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Presented by

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TITLE: WATER QUALITY MONITORING AND VULNERABILITY OF THE COMMUNITY TO CHOLERA A CASE STUDY OF CHITUNGWIZA ZIMBABWE URBAN AREA

Defended on 03/09/2019 Before the Following Committee:

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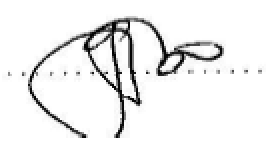
DECLARATION OF INDEPENDENT WORK

I Blessing Barnet Chiniko, National identity number 59-136613 B25 and student registration number PAUWES/2017/475. Do thereby declare that this Master Thesis research project submitted to Pan African University Institute of water and energy sciences (Including climate change), for the Master of Science degree in Water Policy is my own work independently written and aligns well with the code of Academic integrity, including other relevant policies, procedures, rules and regulations of the Pan African University. Safe to say it has not been submitted before to any institution by myself or any other person in fulfillment of the requirements for the attainment of any qualification. I also declare that all material, information, and results from other works presented here have being fully cited and referenced in accordance with the academic rules and ethics.

………  **02/09/2019**

Student Signature **Date:**



02/09/2019

Supervisor Signature **Date:**

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DEDICATION

I dedicate this project to my beloved mother (Mrs. Chiniko) my uncle Mr. Michael Kapachika and Shamiso Maworera who ever gave me the much needed support.

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ABBREVIATIONS

CMHDR- Chitungwiza Municipality Health Department

NCU – National Coordination Unit

NWP – National Water Policy

Goz – Government of Zimbabwe

WASH – Water Sanitation and Hygiene

ZNWP – Zimbabwe National Water Policy

ZINWA – Zimbabwe National Water Authority

RÉSUMÉ

L'étude a permis d'identifier les facteurs de risque affectant la population de Chitungwiza, en relation avec l'approvisionnement en eau, l'étude a fait une analyse de la nature, des sources et des causes des problèmes et a identifié le niveau de risque des personnes au choléra. Par conséquent, le contexte de l'étude a révélé que Chitungwiza est la troisième ville la plus peuplée du Zimbabwe, caractérisée par des infrastructures d'eau et d'égouts vieilles et tendues, avec des ruptures d'égouts plus fréquentes. L'autorité locale ne s'est pas acquittée de ses obligations législatives en matière de fourniture d'eau potable et de services d'assainissement, mais elle a depuis réagi en rationnant l'eau et en donnant aux résidents au moins deux jours d'eau pendant six heures. Les effets du problème ont poussé la communauté à compter sur des puits peu profonds creusés à la main et des forages qui sont rarement surveillés. Cela a conduit à l'apparition continue de maladies d'origine hydrique telles que le choléra, la typhoïde et la diarrhée, avec un record historique d'un taux de mortalité élevé en 2008 et 2018. L'objectif principal de l'étude était de réaliser une surveillance de la qualité de l'eau et des analyses bactériologiques et physico-chimiques pour déterminer si l'eau convenait à la consommation humaine dans 7 forages et 13 puits peu profonds dans le district. 10 paramètres de qualité de l'eau tels que ph, couleur, turbidité, chlorure, sodium, nitrate, dureté totale, sulfate, zinc et fer ont été analysés. Deux forages ont été trouvés contaminés par des bactéries coliformes fécales et forcés de fermer. Alors que le pH était inférieur aux limites de l'OMS et des niveaux élevés de nitrates supérieurs aux normes de l'OMS ont été constatés dans l'ensemble du district. L'enquête sur l'infrastructure des toilettes publiques a révélé un risque élevé d'épidémie de choléra, 95% des toilettes publiques ne fonctionnant pas. Une recherche quantitative et qualitative a été adoptée. Questionnaires structurés et ouverts auto-administrés par le chercheur, utilisant un échantillonnage discrétionnaire et aléatoire sur un échantillon de 150 personnes. Une enquête sur les risques sanitaires a été menée sur les forages et les puits creusés à la main, et l'examen de documents sur la santé et de rapports techniques a fourni des preuves empiriques. Les données ont été présentées à l'aide de diagrammes circulaires, de tableaux et de graphiques pour en faciliter l'interprétation. Une analyse statistique descriptive a été effectuée pour analyser les données. Les résultats de l'examen des documents montrent que la couverture en eau est de 74,1 %, le taux de réponse tardive lors des débordements d'égouts est de 60,5 % et le taux de non-rémunération en eau est de 62,2 %, les échantillons de qualité de l'eau étant conformes aux normes OMS sur une base mensuelle à 85,1 %. Il s'agit de recommandations de politique générale telles que la formulation d'un plan de salubrité de l'eau, un partenariat public-privé, la décentralisation de la surveillance de la qualité de l'eau, des programmes de sensibilisation à la santé publique et le soutien aux clubs de santé communautaires, qui pourraient améliorer la situation de l'eau à Chitungwiza.

MOTS CLÉS, Qualité de l'eau, Choléra, identification des risques, analyse des risques,

ABSTRACT

The study was able to identify the risk factors affecting the population of Chitungwiza, in connection with water supply, the study made an analysis of the nature, sources and causes of the problems and identified the level of risk people are to cholera. Therefore the background of the study revealed that Chitungwiza is the third most urban populated city in Zimbabwe characterized by old and strained water and sewer infrastructure capacity, with sewer bursts occurring more often. Failure of the local authority to execute its legislative duties of providing potable water and sanitation services, however it has since responded by water rationing giving residents at least 2 days with water for 6 hours. Effects of the problem has driven the community to rely upon hand dug shallow wells, and boreholes which are rarely monitored. This has led to continuous occurrence of waterborne diseases such as cholera, typhoid and diarrhea, with a historical record of a high death rate in 2008 and 2018. Prime objective of the study was hinged upon carrying out water quality monitoring, bacteriological and physio-chemical analysis to determine the suitability of the water for human consumption on 7 boreholes and 13 shallow wells in the district. 10 water quality parameters such as including ph, color, turbidity, chloride, sodium, nitrate, total hardness, sulphate, zinc and iron where analyzed. Two boreholes were found contaminated with fecal coliform bacteria, and forced to close. Whereas ph was found to be below WHO limits and high levels of nitrate above WHO standards throughout the district. Public toilets infrastructure survey indicated high risk of cholera outbreak with 95% of public toilets not functioning. Quantitative and qualitative research was adopted. Structured and open questionnaires self-administered by the researcher, using judgmental and random sampling on a sample size of 150. Sanitary risk survey was conducted on boreholes and hand dug wells, document reviews of health and engineering reports provided empirical evidence. Data was presented using pie charts, tables and graphs for easy interpretation. Descriptive statistical analysis was done to analyze data. Results from Document reviews show that water coverage is 74.1%, response late on sewer bursts is 60.5%, and non-revenue water is 62.2%, water quality samples in line with WHO standards on monthly basis 85.1%. Recommendations are coined policy recommendations such as formulation of a water safety plan, public private partnership, decentralizing water quality monitoring, public health awareness programs and support of community health clubs this could improve the water situation in Chitungwiza.

KEY WORDS, Water quality, Cholera, risk identification, risk analysis,

Definition of terms

Water quality – chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose.

Vulnerability – conditions exposing people to danger

Public health - the science and art of preventing disease, prolonging life and promoting human health through organized efforts and informed choices of society, organizations, public and private, communities and individuals.

Sample size -determination is the act of choosing the number of observations or replicates to include in a statistical sample

CHAPTER ONE: INTODUCTION

- **Introduction**

The chapter outlines the study objectives, problem statement, justification of the study, research questions and limitations are going to be found in chapter one. The study is motivated by the need to protect public health from cholera outbreak, through risk identification, risk analysis, risk evaluation. This was done through exploring a mixed methodology to achieve the desired objectives.

Introduction of the study.

The rationale of the study is to break the cycle of cholera transmission route through monitoring of water sources, identifying policy gaps, assessing public sanitation infrastructure and the challenges faced by the community. The study focused on document review dwelling much on water supply indicators such as coverage, continuity, response to complaints, cost recovery, quantity of water available, quality of drinking water. All four districts in Chitungwiza were explored using mixed method approach, with data collection tools such as interviews, observations and surveys. Physio-chemical analysis and bacteriological analysis was carried on 7 boreholes and 13 shallow wells. 2 shallow wells had to be closed in Zengeza due to high level fecal contamination. The water parameters under study include nitrate, sodium, turbidity, chloride, zinc, iron, ph, color, sulphate, and total hardness. Below is a detailed description of all the steps that led to the final results and recommendations.

1.1 Background of the study

Despite many actors involved in water quality monitoring and supply in Zimbabwe which include Ministry of Health and Child Care, Zimbabwe National Water Authority and Ministry of water resources management. Zimbabwe has been continuously been hit by cholera outbreak in 2008 killing 4 000 people and 98 000 people affected according to Bruke (2018). Recently in September and October 2018 cholera struck again with 3621 cumulative suspected cases, with 71 confirmed cases and 32 deaths stated by World Health (2018). Despite efforts to curb cholera such as awareness campaigns and public health education, food inspection, these initiatives are short lived because of poor service delivery which include poor solid waste management, sewer bursts and acute water shortages, lack of frequent water quality monitoring and lack of priority given to water quality monitoring.

There is urgent need to break the cycle of cholera outbreak by blocking the transmission routes through ensuring that the community have access to safe drinking water supply, through efficient water quality monitoring. This problem has intensified because of, raw discharge of untreated sewer in the rivers, combined with pollution from human, industrial and agricultural activities which have made the water very expensive to treat because it will require many chemicals; this was indicated by World Health Organization (2018). Local authorities have also failed to maintain the water infrastructure which is 20 to 30 years old and this has also affected water quality for drinking, because of rusty pipes, water leakages causing high non-revenue revenue in the system and cross contamination from rusty pipes as supported by Ortega (2018).

Chitungwiza Municipality has therefore responded by introducing water rationing where residents receive water for 2 days for a maximum of 6 hours per week, according to Dube and January (2015). This comes from a background of Lake Chivero and Prince Edward dam having low water levels included by high temperatures, causing high evaporation and climate change. Chitungwiza is characterized by a populated high density, than the medium and low density area. This makes the high density residential suburbs more vulnerable to cholera outbreak as a result of high demand of water, insufficient financial capacity to drill boreholes or dig hand dug wells, so they have to rely more on public boreholes and wells according to Gambe (2018).

Maposa and Chambula (2018) stated that the problem in Zimbabwe stretches beyond weak water infrastructure to inadequate public health education, which needs to be addressed to reduce unsanitary behavior which people are practicing in water collection, storage and transportation at especially at the water sources. Additionally the problem is also connected water governance problem which include lack of water safety plan which provides a clear guideline on the frequency of water quality monitoring, lack of water mapping of hotspots, lack of database on the condition of the water sources. Manzungu and Mabiza (2014) has stated that water crisis situation has been worsened by a bureaucratic water quality governance framework where the government laboratory has central control on declaring waterborne diseases diluting the role of private laboratories in reducing water borne diseases.

Without addressing these problems cholera outbreak remains a ticking bomb in the community, therefore the study main aim was to inform the Council that it needs to strengthen water surveillance system. Through objectives such as assessing the water quality from boreholes and shallow wells if there are in line with WHO prescribed guidelines which are used by the community at large. The verification of the water supply status and vulnerability of the community to cholera focusing on key indicators such as quantity, coverage, continuity. Gives the decision makers well detailed information for policy remedies in line with public health.

This research is aligned to Sustainable Development Goal number 6 which seeks to promote access to safe water and for human consumption and bring into light problems on the ground. It also complements

African Union Vision 2063 which supports people driven development, by trying to empower local communities to safeguard themselves against water borne diseases such as cholera.

1.3 Problem Statement

There is need to find a long term solution to reduce cholera outbreak with a specific focus on water quality monitoring to facilitate safe drinking water for the community and protecting public health. Chitungwiza Municipality has since embarked on water rationing whereby the community receives water for 2 or 3 days for 6 hours per week. This has forced the community to rely on hand dug shallow wells, public boreholes have become the primary water which are barely monitored. The council is limited to performing basic water quality tests such as ph, turbidity and residual chlorine, using at least 1 or 2 portable field kits. They heavily rely upon government laboratory which takes at least 1 to 2 weeks for the processing the results. With that the frequent of water quality testing is very low. This has motivated the study to assess the current water quality status on different sources in different locations in order to alert the community and the Council of the current water situation for planning purposes ad rectification of the problem.

Taking into account the background of September and October 2018 cholera outbreak of 2018 with 3621 cases suspected and 71 cases confirmed is an indication of weak water quality governance framework to capacitate local authorities with strong surveillance systems that can easily detect and alert public health hazards and insufficient water and sanitation public health. The efforts to curb cholera outbreak such as public education and awareness campaigns are usually done during an outbreak which shows a reactive approach other than a proactive approach of constantly monitoring key indicators such as the status of water quality of water sources which is consumed by the community. The study also aims at assessing the water supply status taking into account the coverage, continuity, and cost and sanitation conditions by creating an inventory of public toilets that are functional and dysfunctional.

1.4 Justification of the research

Cholera has killed many people already in Zimbabwe, in particular Chitungwiza, mostly associated with drinking contaminated water and in proper disposal of waste. Mostly people in high density suburbs which are overcrowded have no financial capacity to drill private boreholes or hand dug wells with a high vulnerability. So they rely on community wells and boreholes, taking into consideration lack of capacity of the local authority to fully monitor all water sources it is important to monitor water quality at the water sources, identify contaminants and alert the community to treat the water before drinking. Or change their unsanitary behavior through educating them on best practices for safe water collection, storage and transportation that does not promote water quality deterioration. This study is also aimed at bringing into light water governance leakages in terms of policy gap, and promoting proactive public health strategies than reactive public health strategies through prioritizing water quality monitoring.

Though decentralization of laboratories for local authority not to rely more on the government laboratory but to be capacitated to carry out their own water quality analysis, this would save time and financial resources. Apart from focusing on water quality only the study aims at creating an inventory of public toilets that are functioning and dysfunctional for the local authority to use them as a point of reference in development of sanitation infrastructure.

The research is also in line with the national development agenda in Zimbabwe which aims at increasing access to safe water to the community, it also connects easily with sustainable development goal number 6 which aims equitable and equity in access to safe water and sanitation for all. It also subscribes to African Union Vision 2063 for inclusive growth by empowering the community with knowledge of how o safe guard the water source and limit waterborne diseases, especially by focusing on a vulnerable group in the society. Human rights declaration charter also subscribes to the notion that water is a human right and should be of clean. This research pushes for the enacting of water safety plan, decentralization of water quality laboratory, public health awareness education strategy which is implemented continuously thereby if taken into consideration will improve the water situation in Chitungwiza.

1.5 Main objective

To monitor water quality and recommend control mechanisms to protect community water supply sources and identify mechanisms to reduce vulnerability of the community to cholera outbreak.

Specific objectives include:

- To monitor and assess the water quality for drinking and domestic purposes from boreholes compliance with WHO guidelines and standards.
- To evaluate community water supply and public sanitation infrastructure status and assess the vulnerability of the community to cholera outbreak.
- To recommend strategies to strengthen water surveillance system at Chitungwiza Municipality and protect public health.

1.6 Research Questions

1) What is the current water quality status on boreholes and shallow wells and are there in line with prescribed WHO guidelines and standards.

2) What is the current level of water coverage, water quantity, water coverage, water quality and cost recovery of the services and what the challenges in water governance and accessibility are.

3) What is the status of public toilets sanitation infrastructure the risk associated with public health

4) What areas strategies need to be put in place to improve water quality monitoring and reduce cholera outbreak

1.7 Limitations

1 The researcher did not get permission to take tap water samples by Chitungwiza Municipality, this affected the nature of the study as it was aiming to verify quality of water supplied in the taps
2) Government analyst and laboratory took too long to analyze the results a minimum of 2 weeks before giving out the results this slowed down and delayed data analysis.
3) Unavailability of the top officials to respond to the questionnaire

1.8 How the researcher responded to the challenges

The researcher had to settle for telephone interview with the top officials of the government so as to get the require data.
The researcher had to make a follow up to the government analyst so that results would be analyzed in time.

1.9 Conclusion

This chapter bought into light the problems which the study seeks to investigate the magnitude and state of water quality in hand dug wells and boreholes. The chapter explained in detail the main purpose of the research is based upon strengthening water quality surveillance of Chitungwiza municipality, through giving them information on the water sources quality. This comes from a background that strategies to limit cholera outbreak will be short lived if the Council do not adopt a water safety plan which guides them on the frequency of water quality monitoring, selection of water sources and encouraging public health promotions on a regular interval to the community. There is need to take into consideration water supply situation and factors that promote cholera outbreak such as dysfunctional public toilets.

CHAPTER TWO: LITERATURE REVIEW

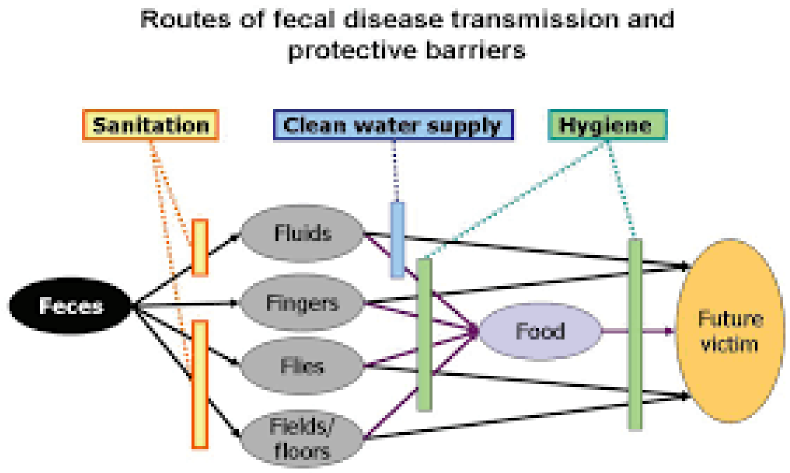
2.0 Introduction

The chapter focused on reviewing the literature related to water and sanitation, the prime goal was to present a case for the need to assess the water quality and sanitation in Chitungwiza on the basis of past experiences. The literature shows experiments, policy review and the lack of hygienic practices that have resulted in cholera outbreaks. The literature review is build up empirical studies and reports focusing on Chitungwiza Municipality Health Department (CMHDR) monthly reports for the year 2018, Chitungwiza Municipality Engineering reports (CMEDR) for the year 2018 and Government of Zimbabwe (GoZ) legislative documents.

