiyuki et al. [57]	Vaccine effectiveness of RV1 and RV5 against rotavirus hospitalisation in northern Japan, where there is a burden of rotavirus disease	Children, 8-59 weeks, with AGE Cases: rotavirus positive (n=55)	Children, 8-59 weeks, with AGE, rotavirus negative (n=189)	RV1 or RV5; None	Vaccine effectiveness Either RV1 or RV5: 70.4% (95% CI 36.0, 86.4)
26	Zaki et al. [14]	Vaccine effectiveness of rotavirus vaccines in reducing hospitalisations for rotavirus AGE in Saudi Arabia, before and after rotavirus vaccines were added to the national vaccination schedule	Two groups (n=730): Group 1: patients admitted to hospital 1 year before the vaccine was introduced to the national vaccination schedule Group 2: patients admitted to the hospital 3 years post-vaccine	None	RV1 & RV5; None	Prevalence of rotavirus-positive gastroenteritis dropped from 38.5% in group 1 to 13.2% in group 2 (P = 0.0001). Median age of rotavirus infection (P = 0.003) Pre-vaccine period: 16 (95% CI 12, 36) months post-vaccine period: 44 (95% CI 21, 56)
27	Araki et al.[66]	Vaccine effectiveness and	Children, ≥ 2 months to <3	Children, ≥ 2 months to <3	RV1 or RV5; None	Vaccine effectiveness against rotavirus AGE: 80.0% (95% CI 72.8,

