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TECHNICAL CONSTRAINTS TO URBAN WASTEWATER MANAGEMENT IN ZIMBABWE

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A thesis submitted in partial fulfilment of the requirements of the degree of Master of Science in Water Resources Engineering and Management of the University of Zimbabwe

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DECLARATION

I, **Shepherd Tawanda Ngwenya**, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Water Resources Engineering and Management (WREM) of the University of Zimbabwe. It has not been submitted before for examination for any degree in any other University.

Signature: ____________________

Date: _____________________

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LIST OF SYMBOLS AND ABBREVIATIONS

ADB	African Development Bank
AusAID	Australian Aid
GIZ	Germany International Corporation
CSO	Zimbabwe Central Statistical Organization
GoA	Government of Australia
GoI	Government of India
GoZ	Government of Zimbabwe
EBC	European Benchmarking Corporation
EPA	Environmental Protection Agency
IBP	International Best Practice
IFRRCS	International Federation of the Red Cross Society
IWSD	Institute of Water and Sanitation Development
JMP	Joint Monitoring Programme
MDGs	Millennium Development Goals
NWP	Netherlands Water Partnership
PWWA	Pacific Water and Wastes Association
UNEP	United Nations Environmental Programme
UNICEF	United Nations Children and Education Fund
WB	World Bank
WHO	World Health Organization
WW	Westernport Water
RS	Reliability Score
SADC	Southern African Development Community
USAG	United States of America Government
VIP	Improved Ventilated Pit Latrine
ZINWA	Zimbabwe National Water Authority
ZIMSTAT	Zimbabwe National Statistics Agency

DEDICATION

To my beloved father: Augustine Ngwenya

You suffered for my JOY and I know you are proud of me!

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ABSTRACT

In urban areas of Zimbabwe, wastewater management receives less attention than water supply. Wastewater management should promote the recycling and reuse of sewage effluent without causing harm to public health and the environment. A research study was carried out from January to June 2013 on the 32 urban areas of Zimbabwe. Its main objective was to assess the extent of technical constraints for improved wastewater management in urban areas of Zimbabwe through performance measurement.

A structured questionnaire was used for data collection and was administered by the researcher. The senior officers of urban local authorities were the targeted respondents. In addition, Focus Group Discussions and key informant interviews with senior wastewater treatment operators were carried out in the field, technicians and superintendents. This was done in order to understand how their systems were working and the challenges faced.

The results obtained from the research revealed that all councils were having difficulties in providing adequate wastewater management services. The coverage of toilets for all councils was 83.3% on average. Other indicators, were the coverage of sewerage network services at 68.7%, efficiency of collection of sewage at 27.4%, meaning that a considerable amount of sewage was not reaching sewage treatment plants; adequacy of capacity for treatment of sewage at 161.5%, meaning that with limited supply of water they are receiving less than they can treat because of water shortages, quality of sewage treatment at 4.3% and the extent of recycling or reuse at 2.9%. There was also a shortage in staffing, with an average of only 2 employees per 1,000 connections of sewerage compared to a recommended international standard of 8 employees per 1,000 connections.

It was concluded that the sanitation coverage in Zimbabwe in 2012 was low. Most waste stabilization ponds lacked maintenance though operational. The study recommends that more low cost technologies like waste stabilization ponds and constructed wetlands, which are easier to maintain, be adopted for all urban areas. There is also a need to market and reuse wastewater for non-potable uses. Further studies should be carried out to explore and find opportunities of reusing wastewater in industries and irrigation.

Key words: wastewater management, public health, performance, Zimbabwe

1. INTRODUCTION

1.1 Background

The world is facing a global water crisis, continuing population growth and urbanisation, rapid industrialisation, and expanding and intensifying food production, which are all putting water resources under pressure and increasing the unregulated or illegal discharge of contaminated water within and beyond national boarders (UNEP and UN-Habitat, 2010). Inadequate handling of wastewater or untreated water can lead to severe sanitary consequences worldwide (WHO, 2011). As approximated by United Nations (UN) data, 2.6 billion people still lack improved sanitation, and 1.2 billion still practise open defaecation (JMP, 2013). Improved sanitation is basic sanitation, that is, access to a facility that ensures the hygienic separation of human excretion from human contact. Worldwide, an estimated 30,000 deaths occur per week due to unsanitary water and unhygienic living conditions, and according to the UN, one tenth of the global disease burden could be eradicated by providing adequate sanitation (WHO, 2011).