2.1 Definition of cholera

According to UNICEF (2016) Cholera is an acute illness characterized with profuse watery, "rice water" diarrhea caused by vibrio cholera. The diseases is transmitted mainly through faecal oral route, this is through eating, and drinking contaminated food or water. The GoZ (2009) defines it as " an acute bacterial enteric disease characterized by sudden onset of profuse watery stool with or without vomiting; in untreated cases it may lead to rapid dehydration, acidosis, circulatory collapse, renal failure and hypoglycemia in children". Hence it is clear that it is a bacterial diseases and the primary preventive mechanism which is at the same time the cure is to maintain high hygienic practices which is mainly facilitated by clean water.

Figure 1: Transmission route of cholera



Source: Rosas and Ferris (2018)

According to Rosas and Ferris (2018) an understanding of these transmission routes, confirms that hardware alone that is (toilets and taps) have limited impact on health. For health to improve changes in hygiene behavior are also needed to break the cycle of disease transmission.

2.1.2 Risk Factors which are connected to cholera

Castro (2014) cited that when the people are not aware of the disease there is higher risk and exposure. In this case, demographic and socioeconomic factors including age, gender and social status play a crucial role to cholera infection, this is because they determine the level of exposure. Cairncross et al (2019) listed risk factors associated with cholera which include:

- Eating or drinking contaminated foods such as uncooked sea food or estuarine waters.
- Lack of continuous access to safe water and safe food supplies
- Attending large gatherings of people including ceremonies such as weddings and funerals cases are reported in that area.
- Physical contact /touching person who died of cholera.

2.1.3 Surveillance goal to monitor cholera

Bhallamudi et al (2019) noted that surveillance system is critical in cholera response and pandemic management. This therefore means that the surveillance strategy is a system set up by government or responsible actors in a cholera affected areas. The major goal is to provide information by monitoring which informs the crisis response strategy. Ecklu-Mensah et al (2019) stated that the purpose of the surveillance goal is to achieve the following:

1) Detection and rapid response to cases and outbreaks of cholera and watery diarrhea
2) Carry out immediate reporting duties of suspected cases and deaths
3) Conducting vital case finding when an outbreak is suspected

2.1.4 Standard Case definition of cholera

Appiah-Effah (2019) standard case of cholera should be suspected when in an area where there is acute water shortage, unprotected food vending and a patient develops acute watery diarrhea, with or without vomiting. Roche (2017) argues that if a patient is aged 5 years or more severe dehydration or death from acute watery diarrhea in an area where there is no cholera can be early sign of cholera effect. It is important to recognize the fact that a standard definition does not constitute a clinical diagnosis. This can only be subsequently proved by laboratory tests according to Wang (2015). However the loophole in the WHO definition is that it excludes people under the age of 2 years, yet it the previous cholera outbreaks that affected Zimbabwe children of 1 year and below were affected in Harare and Chitungwiza, though the cases were not many.

2.1.5 Confirmed case of cholera

According to UNICEF (2018) a confirmed case it is a suspected case in which Vibrio Cholera groups O1 or 0139 has been isolated in a stool, this is normally determined after post clinical tests.

2.1.6 If a cholera case is suspected

According to Abdelrazec etal (2017) when a case is suspected one is supposed to report the information immediately to the nearest clinic or hospital. The health institutions will manage and treat all cases according to the national guidelines. There is also need to enhance strict hand washing isolation and infection control procedures. Conduct case based investigation to identify similar cases not previously reported, to confirm an outbreak, collect bulk stool specimen from 5 to 10 patients within 5 days of onset of acute watery diarrhea before antibiotic treatment is started

2.1.7 If a cholera case is confirmed

Selendy (2015) states that when a case is confirmed, immediate action should be taken to:

- Establish cholera treatment center or unit in locality where cases occur, treat cases onsite rather than asking patients to go to static treatment centers elsewhere.
- Strengthen case management including treatment
- Mobilize community early to enable rapid case detection and treatment
- Survey the availability of safe drinking water
- Work with community leaders to restrict and monitor large groups for funeral and other ceremonies during an epidemic
- Reduce sporadic and outbreak related cases through continuous access to water
- Promote safe preparation of food especially (fish, fruits and vegetables)
- Promote safe disposal of medical, solid and human waste

2.1.8 Laboratory confirmation and Management

According to UNICEF (2018) the diagnostic test through the government and authorized laboratory must be able to confirm identification of cholera from the patients. Immediately the management process kicks in the following actions can be taken:

- Fluid replacement is the basis of treatment for cholera case
- Replace fluids according to the cholera treatment guidelines and patients are treated in the treatment center or camp.
- Antibiotic therapy reserved to the most severe of cases following sensitivity.

2.1.9 **OVERVIEW OF CHOLERA OUTBREAK IN AFRICA**

Table 1: Total cholera cases suspected, confirmed and deaths from 2018 in East and Southern Africa.

Outbreak	Confirmed cases	Deaths	Response Interventions	Challenges
Zimbabwe	177	7	Distribution of water treatment tablets, water chlorination, ad public health awareness campaigns	Water rationing, lack of prioritization of WASH activities, water supply challenges
Uganda	2,658	56	Uganda government partnered with UNICEF in bringing interventions. Social Mobilization and water chlorination.	Informal settlements Having poor toilet coverage. 34% coverage of sanitation. Cited by Uganda Ministry of water sector performance (2017)
Zambia	5,935	114	Closing all public vending sites Community sensitization and water chlorination	Dilapidated water infrastructure, water supply rationing.
Angola	1,046	21	WASH mapping of the water resources, distribution of buckets, water chlorination, public health community outreach programs	7 out of 18 districts mapped as high risk of cholera potential. Poor coverage sanitation
Mozambique	2,435	3	Currently developing contingency plan for cholera outbreak. Water chlorination	Lack of WASH coverage. Exposing the community to cholera.

Malawi	939	32	Establishment of district development disaster response plan and implementing officers	Low WASH coverage and dilapidated infrastructure.
Tanzania	32,098	532	Public health law enforcements, by environmental health officers Community education and awareness.	Low coverage of water and sanitation causing water supply challenges.
Kenya	26,556	421	Kenya government partnered Red Cross in bringing interventions, Public health awareness campaigns through information distribution. Water Chlorination	Insufficient WASH funding, Cholera outbreaks not prioritized by the government. Lack of sectorial coordination
Somalia	6,076	41	Water chlorination, and water trucking supplying. Rehabilitation of water supply systems. Hygiene kits and water treatment products were distributed.	Failure to provide continuous Sanitation facilities because of instability and conflicts, populations constantly relocated.
Rwanda	3	0		Illegal food vending.
Total	77,923	1227		

Unicef (2018)

2.1.9 Gap which needs to be addressed.

The table above summarizes the recent cholera outbreak in East and Southern Africa, it can be noted that cholera outbreak is hugely connected to water supply problems. According to Cairncross et al (2015) SDG, goals can only be achieved through collaborative effort with the community. They is need to increase sanitation coverage, develop disaster risk plan, enforcement of the public health legislation and water quality monitoring.

2.1.10 Overview of cholera outbreak in urban Areas of Zimbabwe

According to UNICEF (2018) urban areas in Zimbabwe are more prone to cholera outbreak than the rural, as a result of the decentralized sewer and water systems compared to the centralized systems in urban areas. Chakaipa (2015) cholera outbreak in urban areas of Zimbabwe signals failure by environmental health management, and lack of prioritization of water and sanitation sector. Mushange (2016) stated that Harare high density areas such as Glenview, Mbare, Mufakose, Machipisa, Budiriro, Tafara Mabvuku are at high risk of cholera because of erratic water supplies. Herald newspaper (2018) stated that Harare water was not safe to drink. According to Red cross Zimbabwe (2018) stated that the doctors without borders have helped to treat cases of cholera in Chegutu were 20 cases, 15 cases in Epworth and 12 in Chitungwiza all connected to poor water and sanitation.

2.1.11 Empirical evidence on the Cholera outbreak in Chitungwiza, Zimbabwe.

Chitungwiza municipality is divided into 4 district areas namely St Marys, Seke North, Seke South and Zengeza. According to Chitungwiza Clinic monthly reports (2018) the cholera outbreak was declared on 09 September 2018 after confirmation of the suspected cases by the government laboratory, with a total of 39 confirmed cases and 1075 suspected cases and a death toll of 3.

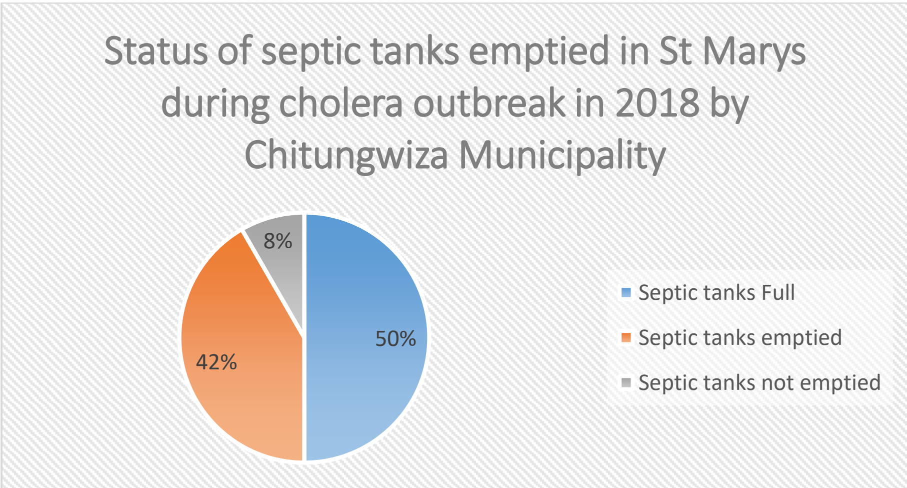
2.1.12 Causes of the cholera outbreak in Chitungwiza

According to Chitungwiza Clinic monthly Reports of September (2018) two boreholes and two shallow wells used for drinking by St Marys Community were heavily contaminated with fecal coliforms and the samples taken tested positive for salmonella and vitriol cholera. Illegal food vending in St Marys was noted and full unemptied septic tanks, promoting open defecation and unhygienic practices. This drove the health officers to take blood cultures to determine co-infection of typhoid and cholera outbreak in patients.

2.1.13 Strategies used to respond to the cholera outbreak in Chitungwiza

According to Chitungwiza Clinic monthly reports of (2018), Chitungwiza carried out a door to door survey to identify septic tanks that were full and unemptied. It is in the same line that the Council was able to plan a schedule and emptied out the full septic tanks at a free cost.

Figure 2: Status of septic tanks emptied in St Marys in response to cholera outbreak



Source: Chitungwiza clinic monthly report (2018)

In reference to figure 2 above, a total of 200 septic tanks identified out of 400 septic tanks surveyed in St Marys. As a result of economic challenges the "honey sucker" the truck responsible for draining the septic tanks is now expensive and most of the residents cannot afford it. 42% of the septic tank was emptied and 8% was not emptied citing reasons that the residents were recommended to construct a new toilet and abandon the old toilets because of the condition of their toilets.

2.1.14 Disinfections and water quality monitoring

Disinfection was done at Cholera treatment center in St Marys, 1oo patients were disinfected of cholera outbreak combined with a door to door surveying of toilet and water conditions in St Marys, as stated by Chitungwiza Clinic monthly reports (2018). Inventory of shallow wells was done with a total of 52 wells and 5 boreholes identified for 387 households. 20 samples were taken to the government laboratory and results showed that 10 hand dug wells were heavily contaminated with fecal coliform, and had to be closed. Lack of proper sanitation knowledge on water handling was noted as the prime causing contamination of water sources.

In response 5000 liters water truck was set up to supply residents with water whilst there were digging another shallow wells. The community was given water treatments tablets, such as aqua, and water guard chlorine and educated to boil water before drinking, to promote water safety.

2.1.15 Food quality monitoring

According to Chitungwiza Clinic reports (2018) Zimbabwe republic police and Chitungwiza Municipality convened food inspection on 50 food outlets in St Marys. The food samples such as fish was taken to the government laboratory and was found contaminated with immediate effect the food outlets lost their operating licensing, this is in line with the foods and food ACT Chapter 15:04.

The community was also sensitized to cook raw food thoroughly and to cover food from dust and flies and avoid contamination. Through posters and flyers on the public places.

2.1.16 Community public health Campaigns: Diarrheal disease prevention

As cited by Chitungwiza Clinic monthly reports (2018) the community public health campaigns were targeted on the affected community and designed to change the behavior of people on WASH practices, these included:

- Door to door campaigners in the community educating people on hygiene issues addressing myths and misconceptions on the causes of diarrheal diseases (cholera, dysentery and typhoid) and misconceptions on cholera.
- Hand washing were encouraged to wash hands with soap and use safe running water to wash the fruits before eating. Most importantly before and after breastfeeding a child, after using the toilet, after cleaning a child's or charging diapers/ nappies, after taking care of someone ill with diarrhea or handling vomitus; lastly if soap is not available use scrub hands with ash and rinse with safe water.
- Sanitation education involved directly contact with the community on encouraging people to use toilets for safe disposal of human excreta. Also the importance of keeping toilets to be kept clean at all times. Placing refuse in containers for council collection at the same time discourage indiscriminate refuse dumping, which promote fly and rodent breeding that spreads diseases. City Health promoters provided reports on sewer blockages, refuse dumpsites and any nuisances that may be hazardous to the health and community.
- In order to prevent diarrheal disease the community was educated through posters and fliers on the need to identify and refer diarrheal cases to the nearest health center for treatment .Encourage the use of salt and sugar solution on diarrheal cases while they are on their way to the health facility and to notify health workers on diarrheal deaths and community rumors on diarrheal cases.

2.1.17 Gap which needs to be addressed

There is need to carry out a full survey in St Marys to identify how many houses have functional and dysfunctional toilets, and how many public toilets are working and not. This is important as it exposes the community to cholera outbreak. The council only managed to carry out a very limited survey which was limited as it did not capture some of the residents in St Marys in order to limit the occurrence of another cholera outbreak. Water treatment tablets were given for free and made available during the outbreak so this means the water treatment tablets should be made available for free to the community in schools, and pharmacies in order for everyone in the community to be able to treat the water.

2.2.0 INSTITUTIONAL, LEGISLATIVE BACKGROUND OF WATER IN ZIMBABWE

2.2.1 Ministry of Lands, Agriculture, Water, Climate and Environment is responsible for water governance in Zimbabwe it is directed by National Water Resources Policy and Water Act (1998). The main functions include, water resources planning and management, borehole drilling and management, water fund management, catchment protection.

2.2.2 National Coordination Unit (NCU) is under the Minsitry of Agriculture, Lands, Water and Climate is responsible for coordinating with local authorities in the area of WASH. It is responsible for WASH strategic planning and implementation both in the rural and urban areas.NAC is responsible for monitoring of WASH situation in Zimbabwe.

2.2.3 National water policy

According to the ZNWP (2012)Zimbabwe water resources is governed through intergrated water resources management principles which are embedded in the National Water Policy (Nwp). They are premised on the values of equity in accessing water, environmental protection, cost recovery and water investment (Section 1.3.1 ZNWP and section 6, Munemo 2015). The water policy has set clear guidelines on the role of service providers who can be a local authority with full capacity to provide water and sanitation at an affordable prize in an efficient manner,or the private sector, non governmental organisation with the capacity to provide services (Section 1.3.3, 1.3.4). Service authorities are local authorites with a amnadate stipulated in the urban and rural councils act of managing water infrastructure and water resources in their own jurisdiction.

2.2.4 Environmental management policy and Environmental management Act

The policy is centred upon protection of the environment, ecosystem, with a goal aimed at sustaianble management. This policy protects the water quality from pollution and regulates discharge of waste into the rivers without treatment. The policy is complemented by the Environmental management Act (Chapter 20:27)which promotes environmental assessment impact on developmental projects with a goal o protect the environment . Particularly section 57 of the act imposes a blanket ban on water polution. It states that:

> "Any person, who discharges or applies any poison or toxic, noxious or obstructing matter, radioactive waste or other pollutants or permits any person to dump or discharge such matter into the aquatic environment in contravention of water pollution control standards shall be guilty of an offence and liable to a fine not exceeding level fourteen or fifteen million dollars, whichever is the greater, or to imprisonment for a period not exceeding five years, or to both such fine and such imprisonment.."

Pursuant to this it requires that industries have certification concerning the cleanliness of the effluent disposed into rivers and other water bodies. As such it requires thorough environmental impact assessment reports.

2.2.5 Water Act (1998) has the following provisions

- Use of water permits for a shorter period of time which can only be renewed after efficient use and replaced water rights.
- Polluter pay principle to have more control over pollution.
- Private onwership of water was removed with a stakeholder driven system of managing water from the catchment level and creation of catchment councils amd greater use of the water in protection of the environment.

2.2.6 Zimbabwe National Water Authority Act (ZINWA ACT)

According to ZINWA ACT Chapter 20:25 it stated that Zimbabwe National Water Authority has the duty to manage dam construction, environmental control, provide water potable to, local authorities without the capacity, drilling of boreholes, water resources management and water pricing. ZINWA manages rural water supply, and through catchment councils Act.

2.2.7 Ministry of Health and Child care role in water quality monitoring

The Ministry of Health and Child Care has the primary role to monitor water quality through the public health Act chapter (15:06), Food and Beverages Act, where water is viewd as a beverage. The Ministry is mandated to respond immeditely to support local authroities in the case of a cholera outbreak and promote public health.

2.2.8 Public health Act chapter (15:06)

The Act sets up a structure in local authority, in the formation of a Health department, Environmental health officer. With a primary role to monitor water quality, and set up plans to promote public health education in the society and respond to cholera outbreak.

2.2.9 Urban Councils Act (chapter 29:15) and Rural District Councils Act chapter (29:13)

The Acts recognizes the role of both rural and urban auhtorities in water provision and management of water infrastructure. The local authority through devolution of power is governed through councillors who constitute health and environmental comittees which are supposed to assist the apointed officials on identification of water related problems in the community. They have a policy making role through full Council meetings were resolutions and by laws are made. The water engineer controls the water department whilst the health deaprtment is controlled by the health director they work together and collaborate to provide potable clean water to the community.