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		duration of protection of RV1 and RV5 against rotavirus AGE, RVGE severity and RV genotype among children aged <3 years in Japan	years, presenting with AGE Cases: rotavirus positive (n=487)	years, presenting with AGE, rotavirus negative (n=925)		85.5) RV1: 80.6% (95% CI 70.7, 87.1) RV5: 80.4% (95% CI 69.1, 87.6) Duration of protection: against AGE >70% up to 2 years after vaccination Vaccine effectiveness increased with severity of AGE: 97.3% (95% CI 88.8, 99.3). RV1 and RV5 similar effectiveness against G1P [8] and G2P[4]
28	Justino et al.[40]	Vaccine effectiveness (VE) against severe rotavirus gastroenteritis (RVGE) hospitalizations in Brazil	Children, > 12 weeks, hospitalized with AGE Cases: rotavirus positive (n=538)	Hospital controls: no AGE, children matched to cases by date of birth (n=507) Neighbourhood controls: children, no signs of gastroenteritis, from the same neighbourhood as the case (n=346)	RV1; None	Vaccine effectiveness against rotavirus AGE vs. neighbourhood controls: 75.8% (95% CI 58.1, 86.0) Age 3 to 11 months 95.7% (95% CI, 67.8, 99.4) Age >12months 65.1% (95% CI, 37.2, 80.6) vs. hospital controls: 40.0% (95% CI 14.2, 58.1) Age 3 to 11 months: 55.6% (95% CI, 12.3, 77.5) Age >12 months: 32.1% (95% CI 3.7, 55.5) Genotypes G2P [4]: 82.0% of AGE hospitalizations. Vaccine effectiveness for G2P [4] vs. neighbourhood controls: 75.4% (95% CI 56.7, 86.0) vs. hospital controls: 38.9% (95% CI: 11.1, 58.0)
29	Braeckman et al.[39]	Vaccine effectiveness in preventing admission to hospital for rotavirus AGE among young children in	Children who had received at least one dose of any rotavirus vaccine, > 14 weeks, presenting with	Children matched to cases by date of birth, not admitted for AGE, rotavirus negative (n=276)	RV1; None	Vaccine effectiveness: 2 doses of RV1 against AGE: 90% (95% CI 81, 95) against admission: 90% (95% CI 79, 96) against severe rotavirus: 91% (80% to 96%) against moderate to mild: 66% (−31% to 91%)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		Belgium. The study also assessed the burden of rotavirus disease, distribution of rotavirus genotypes, and co-infections with other common intestinal viruses	AGE Cases: rotavirus positive (n=215)			against co-infections (adenovirus, astrovirus and/or norovirus): 86% (95% CI 52, 96) at least 1 dose of RV1 against admission: 91% (95% CI 82, 95). Genotypes against G2P[4]: 85% (95% CI 64, 94) against G1P [8] 95% (95% CI 78, 99)
30	Patel et al.[38]	Vaccine effectiveness of 2 doses of RV1 against hospital admissions for rotavirus in Bolivia	Children, > 8 weeks, presenting with AGE Cases: rotavirus positive (n=400)	Hospital controls Children, > 8 weeks, presenting with AGE, rotavirus negative (n=718) Children, not with AGE (n=1200)	RV1; None	Vaccine effectiveness RV1 against hospital admission: vs. rotavirus negative controls: 69% (95% CI 54, 79) vs. non-diarrhoea controls: 77% (95% CI 65, 84) one dose of RV1 vs. rotavirus negative controls: 36% vs. non-diarrhoea controls: 56% Protection was sustained through two years of life Hospital admissions: children under 1 year (64% and 77%) and over 1 year of age (72% and 76%). RV1 provided significant protection against diverse serotypes of Rotavirus
31	Cotes-Cantillo et al.[45]	Vaccine effectiveness of RV1 in preventing rotavirus AGE admissions to emergency departments (ED) in Colombia	Children, > 8 weeks, presenting with AGE Cases: rotavirus positive (n=193)	Children, > 8 weeks, presenting with AGE, rotavirus negative (n=858)	RV1; None	Vaccine effectiveness of RV1 Age 6-11 months 79.19% (95% CI 23.7, 94.32) Age >12 months: −39.75% (95% CI −270.67, 47.24) Against overnight hospitalizations: Age 6-11 months: 84.42% (95% CI 22.68, 96.86) Age >12 months: −79.49% (95% CI, −555.8 to 51.08)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
32	Ichihara et al. [36]	Vaccine effectiveness of RV1 in preventing hospitalization for rotavirus AGE in Brazil and genotype-specific vaccine effectiveness by time since second vaccine dose	Children, 4 to 24 months, with AGE Cases: rotavirus positive (n=215)	Children rotavirus negative matched by age and sex to cases (n=1961)	RV1; None	Vaccine effectiveness 2 doses of RV1: 76% (95% CI 58, 86) lasting for two years after adjusting for confounders: 72% (95% CI 44, 85) Genotypes against G1P [8]: 89% (95% CI 78, 95) against G2P [4]: 76% (95% CI 64, 84) against all G1: 74% (95% CI 35, 90) against all G2: 76% (95% CI 63, 84) all non G1/G2 genotypes: 63% (95% CI 27, 99). 1 dose of RV1: 62% (95% CI 39, 97).
33	Groome et al. [37]	Vaccine effectiveness of RV 1 in preventing admission for rotavirus AGE in children younger than 2 years in a high HIV setting, where infants are HIV exposed in South Africa	Children, 18 weeks to 23 months, admitted with AGE Cases: rotavirus positive (n=540)	Children, 18 weeks to 23 months, admitted with AGE and respiratory infection, rotavirus negative (n=1434)	RV1; None	Vaccine effectiveness 2 doses of RV1 vs rotavirus-negative controls: 57% (95% CI 40, 68) (similar to respiratory controls) Age 12-23 months: 60% (95% CI 21, 80) Age: 18 weeks -22 months: 66% (95% CI 46, 79) Age: 18 weeks to 23 months: 63%(95% CI 45, 75) Adjusted: 18 weeks-11 months: 54% (95% CI 32, 68) Adjusted: 12-23 months: 61% (95% CI 35, 77) HIV exposed: 64% (95% CI 34, 80) HIV unexposed: 54% (95% CI 31, 69) 1 dose of RV1 vs. rotavirus negative controls: 40% (95% CI 16, 57) (similar to respiratory controls) Age 12-23 months: 41% (95% CI -17, 71) Age: 18 weeks -22 months: 60% (95% CI 34 to 76)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
						Age: 18 weeks to 23 months: 54% (95% CI 31 to 69)
34	Bar-Zeev et al.[35]	Vaccine effectiveness of a complete series of RV1 against rotavirus diarrhoea hospitalisation in Malawi	Children, <5years, presenting with AGE Cases: rotavirus positive (n=118)	Hospital controls: presenting with AGE, rotavirus negative (n=317) Community controls (n=380)	RV1; None	Pre-vaccination program: 79/157 (50%) rotavirus positive 2 years Post-vaccination program: 52/170 (31%) rotavirus positive Incidence of hospital admission: 2012: 269/ 100 000; 2013: 284/100 00; 2014: 153/ 100 000, incidence dropped by 43.2% (95% CI 18, 60.7) Vaccine effectiveness of 2 doses of RV1: vs. rotavirus-negative individuals: 64% (95% CI 24, 83) vs. community controls: 63% (95% CI 23, 83) Vaccine was more effective against genotype G1 than against G2 and G12
35	Doll et al.[43]	Vaccine effectiveness of RV1 in preventing rotavirus emergency visits and hospitalizations among young children in Canada, examine the effect of increasing vaccination coverage on the prevalence of paediatric rotavirus over time	Children, 8 weeks to <3 years, presenting with AGE, diarrhoea, vomiting Cases: rotavirus positive (n=32)	Children, 8 weeks to <3 years, presenting with AGE, diarrhoea, vomiting, rotavirus negative: (n=342) Surveillance (n=866)	RV1; None	2012-13 season vs. 2013-14 season: reduced prevalence of 70.1% (95% CI 21.9, 88.6) A 1% increase in 2 dose RV1 coverage in children 1 year of age: reduced prevalence of 3.8% (95% CI 1.8, 5.8) Reduced prevalence of rotavirus homotypic strain: 2011–12 season: 77% (95% CI 68, 89) vs. 2013–14 season: 8% (95% CI 0, 36) Vaccine effectiveness of 2 dose RV1: 91.2% (95% CI 61.6, 98.0)
36	Benhafid et al.[44]	Vaccine effectiveness of RV1 in reducing the prevalence of	Children, < 5 years, diarrhoea positive,	None	RV1; None	Pre-vaccine (2006 to 2010): 1861 children hospitalized with AGE; 766 (41%) rotaviruses positive. post-vaccine (2011 to 2013): 533 children