2.2.11 Climate change policy

The National Climate Change Policy (2016) (NCCP) is aimed at promoting sustainable practices which protect over exploitation of surface and ground water resources. The policy is aimed at creating resilient towards climate shocks, reduce the pollution, promote mitigation measures to reduce the effect of climate change. The policy clearly states that the water sector is one of the major threatened sectors.

2.3 Disaster risk management in Zimbabwe

According to Mupfume (2017) states that government ministries and parastatals administer laws with an in built component of disaster management. These include:

- Ministry of Health and Child Welfare : Public Health Act
- Ministry of Home Affairs : Police Act regulations
- Ministry of Transport : Road Motor transportation Act
- Environmental Management Agency : Environmental Management Regulations
- Ministry of local government : Civil Protection Act
- Ministry of Education : Education Act

2.3.1 Overall coordination

- The Minister of Local government, rural and urban development is charged with the coordinative role as empowered by the Civil Protection and Coordination Act Chapter 10.06 of 1989. The Act has the following provisions
    1. Provision of guidelines for action and maximum use of resources since disaster mitigation requires a multi sectorial and interdisciplinary approach
    2. The establishment of a National Civil Protection Fund which receives money from both government and the public. The fund is applied to the development and promotion of civil protection activities throughout the country.
    3. Declaration of the state of disaster by his excellence the President of Zimbabwe

2.3.2 Subcommittees of the National Civil protection Committee according to Disaster management plan of Zimbabwe (2016):

1. **Emergency services** – chaired by the Republic Police

- Produce minimum standards for search and rescue on land, water from the air and underground
- Produce operational plan to manage mass causality situations inclusive of population displacement.

2. Epidemics and Zoonotic chaired by the Ministry of Health and Veterinary services

- Maintain surveillance system for monitoring environmental and biological hazards
- Develop management protocols

3. Food, Water Crisis Sanitation and Health-chaired Social Services

- Maintain an early warning system for food and water
- Maintenance of strategic food and water supplies
- Production of an operational plan to manage food and water supply crisis

4. **There are 3 levels of management of disaster in Zimbabwe namely**
    - National: The Civil protection Directorate coordinates the activities of a multi sectorial and interdisciplinary committee, Zimbabwe Republic police as the Vice Chairmanship
    - Province: At Provincial level in each of the 10 provinces, the Provincial Administrator (a Ministry of Local government employee) chairs the multi-sectorial Provincial Civil Protection Committee.
    - District: At district level the district administrator (a Ministry of local government employee also chairs the multi-sectorial district civil protection committee).

2.3.3 Gap Identifed

The instituional framework on water resources management is too fragmented with duplication of roles for example the Epidemic zand zoonotic committee is responsible for maintaining surveillance of environmental hazards, which is the same role the environmental health department at Chitungwiza Clinic as the National Unit Committee. Outbreaks of cholera is an indication of lack of coordination among the stakeholders to perform their duties effectively

2.3.4 Demographic profile of Chitungwiza and water supply situation.

According to the ZimSTATS (2012) Census Report, Harare is the most populated city in Zimbabwe with 1,542, 813 population followed by Bulawayo with 699, 395 and Chitungwiza with 356 850. Chitungwiza is composed of 25 wards, and subdivided into 4 districts namely St Marys, Zengeza, Seke North, and Seke South. With the increase in population new settlements in Chitungwiza has emerged such as Nyatsime high, medium and low density residential housing (ZimSTATS 2012).

Table 2: Chitungwiza Population by Residential Type

Residential type	Location	Overall population
High density	330 017	92.5%
Medium density	5600	1.6%
Low density	4489	1.3%
Informal settlements	16734	4.6%
Total population	356840	100%

Source: Greater Harare Strategic plan (2017)

Chitungwiza population expressed in terms of the residential type the most populated areas are high density suburbs consisting of 250- 300m^3 size of the residential stands with 330 017 as a result of rural to urban migration and high birth rate according as cited by Matikiti (2018). Medium density suburbs with a range of 500-700 m^3 sizes of the residential stands composed of5600 population constituting 1.6% total population consisting of relatively medium income earners, whilst the low density is composed of low population 4489with relatively 2000- 3000m^3 the land the land prizes often higher.

Table 3: Future population estimates for Chitungwiza

Residential type	2012 population	Projected 2020 population	Projected population 2030
High density	330 017	356 296	485 125
Medium density	5600	6061	8142
Low density	4489	4858	6523
Informal settlements	16 734	18984	20 185

Source: Zimbabwe National Statistics (2016)

As stated above the population is expected to increase drastically especially in urban areas from 330 017 to 356 296 in 2020 that is next year to 485 125 in 2030. Together with informal settlements which have sprouted the Council with a high population of 16 734 which are estimated to increase to 20 185. According to Mazuru (2018) this is an alarm to the Council that there have to expand the water and sanitation infrastructure in time. The medium density having 5600 will increase to 6061 in 2020 and then 8142, and the Low density from 4489 to 6523 the increase is not much as compared to high density and informal settlements because the land is expensive and not many people can afford it. However this calls for urgent water planning by the local Authority in terms of distribution and monitoring water sources.

2.3.4 Water Distribution

According Gambe (2018) **C**hitungwiza Municipality receives its drinking water supply in bulk from Harare the capital city of Zimbabwe Treatment station such as Prince Edward treatment station which is usually on full capacity during rainy season and Morton Jeffrey works. The average daily water production ranges between 50 000 – 55 000m3/day and a maximum peak of 90 000m3/day.

2.3.5: Figure 2: Principal layout of the water system of Chitungwiza from Harare City

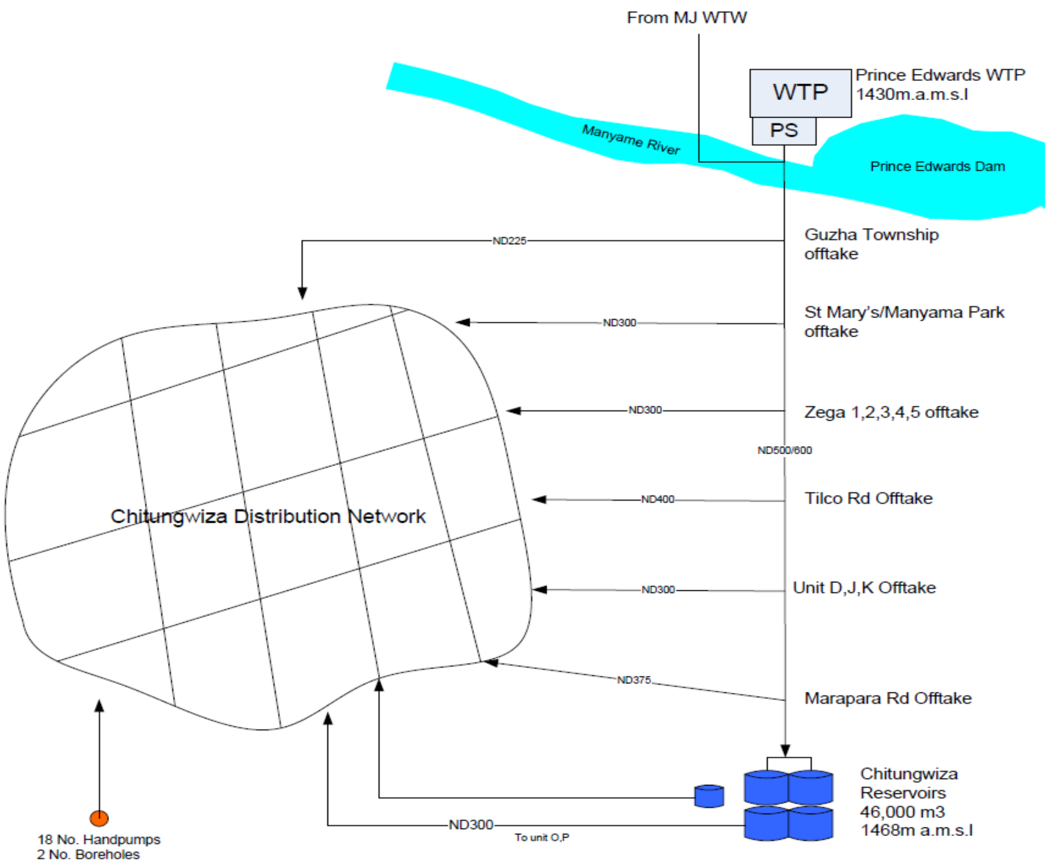


Figure 4-5: Principle layout of the water system of Chitungwiza

Source: Greater Harare Strategic plan (2017)

The figure above shows the distribution network from Harare to Chitungwiza. This diagram clearly shows that Chitungwiza relies more on Harare Water Supply. According to Mhizha (2015) Harare has failed to distribute clean water to its residents, making it difficult for Chitungwiza to receive clean water. Mujuru (2015) states that the pipe from Harare to Chitungwiza is vulnerable to cross contamination and is old infrastructure. The water distribution from Harare represents a political arrangement which have seen Chitungwiza buying water from Harare for the last 6 years as stated by Chakaipa (2015).

2.3.6 Figure 3: Water service on daily basis

Supply Zones	Supply day
Area 1- Old St Mary's and Manyame Park	Monday
Area 2- Zengeza 1	Tuesday
Area 3- Industrial Area	continuous
Area 4- Unit H	Thursday
Area 5 – Unit A	Saturday

Source: Chitungwiza City Council (2018)

The figure 3 above shows the timetable for water rationing in Chitungwiza, with residential areas receiving water once a week. This has forced the community to depend upon public boreholes and hand dug wells. Industrial area is continuous as many industries rely more on the water.

2.3.7 Per capita consumption

According to Mutizwa (2015) water consumption standards in Zimbabwe are determined by the residential status, and income level. The table below shows differences in water consumption as per residential type. The other factors that have contributed to low water consumption standards include leakages, progressive high tariff which discourages high water usage. The table below presents a projection of water consumption in the next 10 years in time, showing a sharp decrease of water consumption with high density and informal settlements at high risk of water crisis.

Figure 4: Proposed specific water consumption figures

Table 5-1: Proposed Specific Water Consumption Figures

Urban areas	At present	2020	2030
	l/cap/day	l/cap/day	l/cap/day
Low Density (LD) areas	300	250	200
Medium Density (MD) areas	200	175	150
High density (HD) areas	85	80	80
Informal*	40	40	40

Source: Citungwiza City Council (2018)

2.3.8 Water demand

According to Greater Harare strategic plan (2017) The domestic consumption is estimated to raise from 29 645 to 42 095, this demand is caused by population growth. Chitungwiza relying on water supply from Harare receiving 16 000m3/day, based upon water rationing. Munemo (2015) stated water supplied to Chitungwiza that is far away from meeting current water requirements not taking into consideration future water requirements.Water demand is divided into; the domestic, institutional, commercial and industrial water consumption. Table shows the projected increase in water demand for Chitungwiza:

Fig 5: The Projected increase in Water Demand

Parameter	Unit	Present	2020	2030
Domestic Consumption	m^3/d	29,645	31,538	42,095
Institutional Consumption	m^3/d	4,447	4,731	6,314
Commercial Consumption	m^3/d	1,681	2,018	2,581
Industrial Consumption	m^3/d	1,811	2,587	3,787
Total	m^3/d	37,583	40,874	54,777
Water Loss Rate	%	31%	25%	20%
Water Loss	m^3/d	16,885	13,625	13,694
Average day demand	m^3/d	54,469	54,499	68,471

Source: Chitungwiza Municipality (2018)

Gap which needs to be addressed

There is need to rehabilitate the bulk transmission water pipeline from Harare to Chitungwiza to minimize water looses and urgent need to address the continued deterioration water supply situation

2.3.9 What is water quality?

According to World Health Organization (2018) defines water quality as the condition of water, counting the physical, chemical, and biological characteristics, giving respect to the use and suitability for a purpose such as drinking or environmental protection. According to WHO (2011) water quality monitoring is important to protect public health and the environment at large. According to the WHO (2015) the minimum level of water quality analysis should include testing for indicators of fecal pollution (thermo tolerant faecal coliforms) turbidity, pH and residual chlorine if the water is disinfected with chlorine.

2.4.1 Water sampling methods

2.4.2 Microbiological analysis

According to Nhapi (2015) Microbiological analysis is the examination of drinking water with emphasis on the hygiene quality of water. This requires isolation and enumeration of organisms that indicate the presence of faecal contamination. Faecal coliform bacteria (>99 per cent of which are E.coli) are an indicator of the level of human and animal waste contamination in water and the possibility of the presence harmful pathogens.

2.4.3 Storage of samples for microbiological analysis

According to WHO (2015) sample collection and analysis should not exceed 6 hours and 24 hours is considered the absolute maximum. It is assumed that the samples are immediately placed in a lightproof insulated box containing melting ice or ice packs with water to ensure rapid cooling. If ice is not available the transportation should not exceed 2 hours, it is imperative that samples are kept in darkness and cooling is rapid. If these conditions are not meet the samples should be discarded.

2.4.4 Physiochemical analysis

According to Humanitarian Charter and Minimum standards (2015) results of physiochemical analysis are of no value if the sample tested are not properly collected and stored. This has important consequences for sampling regimes, sampling procedures and methods of sample preservation and storage. In general time between sampling and analysis should be kept to a minimum of not more than 12 hours, storage in glass or polyethylene bottles at low temperatures (e.g. $4^{o}C$) in the dark is recommended. Sample bottles must be clean but not sterile Swanson and Fipps (2015).

2.4.5 Bacteriological analysis

Principal risk associated with water in small community supplies is that of infectious diseases related to faecal contamination. Bacteriological water analysis is a method of analyzing water to estimate the numbers of bacteria present and, if needed, to find out what sort of bacteria they are. It represents one aspect of water quality. Total Coliforms, Fecal Coliforms, and E. coli. Mehta et al. (2016) states that the most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply.

2.4.6 Fecal Indicator Bacteria

WHO (2017) states that water for drinking and domestic purpose there should be no faecal coliform per 100 ml of water at the point of delivery and use. Any household level water treatment options used are effective in improving microbiological water quality should be accompanied by appropriate training, promotion and monitoring. Ensuring that there is no negative effect on health due to short term use of water contaminated by chemicals (including carry-over of treatment chemicals or radiological sources and assessment shows no significant probability of such an effect. Fecal coliform is an indication of water pollution and not suitable for human consumption as noted by Nhapi (2016).

2.4.7 Total and fecal coliform bacteria test

According to Mehta et al. (2016) total and fecal coliform bacteria test is a primary indicator of portability of drinking water, suitability for consumption, of drinking water. It measures the concentration of total coliform bacteria associated with the possible presence of disease causing organisms.

2.4.8 Water quality parameter: Importance of pH

Huns low (2018) cited that simple tests may be conducted in the field for measurement of pH using comparators such as portable pH electrodes and meters. For laboratory they have to be calibrated against fresh pH standards at least daily for field use, they should be calibrated immediately before each test. The results may be inaccurate if the water has a low buffering capacity. Hunslow also elaborated that ph is important because it determines the acidity or alkalinity of water and should be between 6.5 and 8.5 ranges, stating that it can indirectly affect human health.

2.4.9 Importance of Turbidity

According to Sener and Danvar (2017) turbidity is important because it affects both acceptability of water to consumers and the selection and efficiency of treatment processes. Particularly the efficiency of disinfection with chlorine since it exerts a chlorine demand and protects microorganisms and may also stimulate the growth of bacteria, viruses that can cause diarrhea cases.
WHO (2015) states that in all processes in which disinfection is used the turbidity must always be low preferably below 1 NTU. For water to be disinfected turbidity should be consistently less than 5 NTU.

According to Canter (2018) turbidity may change during sample transit and storage, and should therefore be measured onsite at the time of sampling. This can be done by means of electronic meters (which are essential for measurement of turbidities for the measurement of turbidity below 5 NTU).

2.4.10 Importance of Chloride

Brown (2018) cited that chloride is important in drinking water quality analysis as the presence of high levels of chloride indicate higher levels of organic pollution, which poses public health hazard. WHO recommends that it should not exceed 200 mg/L.

2.4.11 Importance of Nitrate

Major sources of nitrate in water circulates from the atmosphere, animal excreta and plant legumes according to Janine (2015). WHO prescribes that Nitrates should not exceed (45 mg/L). Rehman (2016) states that nitrates are the most common groundwater contamination agents primarily from fertilizers, manure storage and septic tanks. It is not safe for human consumption and can cause blue babies diseases.

2.4.12 Importance of Sodium

Effah (2017) stated that sodium is most readily available element that occurs naturally especially in weathered rocks. It is also available in the ground due to effluent discharge into the ground from sewages and industries. According to WHO guidelines the maximum limit is 200mg/L. Generally it is not poisonous to humans but should be monitored.

2.4.13 Importance of aesthetic water quality parameters

Aesthetic parameters are those detectable by the senses namely turbidity, color, taste, and odor. They are important in monitoring community water supplies because they cause the water to be rejected and (possibility of poorer quality) alternative sources to be adopted and they are simple and inexpensive to monitor in the field.

2.4.14 Importance of Color

Color in drinking water maybe due to the presence of colored organic matter, for example humid substances, metals such as iron and manganese or highly colored industrial waste. For the purposes of surveillance of community water supplies it is useful simply to note the presence or absence of observable color at the time of sampling. Changes in the color of water and the appearance of the new colors serve as indicators that further investigation is needed.

2.4.15 Taste and odor

Odors in water are caused by mainly by the presence of organic substances, some odors are indicative of increased biological activity, other may result from industrial activity.

Sanitary inspections should always include the investigation of possible or existing sources of odor and attempts should be always be made to correct odor problem.

Taste problems are sometimes grouped with odor problems usually account for the largest single category of consumer complaints.

2.4.16 Importance of zinc

Zinc is an essential nutrient for body growth and development, however drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. Water with a zinc concentration of more than 5 mg/L may start to be become chalky in appearance with a detectable deterioration in taste. Excessive absorption of zinc can suppress copper and iron absorption. The free zinc ion in solution is highly toxic to bacteria, plants, invertebrates, and even vertebrate fish.

2.4.17 Importance of iron

Although a low level of iron cannot do much harm, iron in water is considered as a contaminant because it also contains bacteria that feed off it. In addition to this, high iron content leads to an overload which can cause diabetes, hemochromatosis, stomach problems, nausea, and vomiting.

2.4.18 WATER QUALITY INDEX

According to Guo etal (2017) states that the purpose of water quality index is to present water quality data in a simple way.

Table 4: Water quality index

WQI %	Rating of water quality	Grading
96 - 100	Excellent water quality- safe for human consumption	A
90-95	Very good water quality –safe for human consumption	C
51- 89	Reasonably better quality but requires treatment before use	D
28 -50	Polluted water use that is not suitable for human consumption	E
0-27	Very poor water quality polluted not suited for human consumption	F

Source (Jaila 2017)

2.4.19 Location of sampling points

IASC Global Health Cluster (2015) states that the primary objective of surveillance is to assess and evaluate the quality of water supplied by the supply agency at the source and point of use. Any difference between the two have important implication and remedial strategies. Perrin (2016) elaborates that samples must be taken from locations that are representative of the water source, treatment plant, storage facilities, distribution network, points at which water is derived to the customer, and points of use. Noji (2017) states that in selecting sampling points each locality should be considered individually, however the following general criteria are usually applicable.

- Sampling points should be selected such that the samples taken are representative of the different sources from which water is obtained by the public or enters the system.
- These points should include those that yield samples representative of the conditions at the most unfavorable sources or places in the supply system particularly points of possible contamination such as unprotected sources, loops, reservoirs, low pressure zones, end of the system.

- Sampling points should be uniformly distributed throughout a piped distribution system, taking population distribution into account, the number of sampling points should be proportional to the number of links or branches.
- The points chosen should generally yield samples that are representative of the system as a whole and of its main components.
- Sampling points should be located in such a way that water can be sampled from the reserve tanks and reservoirs
- In systems with more than one water source, the locations of the sampling points should take into account of the number of inhabitants served by each source
- There should be at least one sampling point directly after the clean water outlet from each treatment plant.

According to Humanitarian Charter and minimum standards in Humanitarian response (2015) the following factors should be considered in water source selection: water availability, proximity and sustainability of sufficient quantity and quality of water, whether treated is needed and its feasibility including the existence of any social, legal and political factors concerning the source.

2.5 Sampling sites in a piped distribution network

Spiegel et al (2016) states that sampling sites in a distribution network can be classified as

1. Fixed and agreed with the supply agency
2. Fixed but not agreed with the supply agency
3. Random or variable

2.5.1 Fixed and agreed with the supplier

According to WHO (2015) Fixed sites agreed with the supplier are essential when legal action is to be used as a means of ensuring improvement. Otherwise the supply agency may object to a sample on the grounds that the water quality may have deteriorated in the household. However fixed sample points are unknown in some countries. However, fixed sites not recognized by the supplier are used frequently in investigations including surveillance. WHO also added by elaborating that they are especially useful when results have to be compared overtime, but they limit the possibility of identifying local problems, such as cross contamination and contamination from leaking distribution networks.

2.5.2 Random or variable

Murwira (2016) stated that Sampling regimes using variable or random sites have the advantage of being more likely to detect local problems but are less useful for analyzing changes over time.

2.5.3 Sampling frequency

The most important tests used in water quality surveillance or quality control in small communities are those for microbiological quality (by the measurement of indicator bacteria) and turbidity and for free chlorine residual and pH where chlorination is used.

Table 5: Minimum frequency of sampling and analysis of Un-piped water supplies

Source and mode of supply	**Minimum frequency of sampling and analysis**		**Remarks**
	Bacteriological	**Physical/chemical**	
Open wells for community supply	Sanitary protection measures, bacteriological testing only if situation demands	Once initially for community wells	Pollution usually expected to occur
Covered dug wells and shallow tube wells	Sanitary protection measures, bacteriological testing only if situation demands	Once initially thereafter as situation demands	Situation requiring testing change in environment conditions, outbreak of waterborne diseases or increase of waterborne diseases
Deep tube wells with hand pumps	Once initially thereafter as situation demands	Once initial as situation demands	Situation requiring testing change in environment conditions, outbreak of waterborne diseases or increase of waterborne diseases
Protected springs	Once initially as situation demands	Periodically for residual chlorine if water is chlorinated	Situation requiring testing change in environment conditions, outbreak of waterborne diseases

Community rainwater collection systems	Sanitary protection measures bacteriological testing only if situation demands	Not needed	

Source WHO (2015)

2.5.4 INDICATORS USE TO EVALUATE COMMUNITY WATER SUPPLIES SITUATION

2.5.5 Needs /Quantity

The quantities of water needed for domestic use is context based, as they vary according to climate, sanitation facilities available, habits of people, cultural and religious practices, type of food they cook, clothes they wear. Water consumption generally increases the nearer the water source is to the dwelling. Where possible 15 liters per person per day can be exceeded to conform to local standards where that standard is higher. WHO (2015)

Table 6: Showing Basic survival water needs

Survival needs: water intake (drinking and food)	2.5-3 liters per day	Depends on the climate and individual physiology
Basic hygiene practices	2-6 liters per day	Depends on social and cultural norms
Basic cooking needs	3-6 liters per day	Depends on food type and social and cultural norms
Total basic water needs	7.5-15 liters per day	

Source: WHO (2018)

In rural areas daily consumption of water may vary widely in urban areas with piped water supplies to house connections, it may exceed 100 liters per capita per day. Measurements of the volume of water collected or supplied for domestic purposes may be used as basic hygiene indicator. According to WHO (2015) some authorities use a guideline value of 50 liters per capita per day but this is based on the assumption that personal washing and hygiene and laundry are carried out in the home, where this is not the case lower figures are acceptable.

Mabiza (2015) states that in the analysis of bulk figures related to water entering the piped distribution systems, it should be noted that

- Figures will be averages and the consumption in different households may vary widely with socioeconomic status.

- Leakages may make a significant contribution to apparent consumption
- Even a single dwelling using piped water for irrigation or for a commercial purpose may significantly influence the apparent consumption for a community water supply.
- Flow of water entering the distribution system during the day does not necessarily represent the sustained input during 24hours and overflow may be significant at certain times.

2.5.6 Measurement

Household surveys, observation and community discussion groups are most effective methods of collecting data on water use and consumption than the measurement of water pumped into the pipeline network or the operation of hand pumps. Sethpgile (2016).

2.5.7 Coverage

According to World Health Organization (2015) from the public health standpoint the percentage of population provided with drinking water, the coverage is the most important single indicator of the success of the water supply program. From the point of view of the water supply agency, coverage is expressed as percentage of the total population served. It may be subdivided into population served by domestic connections by public stand posts, and by point sources such as wells and springs.

Fetch (2017) states that Health surveillance agency has the primary responsibility for public health aspects of water to the entire population. It is important that the water agency takes wider surveys for the various means on which drinking water is supplied to the population, the estimated population served by each means of supply and the relative risk associated with them. This information is important is should be formally communicated to national planning authorities, which will be used to guide water supply programmes and funding strategies.

2.5.8 Continuity

WHO (2016) States that Analysis of data on continuity of supply requires the consideration of two components – daily and seasonal continuity. Continuity can be classified as follows

- Year-round services from a reliable source with no interruption of flow at the tap
- Year-round service with daily variation of which the most common causes are:
- Restricted pumping regimes in pumped systems whether planned or due to power failure
- Peak demand exceeding the capacity of the reservoir
- Seasonal service variation resulting from source fluctuation which typically has three causes
- Natural variation in source volume during the year

- Volume limitation because of competition with other uses such as irrigation
- Periods of high turbidity when the source water may ne untreatable
- Compounded daily and annual discontinuity.

Manzungu (2017) states that this classification reflects broad categories of continuity which are likely to affect hygiene in different ways. This daily discontinuity results in low supply pressure and a consequent risk of in pipe recontamination. Which is potentially hazardous in the case of chlorinated community water supplies.

WHO (2015) states that other consequences include reduced availability and lower volume use which adversely affect washing habits. Household water storage may be necessary and this may lead to an increase in the risk of contamination during such storage and associated handling. Seasonal discontinuity often forces users to obtain water from inferior and distant sources.

2.5.9 Maximum numbers of people per water source

The number of people per source depends on the yield and availability of water at each source. The approximate guidelines are:

Table 7: Number of people per water source

250 people per tap	Based on a flow of 7.5 liters/minute
500 people per hand pump	Based on a flow of 17 liters/minute
400 people per single user open well	Based on a flow of 12.5 liters per minute

Source WHO (2015)

According to WHO (2015) guidelines above assume that the water point is accessible for approximately eight hours a day and water is constant during that time. If access is greater than this people can collect more than the 15 liters/per day minimum requirement. These targets must be used with caution as reaching those does not necessary guarantee a minimum quantity of water or equitable access.

2.6 Queuing time

According to UNICEF (2017) excessive queuing times are indicators of insufficient water availability due to either inadequate number of water points or inadequate yields at water sources. The potential results of excessive queuing times are reduced per capita water consumption, increased consumption from unprotected surface sources and reduced time for other essential survival tasks for those who collect water. Relief organization (2017) states that the queuing time at a water source should not be more than 30 minutes.

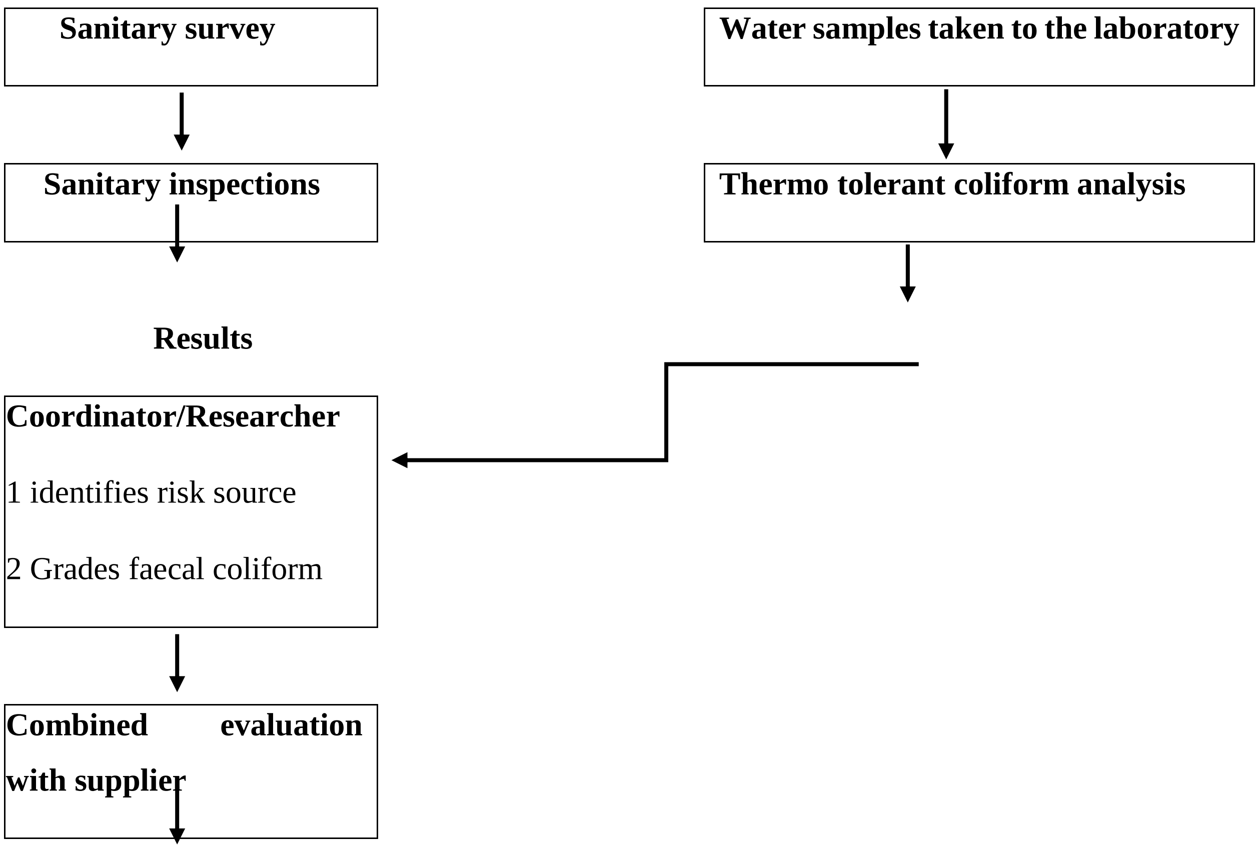
2.6.1 Access and equity

World Vision Organization (2017) states that the maximum distance from a household to the nearest water point should be 500 meters. Even if a sufficient quantity of water is available to meet minimum needs, additional measures are needed to ensure equitable access for all groups. Water sources should be accessible to all, regardless of gender or ethnicity. Where water is rationed or pumped at given time this should be planned in consultation with the users.

2.6.2 Sanitary Survey

A sanitary survey is an assessment of conditions and practices that may constitute a public health risk, it covers possible sources of contamination to water at the source in transportation and in home, defecation practices, drainage and solid waste management. Community mapping is particularly effective way of identifying where public health risks are and thereby involving the community in finding these risks. WHO (2017)

Figure 8 Procedural steps for carrying out a sanitary survey



Prioritize and select urgent actions

↓

Remedial action

↓

Follow up survey

↓

Evaluate results of the impact of rehabilitation

Source (WHO 2017)

2.6.3 COMMUNITY SURVEY

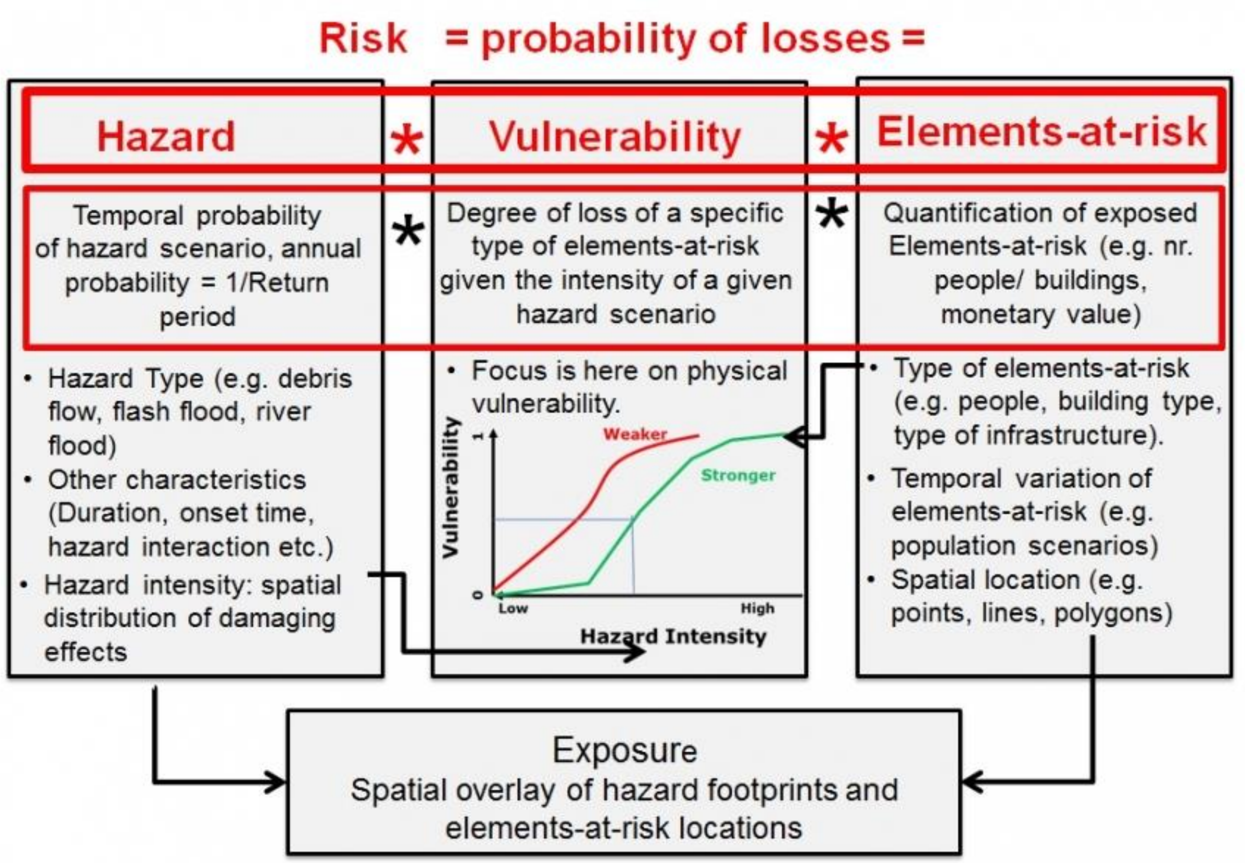
According to WHO (2015) community survey is an evaluation of all factors and resources (physical and human that affect the water supply service, sanitation and environmental health of a community. For sanitary inspection, a community survey is required of a comprehensive database. It should provide four key components namely

1. Basic data on water supply and sanitation facilities with inventories or databases of the water supply systems in the area
2. Sanitary inspection (comprising sanitary inspection and water quality analysis),
3. A quantitative diagnostic summary of the key water supply service indicators (namely quality, quantity, coverage, continuity and cost)
4. Hygiene survey.

2.6.4 METHODS FOR RISK ASSESSMENT

Risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UN-ISDR, 2009, EC, 2011).