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		children hospitalized with rotavirus diarrhoea; describe rotavirus genotype and prevalence before and after the introduction of vaccination in Morocco	Diarrhoea positive Pre-vaccine: (n=1861) post-vaccine: (n=533) Rotavirus positive cases Pre-vaccine: Cases (n=766) Post-vaccine: Cases (n=128)			hospitalized with AGE, 128 (24%) rotavirus positive. Overall decline in prevalence of 41.5%
37	Sahakyan et al.[31]	Vaccine effectiveness of RV1 on reducing disease burden in Armenia	Children, 0–59 months, with diarrhoea. Cases: rotavirus positive, between 6 months and 2 years old	Children, 0–59 months, with diarrhoea, rotavirus negative	RV1; None	1st year post-vaccination: 48% reduction in rotavirus hospitalizations in infants 2nd & 3rd years post-vaccinations: ≥75% reduction in rotavirus hospitalizations in infants Hospitalisations reduced by ≥30% in non-vaccinated children in 3rd year post-vaccine introduction Hospitalizations reduced 69% in children aged <5 years. Vaccine effectiveness of 2 doses of RV1 against hospitalization: Age 6–23 months: 62% (95% CI 36, 77) Aged 6–11 months: 68% (95% CI 24, 86) Age 12-23 months: 60% (95% CI 20, 80) against severe rotavirus disease: 79% (95% CI 55, 90)
38	Gheorghita et al.[32]	Vaccine effectiveness of RV1 in Moldova, impact of RV1 introduction on rotavirus-associated	Children, younger than 5 years, presenting with AGE Cases: rotavirus positive, older	Children, younger than 5 years, presenting with AGE, rotavirus negative (n=875)	RV1; None	Hospitalization for positive rotavirus declined, also in unvaccinated children: 1st year post-vaccine: 45% to 25% (rate reduction, 36%; 95% CI 26, 44) 2nd year post-vaccine: 14% (rate reduction, 67%; 95% CI 48, 88)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		hospitalizations in Moldova	than 6 months (n=100)			The highest reduction in hospitalizations of infants younger than 1 year old. Vaccine effectiveness of 2 doses of RV1: against hospitalization: 79% (95% CI 62, 88) against severe disease: 84% (95% CI, 64, 83)
39	Gastañaduy et al.[60]	Vaccine effectiveness of RV1 in preventing rotavirus diarrhoea requiring hospitalization in Botswana	Children, ≥ 4 months hospitalised with diarrhoea and/or vomiting Cases: rotavirus positive (n=242)	Children, ≥4 months, hospitalised with diarrhoea and/or vomiting, rotavirus negative (n=368)	RV1; None	Vaccine effectiveness of 2 doses of RV1 against hospitalization: 54% (95% CI 23, 73) 1 dose of RV1: 48% (95% CI 1, 72) against G2P [4]: 59% (95% CI 4, 83) Nutrition status & 2 doses of RV1: no undernutrition: 75% (95% CI 41, 89) moderate or severe undernutrition: -28% (95% CI -309% to 60%) (P = 0.02)
40	Bar-Zeev et al. [34]	Vaccine effectiveness of RV1 and rotavirus prevalence in diarrheal stool and hospitalization incidence before and after rotavirus vaccine introduction in Malawi	Children, <5 years, presenting with AGE, HIV positive or exposed or stunted. Cases: rotavirus positive (n=241)	Children, <5 years, presenting with AGE, HIV positive or exposed or stunted, rotavirus negative (n=692)	RV1; None	Vaccine effectiveness Age <12 months: 70.6% (95% CI 33.6, 87.0) Age 12 to 24 months: 31.7% (95% CI −140.6, 80.6) Vaccine effectiveness not influenced by nutritional status (P=0.12) or HIV exposure (P=0.91) well nourished: 78.1% (95% CI 5.6, 94.9) in stunted: 27.8% (95% CI -99.5, 73.9) HIV unexposed: 60.5% (95% CI 13.3, 82.0) HIV exposed: 42.2% (95% CI, −106.9, 83.8)
41	Beres et al.[41]	Vaccine effectiveness of the RV1 vaccine in Lusaka province Zambia	Children, 0 to 59 months, presenting with diarrhoea Cases: rotavirus positive (n=125)	Children, 0 to 59 months, presenting with diarrhoea, rotavirus negative (n=404) Surveillance, children with	RV1; None or pentavalent vaccine (DTP-Hib-HepB)	Vaccine effectiveness of 2 doses of RV1: Age >6months: 26% (95% CI, −30, 58) against hospitalization: 56% (95% CI, −34, 86)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
				vaccination cards (n=1506)		
42	Zaman et al.[30]	Effectiveness of a rotavirus vaccination program in reducing the risk of presenting with rotavirus AGE in vaccination eligible children in Bangladesh	Children, <2 years, eligible for vaccination Cases: 72 villages in vaccine areas with 6527 eligible children	72 villages in non-vaccine areas with 5791 eligible children	RV1; None	Incidence of rotavirus AGE non-vaccine villages: 4.10/ 100 person-years vaccine villages: 2.8/ 100 100 person-years Overall effectiveness: 29.0% (95% CI 11.3, 43.1)
43	Wandera et al. [28]	Effectiveness of a rotavirus vaccination program in Western Kenya on rotavirus AGE and distribution of strains	Children, <5 years Cases: rotavirus positive (n=323)	None	RV1; None	Hospitalizations due to rotavirus AGE declined by 48% (95% CI 27, 64) 1st year decline: 40% 2nd year decline: 51% Dominant strain changed from GIP (8) to G2P (4) after the introduction of the vaccine
44	Restivo et al. [47]	Impact of vaccination coverage on rotavirus AGE hospitalization rates in Sicily Italy, after the first five-years universal rotavirus vaccination, to evaluate changes in hospitalization in different age-groups and Provinces	Children, 0 to 59 months Pre-vaccination (2009 - 2012) Post vaccination (2013 - 2017)	None	RV1; None	Pre-vaccination hospitalizations: 394/ 100 000 post-vaccination hospitalizations: 200/ 100 000 49.2% overall reduction in hospitalizations. Reductions in hospitalization by age: Age 0 to 11 months (-61.4%) Age 12-23 months (-51.2%) Age 24-35 months (-48.8%)
45	Mpabalwani et al.[29]	-	Children, <5 years, hospitalised for AGE Pre-vaccine: Jan 2009-Dec 2011	None	RV1; None	Pre-vaccine hospitalizations: 40% Post-vaccine hospitalizations: 29% Significant reduction ($p < 0.001$) Rotavirus positivity decreased from 2013 to 2015, and increased to 37% in 2016. Post-vaccine years (2012 to 2016), fewer

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			Post-vaccine: Jan 2013-Dec 2016			tests conducted (median decline: 34% range: 20 to 43) and lower positivity (median decline: 52% range: 30 to 65)
46	Jani et al.[42]	Vaccine effectiveness of RV in preventing hospitalisations, and impact on detection rate before and after the vaccine was introduced in mainland Tanzania	Children, < 5 years, presenting with AGE Cases: rotavirus positive (n=154)	Children, < 5 years, presenting with AGE, rotavirus negative (n=670)	RV1; None	Positivity declined after the vaccine was introduced Vaccine efficacy of >/1 RV1 dose against hospitalization among children 5 to 23 months: 53% (95% CI -14, 81) against hospitalization with intravenous rehydration: 66% (95% CI 9, 87)
47	Mujuru et al.[26]	Vaccine effectiveness of routine RV1 vaccination in Zimbabwe	Children, > 6 months, < 5 years Cases: rotavirus positive (n=903)	Children, > 6 months, < 5 years Cases: rotavirus negative (n=2685)	RV1; None	Vaccine effectiveness of 2 doses of RV1: against hospitalization, any severity: 61% (95% CI 21, 81) against severe disease: 68% (95% CI 13, 88) Nutritional status stunted infants: 45% (95% CI -148, 88) normal height for age: 71% (95% CI 29, 88)
48	Maguire et al.[27]	Vaccine effectiveness of RV1, surveillance of rotavirus disease, epidemiology, and genotypic profiles in Australia	Children, > 6 months eligible for vaccination. Cases: rotavirus positive (n=3587), 2010-2017	Cased matched controls 10 controls for each case	RV1; None	Vaccine effectiveness of 2 doses of RV1: Age 6 to 11 months: 88.6% Age 1 to 3 years: 83.7% Age: 4 to 9 years: 78.7% 1st year of vaccination: 5th to 10th year post-vaccination: 77.05% Equine like G3P [8] (48%) and G8P [8] (23%) were most common genotypes in case patients >/6 months.
49	Gikonyo et al.[46]	Impact of RV1 vaccination on the prevalence, age and seasonal distribution of rotavirus	Children, < 5 years Cases: rotavirus	None	RV1; None	Rotavirus infections detected in 49/323 faecal samples, prevalence = 15.2%. In 2015, 21/95 (22.1%) samples were rotavirus positive. In 2016, 17/115 (14.8%) samples were