Figure 9: **Risk assessment**



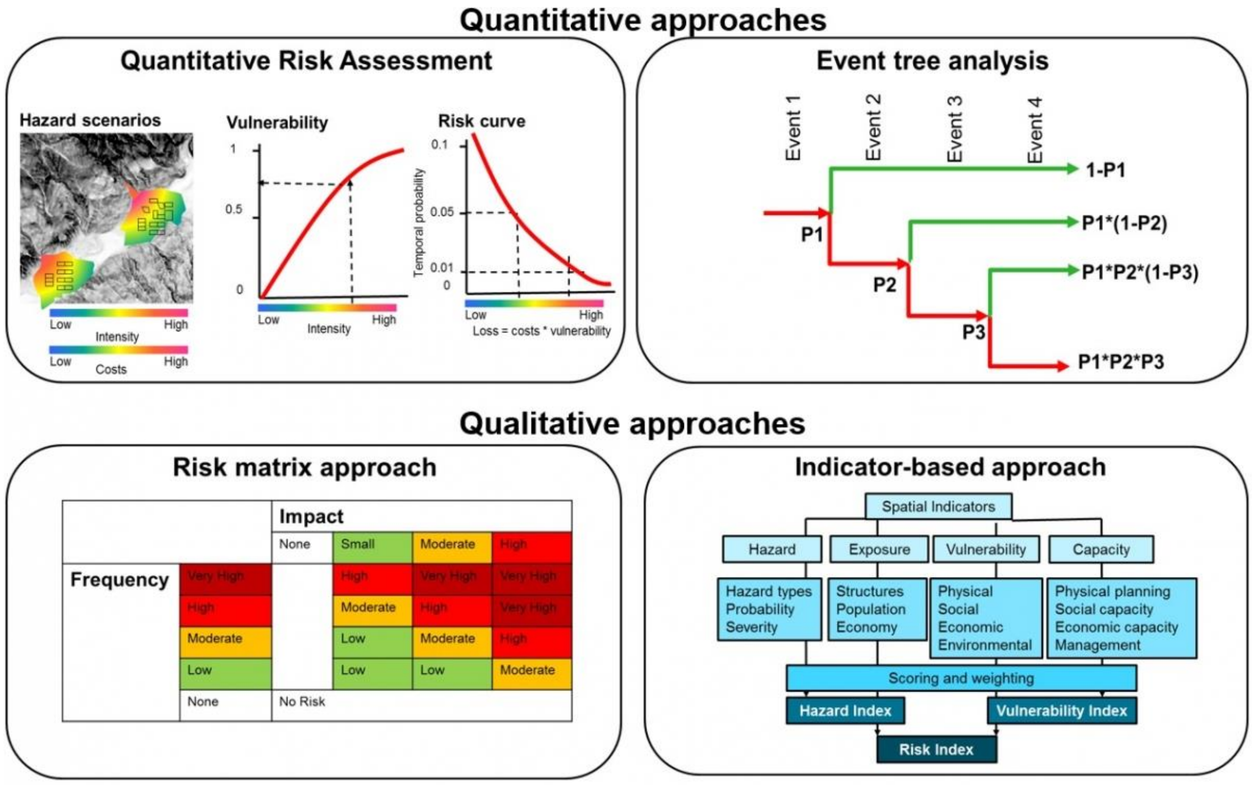
Source : (UNIDR 2009)

2.6.5 Risk assessment and risk mapping

Risk assessment is a process to determine the probability of losses by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a threat or harm to property, people, livelihoods and the environment on which they depend (UN-ISDR, 2009). ISO 31000 (2009) defines risk assessment as a process made up of three processes: risk identification, risk analysis, and risk evaluation. Risk identification is the process that is used to find, recognize, and describe the risks that could affect the achievement of objectives. Risk analysis is the process that is used to understand the nature, sources, and causes of the risks that have been identified and to estimate the level of risk. It is also used to study impacts and consequences and to examine the controls that currently exist. Risk evaluation is the process that is used to compare risk analysis results with risk criteria in order to determine whether or not a specified level of risk is acceptable or tolerable.

Risk mapping for natural hazard risk can be carried out at a number of scales and for different purposes. Table 4 gives a summary. In the following sections four methods of risk mapping will be discussed: Quantitative risk assessment (QRA), Event-Tree Analysis (ETA), Risk matrix approach (RMA) and Indicator-based approach (IBA).

Table 4 : Indication of scales of analysis with associated objectives and data characteristics (approaches: QRA = Quantitative risk assessment, EVA = Event-Tree Analysis, RMA = Risk matrix approach, IBA = Indicator-based approach



Source: (UNDIR 2009)

2.6.7 An event tree

System which is applied to analyze all the combinations (and the associated probability of occurrence) of the parameters that affect the system under analysis. All the analyzed events are linked to each other by means of nodes all possible states of the system are considered at each node and each state (branch of the event tree) is characterized by a defined value of probability of occurrence.

2.6.8 CONCLUSION

The literature review set a tone on the study by unveiling Cholera in Africa with recent outbreaks of 2018 and the causes, thereby showing the magnitude of the problem at hand which needs to be addressed of water and sanitation. Literature review also unraveled the limited survey carried at Chitungwiza on the status of septic tanks in St Marys as they pose a high risk to Cholera. Water governance in Zimbabwe was examined and the coordination weakness where pointed out. The review went further by giving a detailed analysis of the water situation in Chitungwiza. The status of Chitungwiza water system was explained in detail and the potential risk of population pressure in high density, dilapidated infrastructure which needs urgent addressing. Literature review also directed the researcher on the methodology by stating the importance of water quality parameters, sampling methods, which include bacteriological, physio- chemical analysis.

The literature review informed the methodology by bringing into light the standards which are supposed to be followed in water source selection, the main indicators which are used on water supplies evaluation such as coverage, quantity, continuity, measurements which was best alluded by WHO that community discussions, household surveys are the best way to measure water supply matters. Literature review also guided the researcher on the role of sanitary survey and community survey in water quality monitoring. Guided by the objectives the methodology and the results were fully informed by the literature review.

CHAPTER THREE: RESEARCH DESIGN AND PROCEDURES

3.0 Introduction

This chapter gives a detailed explanation on the sampling procedure followed by the researcher, in achieving the above mentioned objectives in Chapter one. The researcher followed the Guidelines prescribed for drinking water quality by WHO. The chapter will explain data collection tools used, sampling tools and the mixed methodology method used.

3.1 Ethical consideration

Before commencing the research was endorsed by the Pan African University Institute of water and energy sciences by the research committee. Then the researcher went further to seek for permission from the Ministry of Health and Child and was then given authority by Chitungwiza Municipality through the Director of Health and Environmental Services. The researcher followed closely research ethics by respecting and treating information with full confidentiality and also informing the participant of the goals of the research in order to get research consent.

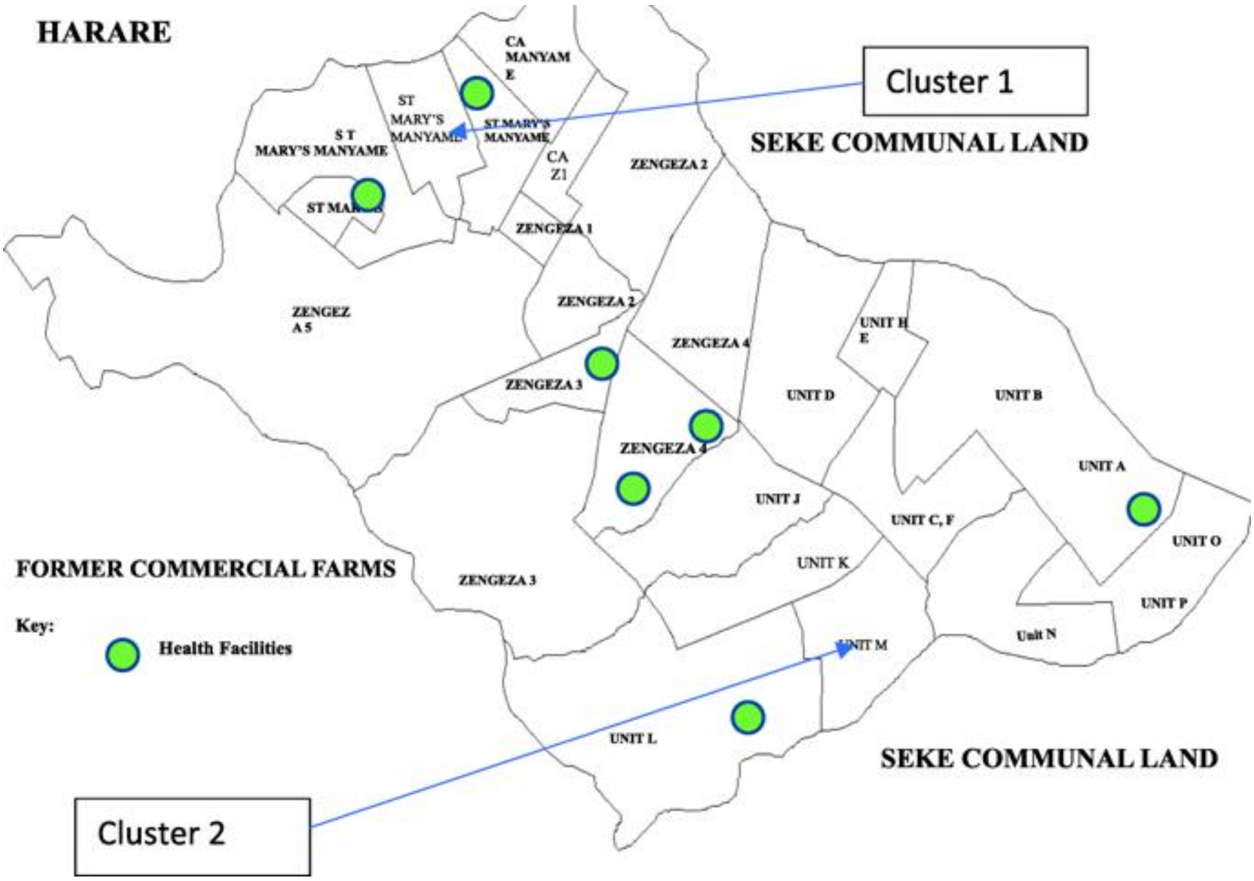
3.2 Description of the study area

Chitungwiza is situated in Zimbabwe Western Lowveld is situated at an average longitude of 20.6 and latitude of 31.9°C with an average altitude of 439 m above sea level according to (World Climate 2019, World Weather Online 2019). Mean annual rainfall ranges from 450 mm to 600 mm which normally occurs during summer period between October and April as supported by World Climate Home 2018.

Figure 7: showing the Map of Zimbabwe and the study area location

Source: Zimbabwe National Statistics (2016)

Figure 8: showing Chitungwiza 4 main districts and clinics



Source: Chitungwiza Clinic (2019)

The min temperature is of 18^{o}C in winter and mean maximum temperature is 37^{o}C in summer. Zimbabwe has a population of 16.5 million according to Zimbabwe National Statistics. The map above shows four districts of Chitungwiza namely Zengeza, Seke, St Marys, Seke North, and Seke South. Cluster 1 is the oldest settlement in Chitungwiza followed by Cluster 2 second oldest settlements were cholera outbreak is continuously occurring. The green dots shows the distribution of health facilities in the area.

3.3 Pretest survey of the data collection tools

Pre-test of the proposed study tools such as the open and closed questionnaire, sanitary inspection risk assessment was conducted at Harare City Council department of environmental health sciences through face to face interviews with Harare City Council health department. Primary reason why it was conducted was to improve comprehensibility, suitability, completeness and reliability of the data collection tools. This added more insight on the protocols to follow when collecting such data.

3.4 Research design

The study took the nature of mixed research approach, by engaging water quality sampling techniques with a quantitative nature. At the same time community discussion, open and closed questionnaires, observations with a qualitative nature.

3.4.1 Sampling techniques used.

In order to secure a representative sample a combination of sampling techniques were used these include:

Random sampling selection of the community participants was conducted because it saves time in St Marys Area, Seke South, and Seke North to get a representative sample size.

Group discussion to identify areas in the community were the toilets are not working well in particular septic tanks and public toilets

Face to face Interviews to state the problems in collection of water,

Interviews to know what can be done to solve the water crisis situation and cholera outbreak

Table 9: showing the distribution of the sample size in the community

Area; District	**Total population**	**Sample size obtained**	**Sampling technique**	**Data collection techniques**
St Marys	200 526	30	Random and Convenient	Group discussion, observations, interviews
Zengeza	16 000	30	Random and Convenient	Group discussion, observations, interviews
Seke North	11 000	20	Random and convenient	Group discussion, observations, interviews
Seke South	19 000	20	Random and convenient	Group discussion, observations, interviews
Total	246526	100		

Source: (Author 2019)

Table 10: showing the sample size

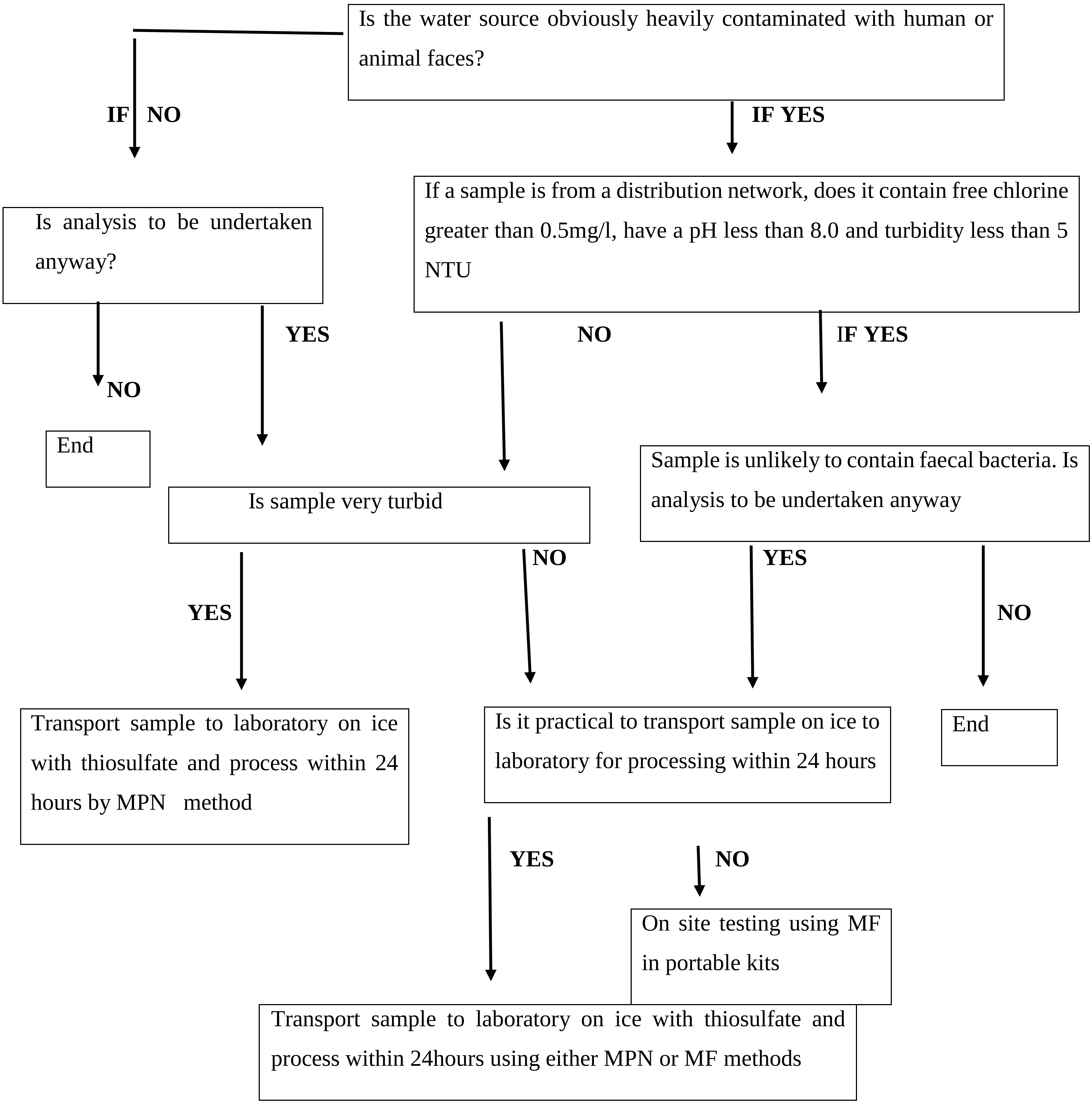
Area	**Sample size obtained**	**Sampling technique**	**Purpose**
Ministry of Health and Child Care	5	Judgmental sampling	1) To understand the challenges in water quality monitoring in Zimbabwe and the solutions there are working on.
Ministry of Water and Environment	5	Judgmental sampling	3)To understand the challenges of water supply and how they are working towards solving them
Chitungwiza Zengeza Clinic	5	Judgmental sampling	· To understand the challenges in water quality monitoring
Total	15		

Source: (Author 2019)

3.5 Water quality monitoring

Water quality analysis is necessary to detect whether contamination is occurring and the intensity. The following questions highlighted in the boxes guided the researcher in making a decision on water quality monitoring adopted from WHO.

Figure 9: showing the decision making network used by the researcher in water quality analysis



3.6 Before bringing forward the water samples to the laboratory. The research under the guidance of a microbiologist carried out a Checklist for effective analytical quality assurance that was observed, for selection of a laboratory to carry test water samples

Ensured that the laboratory had

- Qualified and experienced personnel with adequate experience in water quality testing recognized by the law to carry out water testing
- Enough space adequate for the water quality types and numbers of analyses to be carried out
- Equipment is adequate, regularly serviced and maintained, calibrated and used by authorized personnel.
- Materials bought from a reliable supplier, who carries out quality control
- Proper facilities for the receipt and storage of samples, and systems for coding and identifying them
- Data is archived, retrievable
- Methods are validated, documented and monitored are subjected to analytical quality control
- Safety is assured by adequate working and waste disposal procedures, proper maintenance of equipment.

3.7 Chemical water quality analysis

Water samples were collected using clean 500ml glass bottles, and transported to government laboratory in a cooler box, with ice within 3 hours of collection and analyzed using standard procedures recommended by WHO. Water parameters such as pH were sampled on the field using ph Meter, with the assistance of a microbiologist

Figure: 10 Showing PH Meter

Source: (Author 2019)

Table 11: Location of water points

District	Type of water source	Area, and justification	Rationale and status of the situation
ST MARYS	Public boreholes	Primary school borehole Community borehole Selected using judgmental sampling based on observation of the population served by the water source	Water source is used by the community from St Marys North, and South on daily basis because of erratic water supply and water demand deficiencies. Low frequency of water quality monitoring. Need to protect public health by early detection of water contamination and solve it
ZENGEZA	Public boreholes	Community public borehole Selected using judgmental sampling based on the population served by the water source,	Used by the community on daily basis from Zengeza 1, 2, and 3 because of erratic water supply. The water sources are heavily populated presenting unfavorable conditions, and posing public health hazard potential. With low frequency in water quality monitoring by the key authorities
SEKE NORTH	Public boreholes	Community Public boreholes Public boreholes Selected using random sampling based on the high population served by the water source	Used by the community on daily basis and heavily populated, making the water vulnerable to contamination. Need to protect public health and prevent occurrence of cholera. Insufficient frequent monitoring of the water sources
SEKE SOUTH	Public boreholes	High school borehole Primary school borehole Selected using judgmental sampling based upon the population served by the water source	Used by the community on daily basis because of unreliability of water supply, the area was once affected by cholera outbreak and there is need to reduce re-occurrence of the diseases. Lack of a systematic water monitoring of the sources

Source: Author (2019)

3.7.1 Total samples selected for boreholes

A total of 7 boreholes was selected from four districts of Chitungwiza namely Seke North, Seke South, St Marys, and Zengeza for bacteriological water quality analysis.