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		gastroenteritis in urban, Nairobi County, Kenya	positive (n=323), 2015-2017			rotavirus positive. In 2017, 11/ 113 (10%) samples were rotavirus positive. Age distribution of rotavirus prevalence ≤ 6 months: 8.5%, 7 to 12 months: 27.4%, 13 to 24 months: 41.4%, 25 to 36 months: 16.4%, 36 to 65: 6.3%. Rotavirus diarrhoea was more common in wet and cold months, highest prevalence in August (24.5%), July and March (12.3%), April (10.2%).
50	Bompangue et al.[74]	Temporal pattern of cholera outbreaks, number of cases per health zone in Kinshasa Province DRC, before and after interventions were implemented	Any person >/2 years, cholera cases (2017 to 2018), n=1712	None	Grid approach: Emergency water supply, Household water treatment, safe storage, home disinfection, hygiene promotion; None	Weekly cholera cases dropped by an average of 57% after 2 weeks and 86% after 4 weeks of interventions. The total weekly cases dropped by 71% , following the peak of the outbreak.
51	Ali et al.[80]	The impact of the mass vaccination campaign on the spatial patterns of typhoid fever using Geographic Information System (GIS) methodologies	Persons aged two years and older, living in the area where Vi vaccine was given (n=37763) 1st year post-vaccine (n=37 578) 2nd year post vaccine (n=36 376)	Persons who got a single dose of the inactivated hepatitis A vaccine, outside of the Vi vaccine area	Vi polysaccharide; Inactivated hepatitis A vaccine	Typhoid was randomly distributed in the pre-vaccine period. Following mass vaccination, control clusters were the high-risk areas for typhoid, low-risk areas were dominated by Vi clusters. Control clusters surrounded by Vi clusters also had low risk for typhoid fevers. Pre-vaccination incidences: Salmonella typhi (S. typhi): 194/100 000 Salmonella paratyphi (S. paratyphi): 104/100 000 1st year post-vaccination: incidence of S. typhi dropped, incidence of S. paratyphi similar to pre-vaccination period. 2nd year post-vaccination period:

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
						S. typhi: 190/100 000 S. paratyphi: 170/100 000
52	Pollock et al.[79]	Association between Loch Katrine sourced water with the local incidence of cryptosporidiosis in Scotland	Community members with cryptosporidiosis (n=395)	None	Enhanced water filtration/ No enhanced filtration/ non-Loch Katrine areas	Incidence of cryptosporidiosis associated with, unfiltered Loch Katrine drinking water supplied to the home (OR, 1.86, 95% CI 1.11, 3.11)
53	Khatib et al.[78]	Effectiveness of oral cholera vaccination in high-risk populations to estimate the indirect (herd) protection Tanzania	People 2 years and older Vaccine eligible (n=48178) Received the vaccine (n=23921)	None	Two doses of a killed whole-cell B-subunit cholera vaccine; None	Vaccine effectiveness of doses of cholera vaccine: 79% (95% CI 47, 92) Reduced risk of cholera for people living in neighbourhoods of high vaccine coverage. Herd immunity was also found
54	Wierzba et al. [76]	Effectiveness of cholera vaccine for local staff, cold chain equipment staff and logistics staff to prevent clinically significant cholera in India	Patients, > 1 year, with acute diarrhoea Cases, cholera positive (n=44)	Patients, > 1 year, with acute diarrhoea, cholera negative (n=366)	Two (2) dose cholera vaccine; None	Vaccine effectiveness of 2 doses of cholera vaccine: 69.0% (95% CI 14.5, 88.8%) Single dose: 33%, test for trend, p = 0.0091 Incidence of cholera: 2.42/100 000 population
55	Franke et al. [77]	Effectiveness and duration of 2 doses and 1 dose of cholera vaccine	Participants ≥12 months, positive for Vibrio cholerae 01 (n=178)	4 community controls selected for each case, from the same area (n=706)	Killed, bivalent, whole-cell oral cholera vaccine; None	Vaccine effectiveness of 2 doses of cholera vaccine over 4-years: 76% (95% CI 59, 86). Vaccine effectiveness of a single dose: 1st year: 79% (95% CI 43, 93) Dropped zero by the end of 2nd year
56	Luquero et al. [75]	Effectiveness of the Shanchol vaccine in response to a cholera	Suspected cholera patients, > 12 years. Cases:	Neighbours, same age and sex as cases who did not seek care for	Shanchol vaccine 2 dose cholera vaccine; None	Vaccine effectiveness with 2 complete doses: 86.6%; 95% CI 56.7, 95.8 (P = 0.001)

No.	Author	Objective(s)	Participants (sample size)	Control group (sample size)	Intervention(s); Comparison	Results
		outbreak in an African country	cholera positive (n=40)	diarrhoea during the outbreak (n=160)		

Appendix 10: Proof of article publication (BMC systematic reviews)

Meki et al. Systematic Reviews (2022) 11:73
https://doi.org/10.1186/s13643-022-01947-y

Systematic Reviews

RESEARCH Open Access

Community-level interventions for mitigating the risk of waterborne diarrheal diseases: a systematic review

Chisala D. Meki[1,2*], Esper J. Ncube[2,3] and Kuku Voyi[2]

Abstract

Background: Waterborne diarrhea diseases are among the leading causes of morbidity and mortality globally. These diseases can be mitigated by implementing various interventions. We reviewed the literature to identify available interventions to mitigate the risk of waterborne diarrheal diseases.