Total boreholes in the districts amount to 15 and 7 were selected as a representative of the water situation. Water quality parameters tested include:

3.7.2 Coding

The samples for boreholes were coded as A1, A2, for St Marys,

B1, B2, then Zengeza, C1, C2 followed by Seke North. D1, D2 for Seke South. For easy interpretation of results and analysis.

3.8 Hand Dug wells

Table 12: bacteriological sampling for hand dug wells

District	Type of water source	Area/ location	Rationale and status	Number #
St Marys	Hand dug shallow wells	St Mary's Community shallow wells.	The oldest settlements associated with chronic water shortages and heavily populated since it is a high density area for the low income earners and characterized by, informal settlement where hand dug wells are very prevalent, epicenter of cholera outbreak of 2018	3
Zengeza	Hand dug shallow wells	Zengeza community shallow wells used for drinking and domestic purposes	High population in Zengeza 1, 2 and hand dug wells more prevalent for drinking and cooking purposes. Because of shortage of water for drinking. Lack of clear guidelines to monitor the wells frequently.	4
Seke North	Hand dug shallow wells	Unit N, Unit O, Unit P Community shallow wells	Highly populated area with the second highest cases of cholera outbreak reported in 2018. High dependency upon	3

			hand dug wells for drinking water purposes.	
Seke South	Hand dug shallow wells	Unit L, Unit M, community shallow wells	It was observed that the area is mainly composed of hand dug shallow wells because most of the settlements are informal and not connected to the water distribution network and there is no proper water quality monitoring policy in place to guide well monitoring.	3

Source ; (Author 2019)

Total number of samples for hand dug wells are 13 samples tested for bacteriological analysis for suitability of drinking purposes and presence of the fecal coliform indicator.

3.8.1 Coding of the hand dug wells –

St Marys hand dug wells coded as W1 - W10 then for Zengeza coded as V1 - V8 then for Seke North T1-T10, then Seke South K1-K10. Was used to make it easy for data analysis and interpretation.

3.9 Sanitary risk inspections was carried out to compliment water quality analysis

- Sanitary risk inspection is a fact finding exercise that was undertaken to identify system deficiencies not only sources of actual contamination but also inadequacies and lack of integrity in the system that could lead to contamination. Sanitary inspection – identifies potential hazard and analysis, whilst indicates whether contamination is occurring or not, and its intensity.

3.9.1 Procedure

A sanitary risk survey inspection was carried out for the mapping of potential sources of contamination from 13 hand dug wells, 7 public boreholes. The process included physical inspection of the sources accompanied by inspection of the immediate environment and recording the status (No or Yes) the 8 commonly identified risk conditions.

3.9.2 Specific functions of the sanitary inspections report was to

- Identify potential sources and points of contamination of water supply
- Provide a clear, graphical means of explaining the hazards to the community.
- Provide clear guidance as the remedial action required to protect and improve water supply.

Table 12: Potential risk factors for water quality

Source of water supply	Potential risk factors
Public boreholes	Unsanitary conditions/ accompanied by deteriorated seal of borehole pump
	Less distance from the pit latrine With a high possible of percolating into the soil/ sewer
	environmental pollution such as garbage dumping, within 10 m radius
Hand dug wells	Rope or bucket not properly cleaned
	Latrine or septic tank close by 10 m within the well
	No top covering of the well
	Close by sources of contamination such as wastewater discharge

Source (Author)

3.9.3 Document review was carried out

The researcher was guided by WHO indicators which include quality, quantity, coverage, cost and continuity that are used to evaluate community water supplies and carried out a documents review to review community water supply status.

Service Level benchmark report which shows the efficiency and effectiveness of water supply system, wastewater management and solid waste management.

3.9.4 Survey on the status of sanitation infrastructure in Chitungwiza

Physical survey was carried out by the researcher identifying 28 public toilets and their status either functional or dysfunctional which are located in market places, and bus stop terminus.

3.9.5 Limitations

1. The government laboratory took 2 weeks to return the results of the water samples which delayed the analysis of results
2. The researcher was not allowed to take tap water samples by Chitungwiza Municipality since they have a policy which does not allow external researchers to take tape water samples only authorized government laboratory officials are mandated to take water samples which then limited the scope of the research.

3.9.6 Conclusion

This chapter clearly outlines the procedures taken to collect primary data and secondary data. This ranged from the decision making framework that guided the research selection of water sources and sampling techniques. The data collection tools were meant to collect qualitative and quantitative data. The methodology provided a holistic approach to water surveillance system by focusing on key indicators such as quality, quantity, cost and their relation to vulnerability of the community to cholera outbreak. Surveys and sanitary risk assessment complimented water quality monitoring, to find more the problem on a policy perspective.

CHAPTER 4: RESULTS AND DISCUSSION

4.0 Introduction

In this Chapter, statistical analysis of data was carried out, mostly data was presented pie charts, graphs, tables and photos taken on the ground by the researcher.

4.1 Results for the borehole water sampling.

Below is an overview of the chemical water quality results of the boreholes in Chitungwiza.

Table 13: Descriptive statistics for the four districts of Chitungwiza

Water parameters	Maximum	Minimum	Mean	Standard Deviation	WHO Guideline Value
PH	7.44	5.49	6.54	0.65	6.5 – 8.5
Color	0	0	0	0	15
Turbidity	105	0.01	11	25.45	5
Chloride	29.6	0.42	18.6	7.35	600
Sodium	120.08	100	29.6	8.793	200
Nitrate	96.52	24.25	39.11	28.18	50
Total hardness	211.1	200.1	205.26	4.95	500
Sulphate	580	3.17	50.6	2.079	250
zinc	0.2	0.1	0.18	0.04	3.0
Iron	0.3	0.1	0.13	0.08	0.3

Source: (Author 2019)

4.1.1 PH

According to WHO (2015) the pH of a solution refers to the negative logarithm of hydrogen ion (H+) concentration in moles per liter. It determines the acidity or alkalinity of water. It is a parameter of paramount importance for different water uses. WHO recommends the pH values to be between 6.5 and 8.5. In the study area pH level of water ranges from 5.49 to 8.3 and has an average value of 6.54. This shows that the groundwater in the study area is not within recommended range of WHO standards, and is slightly acidic. This can be because acid water can be naturally occurring, or caused by a high level of dissolved oxygen. Acidic waters are typically low in buffering calcium minerals, but are high in dissolved carbon dioxide, which can cause the low pH or acidity

4.1.2 Color

The study areas showed that color was in line with WHO standards throughout the district and poses no health risk to the community.

4.1.3 Turbidity

Turbidity refers to how clear a liquid is. High turbidity means that the liquid is not very clear, implies low water quality, low turbidity means that the liquid is clearer. Turbidity is caused by solid particles being suspended in a liquid. According to WHO (2015) Turbidity it could cause disinfection problems with the wastewater treatment methods. Suspended materials that are not adequately filtered out may become health risks to humans. Excess turbidity can cause heavy metals to be added to the water supply. Permissible limits for turbidity by WHO is 5 NTU and 25 NTU respectively. Undesirable levels were observed in the four Districts of Chitungwiza. The maximum turbidity level was 105 NTU and the average turbidity level in the study area was 11 NTU. This slight turbidity indicates that there may be the presence of inorganic particulate matter and non-soluble metal oxides. The consumption of high turbid water may cause a health risk, as excessive turbidity can protect pathogenic microorganisms from effects of disinfectants.

4.1.4 Chloride

Chloride is a vital water quality assessment parameter. High levels of chloride suggest higher levels of organic pollution. This limits the use of such water for domestic, agricultural and industrial use. The recommended concentration for chloride is 200 mg/L according to WHO. In the study area, the chloride concentration varies from 0.42 mg/L to 26.9 mg/L with an average value of 18.6 mg/L. The water sample values hence are all within the recommended limits.

4.1.5 Sodium

Sodium is the most readily available element that occurs naturally especially in weathered rocks. It is also available in the ground due to effluent discharge into the ground from sewages and industries. WHO, the recommended level of sodium in groundwater is 200 mg/L. In the study area, the sodium concentration varies from 120mg/L to 100 mg/L with an average value of 29.6 mg/L. The water sample values hence are all within the recommended limits. According to WHO (2015) sodium salts are not actually poisonous to humans.

4.1.6 Nitrate

Groundwater contains nitrate due to leaching of nitrate with the percolating water. Groundwater can also be contaminated by sewage and other wastes rich in nitrates (Sirajudeen and Mubashir 2015). Nitrate commonly occurs naturally in groundwater, but high concentration might be

Associated with animal and human waste, open septic or sewage systems and fertilization of farms (Akaahan et al. 2016). The maximum concentrate is 96.52 which exceeds the recommended WHO requirements followed by 24.25 the minimum and the average being 39.11. Excessive NO3

In drinking water can cause a number of disorders including methemoglobinemia in

Infants or pregnant women, gastric cancer, goiter, birth malformations and hypertension (Majumdar and Gupta 2015). Higher nitrate content is mainly due to over application of fertilizers, inadequate manure management practices, sewage effluent, septic tanks, kraals or open dump sites.

4.1.7 Total hardness

Water hardness results from accumulation of calcium, magnesium, and other minerals as it moves through the earth. WHO 500 mg/L as desirable levels. Total hardness less than 80 mg/L may lead to corrosive water, while hardness above 100 mg/L may result in the need for more soap during bathing and laundering. Excessive hardness may also lead to scale deposits in pipes, heaters and boilers. In the study area, the values are a maximum of 211.01 to 200.01 minimum and a mean of 205.01. Water can be classified into soft (75 mg/L), moderately hard (75–150 mg/L), hard (150–300 mg/L) and very hard (300 mg/L) based on hardness (Sawyer and McCarty 2015). This implies that the water in Chitungwiza region is hard basing with those ranges. Long-term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, prenatal

Mortality, some types of cancer and cardiovascular disorders (Agrawal and Jagetia 2015).

4.1.8 Sulphate

Sulfate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge of industrial wastes and domestic sewage tends to increase its concentration (WHO 2015). Sulphate varied between 580-3.17 and average being 50.6. High sulphate can be explained by the observation of high application of inorganic fertilizers close by the community gardens.

4.1.9 Iron and Zinc

In this study Iron and Zinc concentrations were in line with WHO Standards and guidelines.

Zinc is an essential nutrient for body growth and development, however drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. Water with a zinc concentration of more than 5 mg/L may start to be become chalky in appearance with a detectable deterioration in taste.

4.2 BOREHOLE WATER SUITABLE FOR HUMAN CONSUMPTION

Table 15: physio-chemical water quality results for Seke South (D1)

Parameter	**Unit**	**Guidelines Value WHO (2008)**	**+5% error**	**Actual Results**
pH	T.C.U	6.5 – 8.5	6.175-9.975	6.65
Color	HU	15	0.75	0
Turbidity	N.T.U	5	0.25	0.01
Chloride	Mg/L	600	12.5	21.99
Sodium	Mg/L	200	10	100
Nitrate	Mg/L	50	2.5	27.78
Total hardness	Mg/L	500	25	206.10
Sulphate	Mg/L	250	12.5	3.17
zinc	Mg/L	3.0	0.15	0.2
Iron	mg/L	0.3	0.015	0.3

Source: (Government analyst report 2019)

With respect to the government analyst report the parameters found in borehole (D1) was in line with WHO guidelines and deemed safe for human consumption. It was also observed and reported by the community that people pay to get water, the funds have been utilized to keep the borehole clean and control water collection, to safeguard water quality. However the community welcomed the initiative of water quality testing by the researcher and collaborated.

Table 16: physio-chemical water quality results for Seke South (D2)

Parameter	Unit	Guidelines Value WHO (2008)	+5% error	Actual Results
PH	T.C.U	6.5 – 8.5	6.175-9.975	7.44
Color	HU	15	0.75	0
Turbidity	N.T.U	5	0.25	2.23
Chloride	Mg/L	600	12.5	28.99
Sodium	Mg/L	200	10	101.01
Nitrate	Mg/L	50	2.5	27.78
Total hardness	Mg/L	500	25	200.10
Sulphate	Mg/L	250	12.5	7.17
zinc	Mg/L	3.0	0.15	0.2
Iron	mg/L	0.3	0.015	0.1

Source: (Government analyst report 2019)

According to the results delivered by the government analyst the parameters of Seke South (D2) were deemed safe for human consumption with all the parameters falling in the range recommended by WHO standards. It was observed that there was a political committee responsible for controlling water collection, to avoid and manage conflicts and in return the community pay a fee monthly for water collection.

Table 17: physio-chemical water quality results for Seke North (C1)

Parameter	Unit	Guidelines Value WHO (2008)	+5% error	Actual Results
PH	T.C.U	6.5 – 8.5	6.175-9.975	6.18
Color	HU	15	0.75	0
Turbidity	N.T.U	5	0.25	0.23
Chloride	Mg/L	600	12.5	58.98
Sodium	Mg/L	200	10	120.08
Nitrate	Mg/L	50	2.5	24.25

Total hardness	Mg/L	500	25	202.10
Sulphate	Mg/L	250	12.5	8.00
zinc	Mg/L	3.0	0.15	0.2
Iron	mg/L	0.3	0.015	0.1

Source: (Government analyst report 2019)

According to the Government analyst the borehole water was safe for human consumption. The borehole is controlled by a faith based organization responsible for controlling water collection and upkeep of the water source. This has managed to safeguard water quality against unsanitary water collection practices.

Table 18: physio-chemical analysis water quality results for Seke North (C2)

Parameter	Unit	Guidelines Value WHO (2008)	+5% error	Actual Results
PH	T.C.U	6.5 – 8.5	6.175-9.975	6.79
Color	HU	15	0.75	-
Turbidity	N.T.U	5	0.25	0.15
Chloride	Mg/L	600	12.5	21.99
Sodium	Mg/L	200	10	115.02
Nitrate	Mg/L	50	2.5	29.78
Total hardness	Mg/L	500	25	201.10
Sulphate	Mg/L	250	12.5	9.00
zinc	Mg/L	3.0	0.15	0.1
Iron	mg/L	0.3	0.015	0.1

Source: (Author 2019)

According to the government analyst borehole water was deemed safe for human consumption. However it was observed that the borehole is not controlled as other boreholes and this has caused conflicts and conflicts in water collection. In that same line unsanitary water collection practices are evident. The Environmental health department in Chitungwiza was notified to set up a committee to control that water source.

4.3 Boreholes water found not suitable for human consumption

Boreholes in Zengeza District

Table 19: physio-chemical results of borehole water for Zengeza (B1)

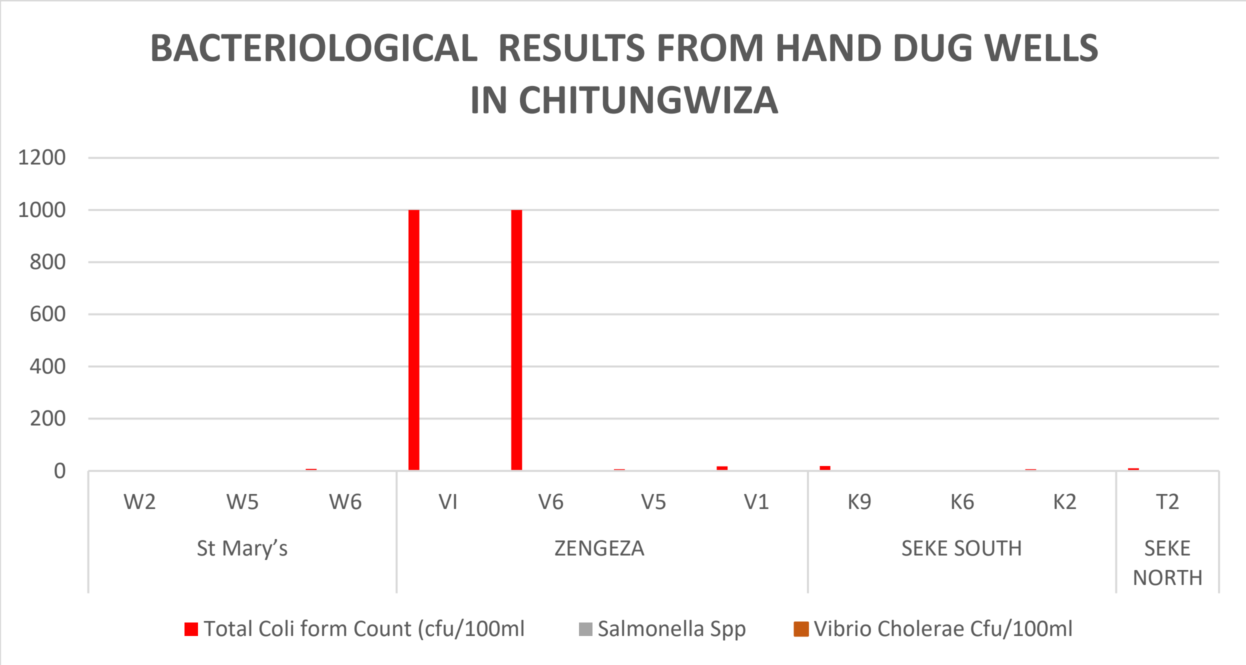
Parameter	Unit	Guidelines Value WHO (2008)	+5% error	Actual Results
PH	T.C.U	6.5 – 8.5	6.175-9.975	5.7
Color	HU	15	0.75	-
Turbidity	N.T.U	5	0.25	0.02
Chloride	Mg/L	600	12.5	72.98
Sodium	Mg/L	200	10	-
Nitrate	Mg/L	50	2.5	96.52
Total hardness	Mg/L	500	25	202.10
Sulphate	Mg/L	250	12.5	8.00
zinc	Mg/L	3.0	0.15	0.2
Iron	mg/L	0.3	0.015	0.1

Source: (Government analyst 2019)

According to government analyst results Zengeza borehole water is not safe for human consumption. This is because water parameters such as ph was below the recommended range of WHO. Meaning that the water was slightly acidic and high nitrates level because of application of fertilizer as the borehole is near a vegetable community garden. The government analyst recommended treatment of water before use, and rehabilitation of the borehole. According to the community the Council had a committee responsible for running of the borehole but was heavily politicized and led to improper maintenance of the borehole.