Methods: We conducted a systematic database review of CINAHL (Cumulative Index to Nursing and Allied Health Literature), PubMed, Web of Science Core Collection, Cochrane library, Scopus, African Index Medicus (AIM), and LILACS (Latin American and Caribbean Health Sciences Literature). Our search was limited to articles published between 2009 and 2020. We conducted the review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement checklist. The identified studies were qualitatively synthesized.

Results: Our initial search returned 28 773 articles of which 56 studies met the inclusion criteria. The included studies reported interventions, including vaccines for rotavirus disease (monovalent, pentavalent, and Lanzhou lamb vaccine); enhanced water filtration for preventing cryptosporidiosis, Vi polysaccharide for typhoid; cholera 2-dose vaccines, water supply, water treatment and safe storage, household disinfection, and hygiene promotion for controlling cholera outbreaks.

Conclusion: We retrieved few studies on interventions against waterborne diarrheal diseases in low-income countries. Interventions must be specific to each type of waterborne diarrheal disease to be effective. Stakeholders must ensure collaboration in providing and implementing multiple interventions for the best outcomes.

Systematic review registration: PROSPERO CRD42020190411.

Background

Waterborne diseases are transmitted through drinking water that is contaminated with human or animal fecal matter containing pathogenic microorganisms [1], including viruses, bacteria, and protozoa that survive and multiply in food, water, and other surfaces [2, 3]. Most waterborne diseases including cholera, dysentery (shigellosis and amebiasis), typhoid, cryptosporidiosis, giardiasis, cyclosporiasis, yersiniosis, salmonellosis, campylobacteriosis, and other gastroenteritis infections caused by rotavirus, adenovirus norovirus, enterovirus, caliciviruses, astroviruses, and reoviruses manifest as diarrhea [4]. Diarrhea is one of the major causes of mortality and morbidity around the world especially among children [5–8].

Morbidity and mortality from diarrheal diseases can be reduced by applying various interventions that help to cut the fecal-oral transmission route. These interventions include providing adequate and safe water, proper sanitation, handwashing facilities, practicing personal hygiene and food hygiene, education, and vaccinations [9–14].

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Appendix 11: Proof of article publication (PLoS One)

PLOS ONE

RESEARCH ARTICLE

Frameworks for mitigating the risk of waterborne diarrheal diseases: A scoping review

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OPEN ACCESS

Citation: Meki CD, Ncube EJ, Voyi K (2022) Frameworks for mitigating the risk of waterborne diarrheal diseases: A scoping review. PLoS ONE 17(12): e0278184. https://doi.org/10.1371/journal.pone.0278184

Editor: Ricardo Santos, Universidade Lisboa, Instituto superior Técnico, PORTUGAL

Received: May 19, 2022

Accepted: November 11, 2022

Published: December 9, 2022

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: https://doi.org/10.1371/journal.pone.0278184

Data Availability Statement: All relevant data are within the manuscript under the list of references and Supporting information file(SI2).

Funding: This manuscript is part of a PhD study funded by the National Research Foundation South

Abstract

Background

Diarrhea is one of the major cause of death and morbidity around the world.

Objectives

This scoping review summarizes existing frameworks that aim to mitigate the risks of waterborne diarrheal diseases and describe the strengths and weaknesses of these frameworks.

Eligibility criteria

Published frameworks designed to mitigate the risks of waterborne diarrheal diseases. Frameworks published in English, from around the world and published since inception to date.

Sources of evidence

PubMed, Scopus, Web of Science, Google Scholar, Google Free Search, organization websites and reference lists of identified sources.

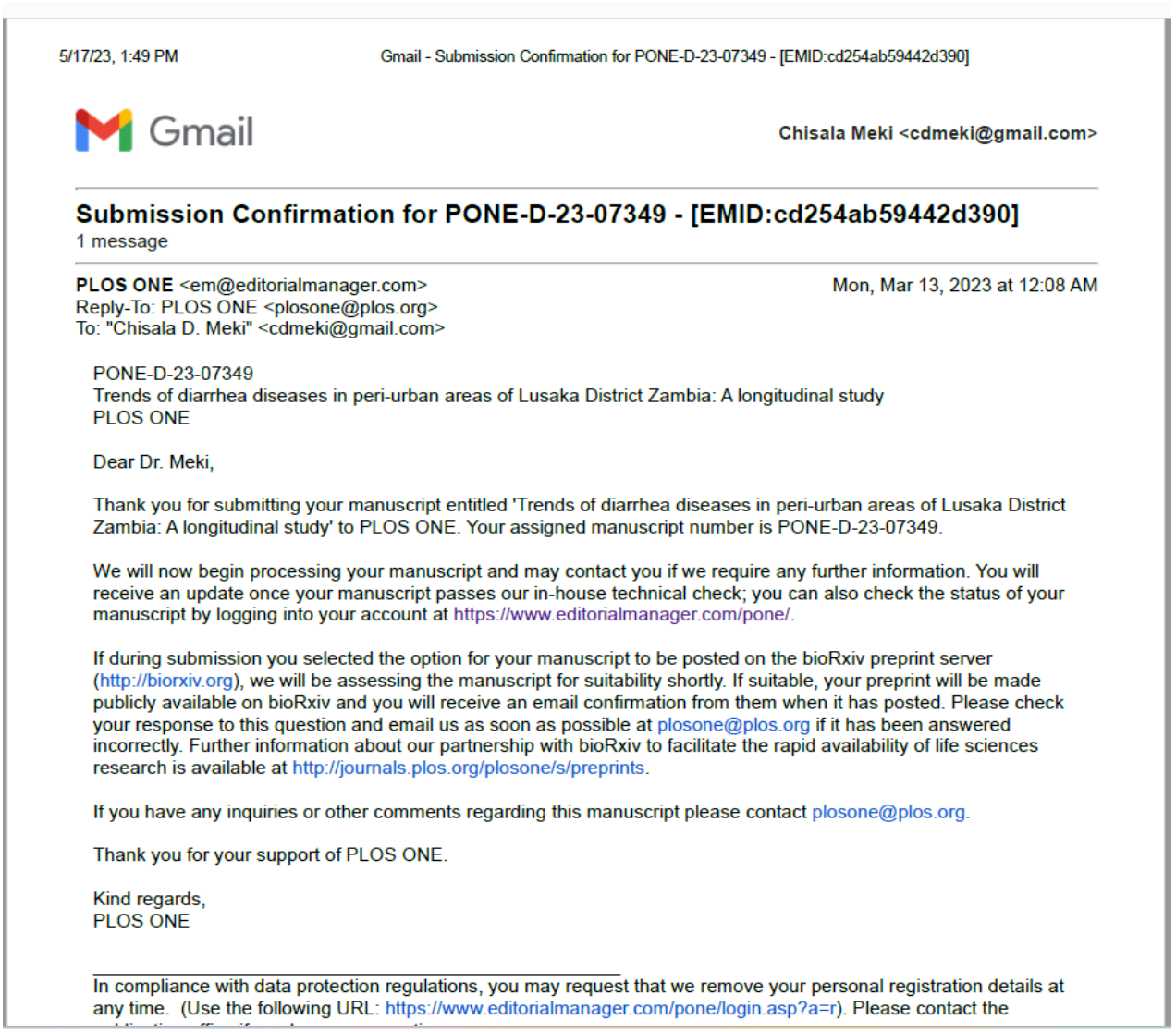
Charting methods

Data were charted using the Joanna Briggs Institute tool. Results were summarized and described narratively. A criterion to score the strengths and weaknesses of the included frameworks was also developed.

Results

Five frameworks were identified including: the hygiene improvement framework, community led total sanitation, global action plan for pneumonia and diarrhea, participatory hygiene and sanitation transformation, and sanitation and family education. These frameworks shared several common components, including identification of problems and risk factors, identification and implementation of interventions, and evaluation and monitoring. The frameworks

Appendix 12: Proof of article submission



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