4.3 Bacteriological analysis of hand dug shallow wells

Figure 11: Bacteriological results



Source (Author 2019)

According to the government analyst results the most of the hand dug wells in Chitungwiza District were safe for human consumption, as they were in line with WHO guidelines. Namely St Marys, Seke South and Seke North. However Zengeza had two shallow wells that were contaminated and showed high presence of fecal coliform, vibrio cholera, causing high vulnerability to cholera outbreak. Firstly the owners of the well were informed before informing Chitungwiza Health department. The two wells were forced to close despite them having a high yield. The community was advised to dig a new well, at the same time find new water sources.

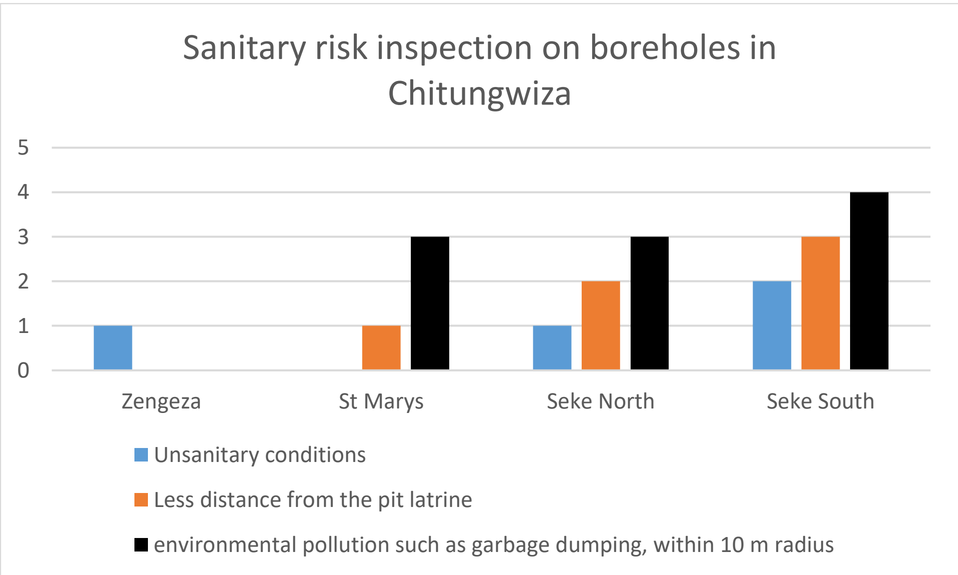
Below is a photo of the well that was contaminated, the rope was not properly cleaned and the bucket. The well was not controlled and a huge number of people including water vendors who came and fetch the water, lack of monitoring of the water source exposed it to fecal contamination. According to Jenkins (2015) unsanitary behavior such as not washing the hands after using the toilets then using the rope to fetch water could potential pollute the water

Figure 12: Hand dug well sanitary condition in Zengeza

Source: (Author 2019)

4.4 Sanitary risk inspection on boreholes

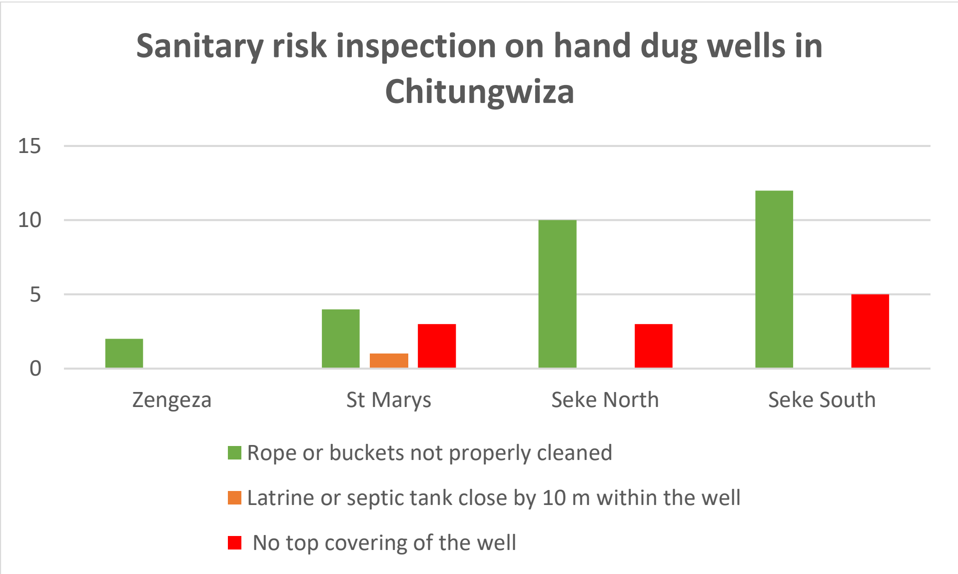
Figure 13: Sanitary risk inspection on boreholes



Source (Author 2019)

Despite Zengeza having two shallow wells heavily contaminated with fecal coliforms when it comes to borehole sanitation it was better with one borehole having poor sanitary conditions. As compared to Seke South having the highest unsanitary conditions on boreholes, followed by Seke North and St Marys. This is a clear indication of insufficient public health education on the community to be aware of the benefits, health implications and dangers of sanitary behavior around the boreholes. This poses a high risk of cholera especially in Seke South and North. There is urgent need to ensure there is a clean environment around the boreholes.

Figure 14: Sanitary hand dug well risk assessment result

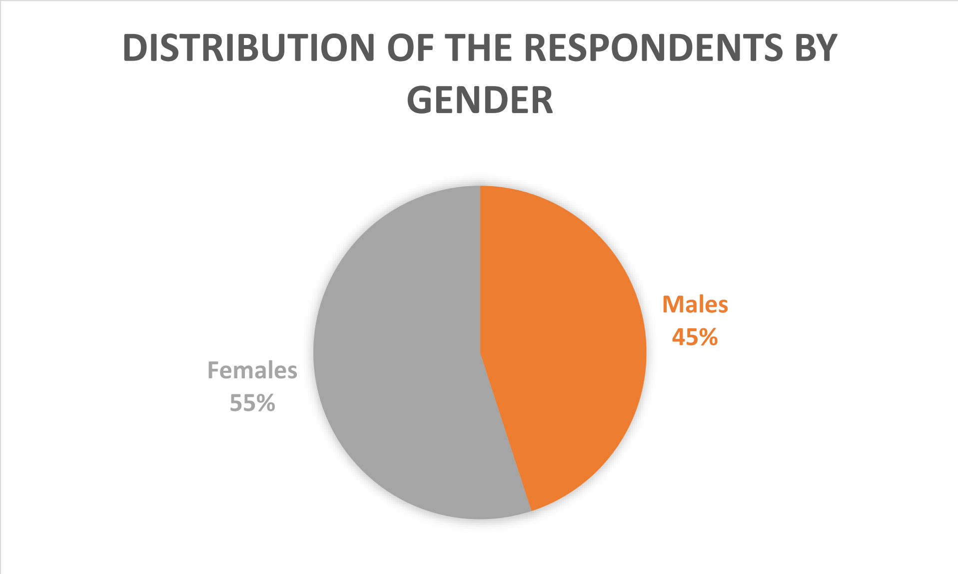


Source: (Author 2019)

Through a survey on sanitary risk the researcher noted that Seke South and North districts were at high risk of cholera outbreak. With a high number of no top covering of their hand dug wells which are classified as unsafe water sources, with the rope used to fetch water not clean. His is because of a high number of people fetching the water who are not controlled. Lack of public health education is also another factor. There is need for urgent addressing of the situation before another cholera outbreak occurs again, the recommendation were passed to Chitungwiza Municipality.

4.5 Challenges facing the community in water accessibility

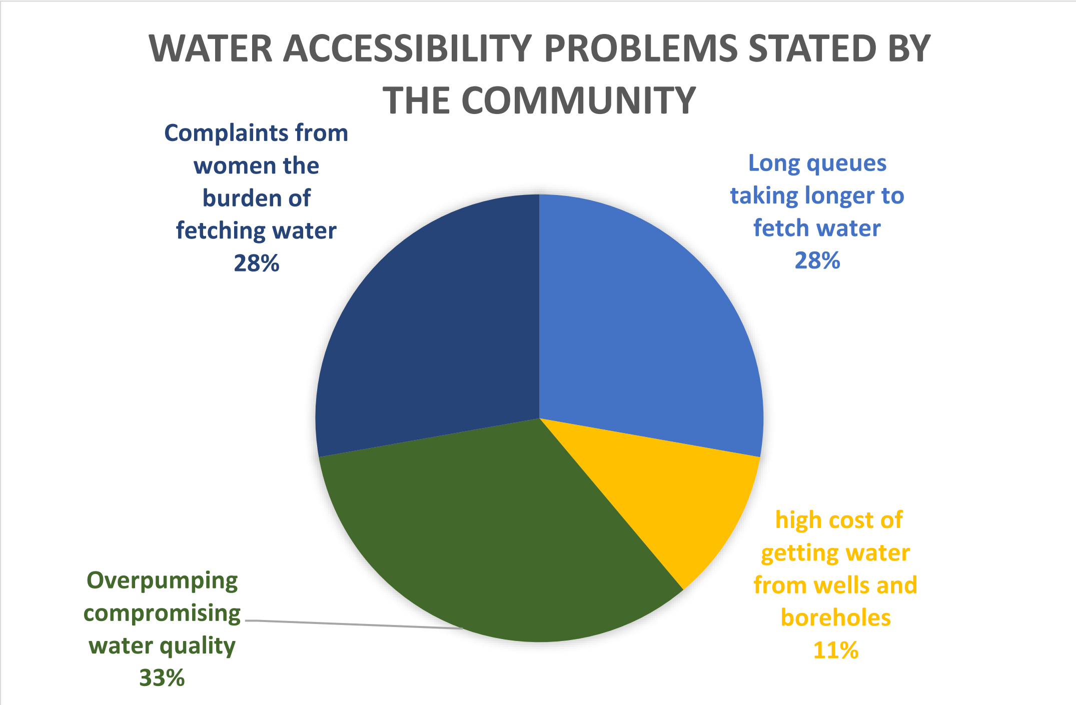
Figure 15: Distribution of respondents by gender from Chitungwiza



Source: (Author 2019)

The survey noted that 55% of the respondents were women this reason being that women have the primary role of collecting of water in Chitungwiza, as compared to men, constituting to 45%. The majority of the male respondents were water vendors that are directly involved in water collection. The water challenges in Chitungwiza has laid a burden on women as they have to walk carrying the buckets on top of their heads. Unlike their male counterparts who can use a wheelbarrow to carry water. The men and women were selecting randomly and included the vulnerable groups in the society such as the disabled, and old people. It was observed these group of people have special needs when it comes to water and the Council is doing nothing to address this challenge, as there cannot walk long distances to fetch water as the water is not available on the taps.

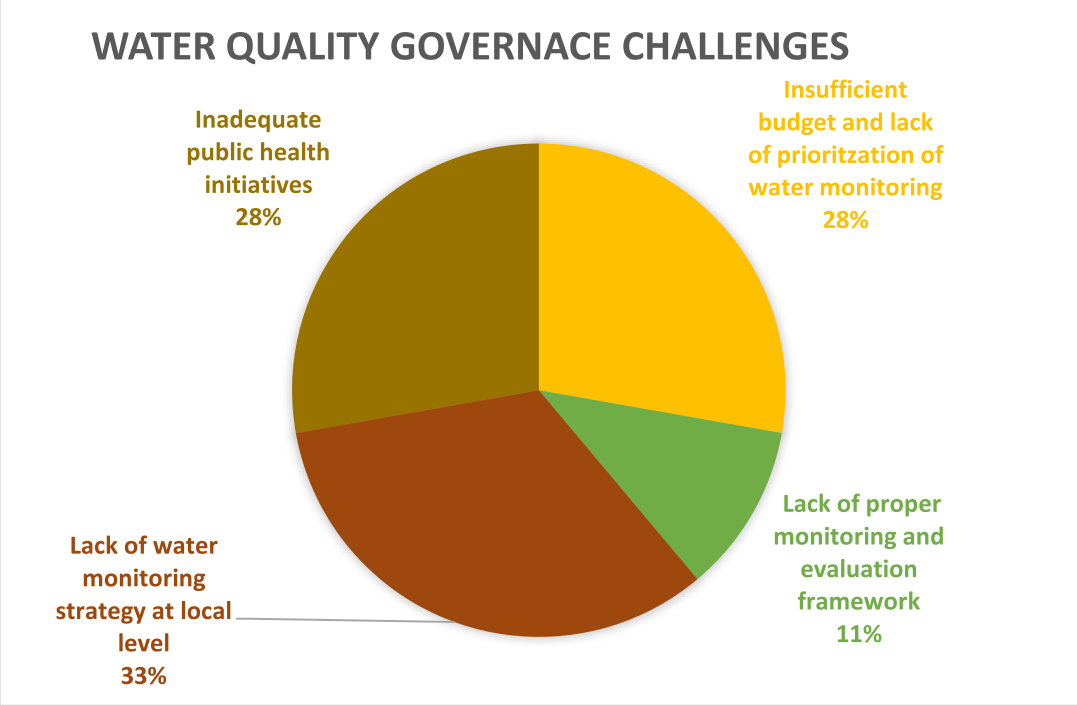
Figure 16: COMMUNITY WATER ACCESSIBILITY PROBLEMS



Source (Author 2019)

The results from the interviews showed that 33% of the community from four districts of Chitungwiza agreed that over pumping of the water from the wells and boreholes was compromising water quality. The residents expressed concern over lack of water and high water demand, stating failure of the local authority to perform its duties. According to Sorensen et al. (2015) over pumping of bore wells and wells has often resulted in lowering of the water table and low yields of water. 28 % of the respondents expressed complaints on the burden of women walking long distances to collect water and take care of the family at the same time. Water shortages have caused this problem. 28% complained about waiting in the queues for long hours to collect water stating that it is killing their productive time. According to literature in Chapter 2 waiting for long hours in queues in fetching water is an indication of low yields of the water source or overcrowding. 11% stated the problem of high cost which is charged by water vendors in selling water, 20 liter one bucket of water costs 1 USD. The water vendors are now taking advantage of the water crisis and charging exhibited prizes.

4.6 Figure 17: Water quality governance challenges



Source (Author 2019)

In order to understand water quality governance challenges the researcher conducted interview with the responsible institutions responsible for water quality in Zimbabwe. 33% of the respondents stated lack of monitoring strategy at local level as the main challenge in water quality governance. The absence of water quality monitoring strategy is an indication that there is no plan to safeguard water sources and are reactive when it comes to cholera outbreak. This comes from a background that there is no regulation that controls digging of shallow wells in Chitungwiza, this has led to many people digging shallow wells and drinking water which is not monitored. 28% respondents stated insufficient budget and lack of prioritization of water monitoring, stated examples of dilapidated sanitation infrastructure, monopolizing of waste water treatment by the government. 28% stated that inadequate public health initiatives as the root problem in water quality governance, this include public health awareness strategic plan at local and national level. This has caused a back log in public health awareness in Zimbabwe as evidenced by unsanitary practices.

4.7 Table 20: Status of public toilets in Chitungwiza districts

Area (Zengeza District)	**Status Quo**
• Behind Telone (Old bus stop) –Zengeza 2	Not Functional
• Zengeza 2 public toilet	Not functional
• Zengeza 2 market public toilet	Partially functional
• Zengeza 2 Mbizi public toilet	Not functional
• Zengeza 3 public toilet	Partially functional
• Zengeza 4 pagomba public toilet	Not functional
• Zengeza 4 terminus public toilet	Not functional
• Zengeza 5 main shops	Not functional
• Zengeza 5 cornershops	Not functional

Source: (Author 2019)

Table 21: Status of public toilets in Seke South District

Area (Seke South District)	**Status Quo**
• Unit L Shops public toilet	Functional
• Unit M public toilet	Not functional
• Unit M Jambanja public toilet	Partially functional
• Unit D shops public toilet	Not functional
• Unit K public toilet Chirunga	Not functional
• Unit J public toilet	Partially functional
• Unit K Luciano public toilet	Not functional

Source: (Author 2019)

Table 22: **Status of public toilets in Seke North District**

Area (Seke North District)	**Status Quo**
• Unit A Shops public toilet	Not Functional
• Unit P public toilet	Partially used
• Chidochevanhu public toilet unit N	Not functional
• Unit G hostels public toilet	Not functional/ collapsed structures
• Unit H public toilet	Not functional (used as gym ad carpentry)
• Unit O public toilet	Not functional

• Unit F shops public toilet	Functional
• Makoni Terminus pay toilet	Partially functional
• Makoni market public toilet	Partially

Source: (Author 2019)

Table 23**:** Status of public toilets in St MARYS

Area (ST Marys District)	**Status Quo**
6.0 Huruyadzo public toilet NEAR OK shop	Not Functional
7.0 Huruyadzo public toilet market place	Not Functional
8.0 Chigovanyika public toilet	Not functional
9.0 Mangoromera public toilet near Black Beauty Saloon	Not functional/ collapsed structures
10.0 Katanga corner shops public toilet	Not functional (used as gym ad ca

Source: (Author 2019)

The results of the status of public toilets sanitation infrastructure in Chitungwiza showed that Zengeza has a total of 9 public toilets mostly located in market places and bus terminus. 7 of the public toilets are not functional and 2 of the public toilets are partially functional. The public toilets not functioning showed presence of open defecation especially near the market place and public beerhalls. The partially functional toilets there was no hand washing facilities available and no water facilities. This poses a health hazard to the community especially in the market place where vegetables and meat are sold the authority were notified of this health hazard.

Seke South has a total of 7 public toilets. Having 4 public toilets not functional, 2 functional and 1 functional public toilet. One functional public toilet is has no water facilities for hand washing and not properly clean. This poses a serious health risk to the community.

Seke North has a total of 9 public toilets. Having 5 dysfunctional public toilets and 3 are partially functioning and 1 functional. Seke South has a busy market place and it having only one public toilet is a health hazard risk. In connection with cholera outbreak.

St Marys which is the oldest settlement in Chitungwiza has only 5 public toilets which are in turn not functioning. This show lack of prioritization of the sanitation infrastructure in Chitungwiza and this calls for urgent rehabilitation or construction of public toilets services. There are serious presence of open defecation near the dura-walls of schools as a result of lack of public toilets.

4.8 Document review was carried out to assess water quality indicators.

Table 24: Coverage of water supply in Chitungwiza

	Response
1) Coverage of water supply	74.1%
2) Properties supplied through public standpipes or tankers	205
3) Properties completely dependent on boreholes	14 979
4) Properties completely dependent on open wells	14 000

Source: (Chitungwiza Municipality monthly reports 2019)

According to Service Level benchmark report for Chitungwiza, water supply coverage is 74.1% meaning to say 26% of the population have no water supply coverage. This is clearly shown by 14 979 people relying on boreholes and 14 000 people relying on open wells. 205 relying upon standpipes or tankers. Low water supply coverage is a clear indication of insufficient water reticulation projects in the study. Water quality monitoring strategy is therefore crucial as indicated by a high number depending on open wells and boreholes in order to be alert of the water quality changes and protect public health.

4.9 Per capita supply of water

Total water supplied to consumers expressed by population served per day.

Table 25: per capita supply of water

	Response
• Population receiving water at a rate less than 50 L/cap.day	68.9%

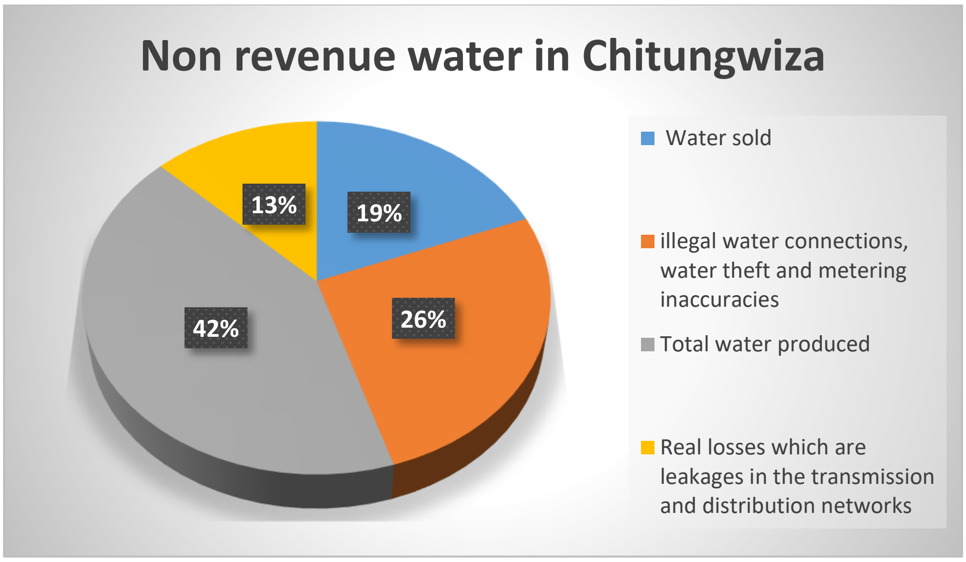
Source: (Chitungwiza Municipality monthly report 2019)

Population receiving water at a rate less than 5 l/cap.day is 68.9% which is an indication of water shortage in the District. The Council imposed water rationing were the community receive water for 2 days in a week for a maximum of 6 hours. According to the literature above a person is supposed to have at least access to 2 liters a day, this is a different case in Chitungwiza as people ought to save water, because the more one consume the water, the more one is forced to buy more water on daily basis as a result of scarcity of water supply.

5.0 Extent of non-revenue water (NRW)

Definition: This indicator highlights the extent of water produced which does not earn the council any revenue. This is computed as the difference between the total water produced (ex-treatment plant) and the total water sold expressed as a percentage of the total water produced. NRW comprises: a) Consumption which is authorized but not billed, such as public stand posts; b) Apparent losses such as illegal water connections, water theft and metering inaccuracies; and c) Real losses which are leakages in the transmission and distribution networks.

Figure 18: Non-revenue water



Source (Author 2019)

Non-revenue in Chitungwiza is high an indicator why the community has failed to get access to water. As s indicated by the diagram below

Table 26: Analysis of non-revenue water

	Analysis	Response
• Total water produced and put into the transmission and distribution system	This is the amount of water produced or bought by the council and supplied to consumers. Daily quantities are measured through metering, and records on the transmission and distribution system are maintained. The total supply for the month are based on the aggregate of the daily quantum. Only treated water input into the distribution system should are measured. Water distributed from multiple points, the aggregate of that quantity should be considered. This quantum should include water purchased directly from any other sources and put into the distribution system.	793 329
	Apparent losses such as illegal water connections, water theft and metering inaccuracies	371 873
	Real losses which are leakages in the transmission and distribution networks	122 966
	Total water sold	299 162
	Non-Revenue Water	62.3%

Source: (Author 2019)

There is a high difference between water produced and apparent losses amounting to 421 456 and 62.3% that is very high indication of loss of water revenue by the Council to sustain its operations and continuous. This is also an indication of lack of proper monitoring of the water supply system by the council which has created inequalities in terms of water supply situation. Forcing people to look for alternative sources of drinking water, improper sanitation methods.

5.2 Quality of water supplied

The percentage of water samples that meet or exceed the specified potable water standards, as defined by the WHO guidelines. The sampling procedures should meet standards laid down.

Table 26: Quality of water supplied

	Analysis	Response
• Total number of water samples taken in a month	The actual number of water samples that are taken for testing in the month. Samples should be drawn at both points—outlet of the treatment plant and at the consumer end. The sampling procedures were meet according to laid down standards and norms.	58
• Number of samples that meet the specified potable water standards in the month	Of the total number of samples drawn in the month, the number of samples that have met or exceeded the specified potable water standards	50
• % of water quality which meets WHO guidelines supplied		85.6%

Source: (Author 2019)

According to Chitungwiza Municipality department of Water monthly reports a total of 58 samples were taken from tap water which are far away from the water treatment stations such as residential areas in Seke area. With the perspective that residual chlorine decreases with the distance and households were chosen randomly. Water quality monitoring showed efforts by the Council to protect public health. But the limitation of the samples were pinned upon inadequate financial resources to fully carry out water quality monitoring.

Table 27: Residual chlorine analysis

	Water quality analysis frequency	Response
1.	Residual Chlorine - No. of Samples taken at the outlet of WTP (in a year)	0
2.	Residual Chlorine - No. of Samples taken at intermediate points (in a year)	28
3.	Residual Chlorine - No. of Samples taken at consumer end (in a year)	270
4.	Total Samples taken for Residual Chlorine tests	298
5.	Number of samples passed	270

Source: (Chitungwiza monthly reports 2019)

Discussion

Residual chlorine analysis is very important in verifying the quality of water supplied to the consumers. Inadequate water quality sampling is cited by the researcher as being the main challenge in the water surveillance system. Where about 42 756 households are connected to the water supply source and only 270 samples taken within a year. The water samples taken are not representative of the total population. It was noted that zero samples were taken at the outlet of the water treatment plant and about 28 samples did not pass which is an indication that the water was distributed with low free residual chlorine, exposing people to unsafe drinking water, which people will store in storage containers.

Table 28: Physio-chemical analysis

	Water quality analysis frequency	response
1.	Physical/Chemical - No. of Samples taken at the outlet of WTP (in a year)	0
2.	Physical/Chemical - No. of Samples taken at intermediate points (in a year)	28
3.	Physical/Chemical -No. of Samples taken at consumer end (in a year)	270
4.	Total Samples taken for Physical and Chemical tests	298
5.	Number of samples passed	250

Source: (Chitungwiza monthly report 2019)

Discussion

Chitungwiza tend to be restricted to basic tests such as testing for residual chlorine, pH and turbidity because of lack of equipment. Few tests were done at intermediate points whilst there is no standard regime for tests at consumer end. Councils therefore need to come up with an appropriate sampling, testing and quality control protocol in order to improve the protection of their water consumers. Councils should also send their samples for independent verification

Table 29: Bacteriological water quality results

	Water quality analysis frequency	response
1.	Bacteriological - No. of Samples taken at the outlet of WTP (in a year)	0
2.	Bacteriological - No. of Samples taken at intermediate points (in a year)	3
3.	Bacteriological - No. of Samples taken at consumer end (in a year)	96
4.	Total Samples taken for Bacteriological tests	99
5.	Number of samples passed	55

Source: (Chitungwiza monthly report 2019)

Discussion

According to the survey a total of 99 samples were taken for testing and only 55 passed. This is an indication that tap water is not suitable for human consumption and the Council should educate the community and promote household water treatment.

Table 30: Total number of all tests

	Water quality analysis frequency	response
1.	Total Number of Samples taken for all types of tests	695
2.	Total Tests Passed	595

Source: (Chitungwiza Municipality monthly report 2019)

The results show that they is no number of samples taken at the outlet of water treatment plant and the difference of 100 samples which did not pass the test showed that the water quality situation is compromised. This can be attributed to cross contamination, bursts of pipes and old dilapidated infrastructure. This is an indication that the surveillance system of Chitungwiza is weak, which is supposed to contribute to the protection of public health by promoting the improvement of water supply.

Efficiency in satisfactory response/reaction to customer complaints

Definition: The total number of water supply-related complaints redressed within 24 hours of receipt of complaint, as a percentage of the total number of water supply-related complaints received in the given time period.

Table 31: Efficiency in response to customer complaints

		response
Total number of water supply-related complaints received per month	The total number of all supply-related complaints from consumers received during the month. Systems for receiving and logging in complaints should be effective and easily accessible to the citizens. Points of customer contact will include common phone numbers, written complaints at local council offices, collection centers, drop boxes, online complaints on the website, etc.	223
Total number of complaints redressed inside 24 hours within the month	The total number of water supply-related complaints that are satisfactorily redressed within 24 hours or the next working day, within that particular month. Satisfactory resolution of the complaint should be endorsed by the person making the complaint in writing, as a part of any format that is used to track complaints.	135
Efficiency in addressing complaints		60.5%

Source: (Chitungwiza Municipality monthly report 2019)

The efficiency in addressing complaints is very low at 60.5% which has exposed the community to diseases as a result of sewer bursts which are caused by population pressure against the dilapidated infrastructure. Council has to respond rapidly to sewer bursts promptly in order to reduce the vulnerability of the community to cholera outbreak.

Figure 18: Exposure of the community to sewer bursts in Chitungwiza

Source: (Author 2019)

The above photo shows sewer bursts and this is a clear indication of population pressure on the services and the slow response of the Council has caused diseases and exposure to cholera to be high.

Cost recovery in water supply services

Definition: The total operating revenues expressed as a percentage of the total operating expenses incurred in the corresponding time period. Only income and expenditure of the revenue account must be considered, and income and expenditure from the capital account should be excluded.

Table 32: cost recovery

		response
Total annual operating expenses	Should include all operating expenses (for the year) such as electricity, chemicals, staff, outsourced operations/staff related to water supply, bulk water purchase costs and other operations and maintenance (O&M) expenses. Should exclude interest payments, principal repayments and other capital expenses.	USD 3.454,972.43
Total annual operating revenues	Should include all water supply-related revenues (billed) during the corresponding time period, including taxes/surcharges, user charges, connection charges, sale of bulk water, etc. This should exclude capital income such as grants, loans, etc.	USD 5.129.478.59
Cost recovery		%148.5

Source: (Chitungwiza Monthly report 2019)

Chitungwiza Municipality uses flat charging fee and basing with the revenue collection mechanism the Council has been able to raise sufficient funds to recover operating costs. The residential fees are flat to allow the vulnerable groups to get access to water, they is need for water infrastructure expansion to respond to growing population demands and water shortages. This would allow the Council to set up its own water treatment plant other than buying water from Harare City Council.

CONCLUSION

The chapter discussed the results in detail ranging from the boreholes and shallow wells that were found safe for human consumption. To the sanitary risk inspection on the condition of the boreholes and wells, this chapter also exposed the challenges on water accessibility by the community, and water governance challenges. The main results discussed pointed to the fact that they is need for constant water quality monitoring as the water in the district has a low ph values, and shallow wells are vulnerable to pollution and contamination. Document review focused on assessing the key indicators for verifying community water supplies bring into light results which are necessary for water planning

CHAPTER 5: CONCLUSION AND RECOMMENDATION

Chapter introduction

All the chapters are summarized below and conclusions are drawn. A set of recommendations are drawn from the findings, secondary information that the Researcher came across during undertaking the project.

5.1 Conclusion

In an attempt to find long lasting solutions to cholera outbreak in Africa which killed many people in 2018, including the previous years and Zimbabwe at large the study aimed at evaluating ground water quality focusing on boreholes and shallow wells. The study was also underpinned by assessing community water supplies guided by indicators such as quantity, coverage, continuity, quality, cost and response to customer complaints and the vulnerability of the community to cholera outbreak which aimed at assessing the public sanitation infrastructure status. A combination of qualitative and quantitative data collection methods was implored to achieve the desired objectives. The findings indicated that many boreholes and shallow wells were safe for human consumption, but still needed frequent monitoring.

The interviews conducted gave a chance for the community to express their concerns on water accessibility this led to the identification of a crucial area which needs more research on the water needs of the old and disabled which are ignored by the service providers as they cannot walk long distances to fetch water. Interviews also revealed the need for prioritization of the water sector by investing financially. This would in turn equip local authorities to be able to run their water quality internally.

Survey carried out on the status of sanitation infrastructure, clearly showed that many public toilets are not functional and this poses a serious health hazard risk. The study managed to make an impact to the community by educating the community as well of the best practices in collection of water and health hazard associated with improper water handling. Water quality monitoring therefore requires stakeholder collaboration, with all the actors involved to be able to implement legislation available and safeguard public health.

Recommendations

The objective of the surveillance is not simply to collect and collate information but also to contribute towards the protection of public health by promoting of the improvement of water supply with respect to quality, quantity, coverage, cost and continuity. To inform policy making and address the water supply challenges through the following recommendations:

Policy recommendation

- There is need for the government of Zimbabwe through the Ministry of Health to develop a water safety plan. That will be responsible for guiding the water quality monitoring, this policy should map out the hotspots which are supposed to be monitored, frequency of water source sampling should be clearly defined, creation of a database on the status of water sources, monitoring system which gives warning signals of the public health issues in the community.
- At local level the Municipality should develop its water safety implementing plan through the department of health and committee of health. This would allow timely monitoring of the water sources.
- Water access policy for the old, disabled should be developed to cater for their special water needs in the community. This policy should be targeted on ways which the local authority can sell water either in tanks for the disadvantaged groups in the society.

Public private partnership

- The study noted that many public toilets are not working properly in Chitungwiza and this poses a serious health hazard and the community is at risk of another cholera outbreak. There is need for public private partnership in rehabilitation and construction of new of the public toilets especially in St Marys were there are few public toilets. Partnership with organizations such as UNICEF that are already implementing WASH projects. Additionally installation of water services to enable people to wash hands after using toilets.
- The study also noted that coverage of water supply 74.1% and non-revenue water is 85.1%. There is urgent need to partner in the development and expansion of water reticulation system in order to enable 100% water supply coverage.

Decentralization of water quality laboratory

- The study observed that local authority was only restricted to basic water testing, with the major water quality testing done in government laboratory in Harare which is 20 kilometers from the town. The laboratory results takes a minimum of 2 weeks before given out. So there is need for decentralization of this service by having a local government laboratory in Chitungwiza responsible for water quality testing in Chitungwiza only. Alternatively to have a local authority having its own water quality laboratory which does full water quality monitoring.

Public health awareness programs and promotion of health clubs

- The study noted that cholera outbreak which took place in Chitungwiza was as a result of insufficient public health. Activities There is need for Action plan detailing public health programs which should be continuous all year, in schools and around the community.
- There is also need to promote health clubs in the community to mobilize each other and complement the work of the council in promotion of public health, by engaging them to do clean-up campaign

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ZIMBABWE

Reference:
Ministry of Health and Child Care
P O Box CY1122
Causeway
HARARE

4 July 2019

Blessing Barnet Chiniko
8 Mhakure Road
Zengeza 2
Chitungwiza

Dear Mr Chiniko

REQUEST FOR PERMISSION TO CONDUCT RESEARCH ON WATER QUALITY MONITORING IN CHITUNGWIZA

Thank you for your request to conduct a research on assessing the quality of water from different water sources and vulnerability of the Community to Cholera outbreak a Case Study for Chitungwiza Municipality.

May you please liaise with the Chitungwiza Municipality and endure that you have Institutional Review Board (IRB) approved protocol for your research.

Sincerely

SECRETARY FOR HEALTH AND CHILD CARE
(01) SECRETARY'S OFFICE (01)
08 JUL 2019
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

Dr A Mahomva
SECRETARY FOR HEALTH AND CHILD CARE

CHITUNGWIZA MUNICIPALITY

The Municipality of
CHITUNGWIZA

All Correspondence to be addressed to the Town Clerk

If Calling, Please
Ask for...M.MUKONYORA

P. O. Box 70, ZENGEZA
Chitungwiza.

PHONES: 23001/4: 23000/9; 23022/3;
FAX: 070-23337

13 May 2019

Chiniko B Barnet
Institute for Water and Energy Sciences
C/o Abou Bekr Belkard University of Tlemcem
B.P. 119
13000 Tlemcen
ALGERIA

Dear Sir / Madam,

PERMISSION TO CARRY OUT A RESEARCH PROJECT

I acknowledge receipt of your letter dated the 3rd of May 2019, on the above captioned subject.

Please be advised that, the Council will be making the necessary provisions to assist you with information you require for your project. Furthermore, be advised that the Council is also interested in the findings of your research. You are therefore required to submit your findings/project results to the Human Resources.

Kindly report to the Human Resources office on the 15th May 2019 to receive further instructions.

For more information you are advised to approach the undersigned.

Yours faithfully

M.MUKONYORA
HEAD HUMAN RESOURCES
CC: Town Clerk

Blessing 18 May 2019