Globally, two million tonnes of sewage, industrial and agricultural waste are discharged into the world’s water ways annually and at least 1.8 million children who are under 5 years old die every year from water related diseases, or one die every 20 seconds (UNEP and UN-Habitat, 2010). Furthermore, inaction towards wastewater has serious consequences to the environment, human health and economic development in nations. This is due to contamination of water supplies, which could lead to an increased risk of spreading infectious diseases and the deterioration of existing ecosystems. The other aim of wastewater management is to recover energy, nutrients, water, and other valuable resources from wastewater (Templeton and Butler, 2011).

Globally, populations are growing rapidly, particularly so in urban areas where the rate of urbanisation far outstrips planning and wastewater infrastructural development (UNEP and UN-Habitat, 2010). The existing wastewater infrastructure for most cities is decaying or is no longer appropriate and in slum areas, there is no planning and few facilities. Urbanization is a pervasive and rapidly growing form of land use change. In 1950, Africa was the least urbanized continent with only 14.5% of the population in urban areas, but by 1988, about 35% of Africa's population of 749 million people was urbanised (Nsiah-Gyabaah, 2003). It is expected that more than 60% of the world's population will live in urban areas by the year 2030, much of this growth occurring in developing nations (Michael *et al.*, 2001). This extensive and ever increasing urbanization represents a threat to stream ecosystems. Over 130,000 km^2 of land in the United States of America is impaired by urbanization. This makes urbanization only second to agriculture as a major cause of stream impairment (USEPA, 2000). This has since pushed for the urban wastewater management strategies and technologies (Steven *et al.*, 2010).

Wastewater management is a human requirement whose main purpose is to separate human waste from human settlements in order to prevent diseases (Flores *et al.*, 2008). Wastewater is water that has been used and may carry substances such as human waste, food scraps, oils, soaps and chemicals. Wastewater is derived from residential, commercial and industrial activities. In wastewater management, one of the big challenges is that of building new toilets and wastewater collection systems (Fürhacker, 2009). For those people with income levels so low that they can hardly provide enough food for themselves, poverty prevents them from investing in their sanitary facilities.

Most cities face numerous challenges with respect to water and sanitation services. Some of the challenges include those of complying with wastewater standards, the reliability of power supply, management of ageing infrastructure, extending infrastructure to meet developmental needs, ensuring financial sustainability, and building human capacity capable of addressing these pressing challenges (Carden *et al.*, 2009).

Water and sanitation are essential to life, health, livelihood and dignity. They are regarded as basic human rights (IWSD, 2012). The Universal Declaration of Human Rights, 1948, Article 25 (UN, 1949) states that: "everyone has the right to a standard of living adequate for the health and wellbeing of himself and his family". The timely and adequate provision of clean water and sanitation to communities is of special importance given that people have traditionally faced difficulties in fully exercising their rights and are very prone to exploitation (Shrestha and Cronin, 2006).

In 2011, the global sanitation coverage was 64% (JMP, 2013). There were 2.5 billion people who did not use an improved sanitation facility. Of these, 761 million people used public or shared sanitation facilities and another 693 million used facilities that do not meet minimum standards of hygiene. The number of people who practised open defecation increased to over a 1 billion in 2011 (JMP, 2013). Seychelles and Mauritius achieved sanitation coverage of 100% and at the other end of the spectrum Tanzania and Madagascar had low sanitation coverage of 10 to 14%. Tanzania had the lowest sanitation coverage in Southern Africa (SADC, 2013).

In Zimbabwe, waste disposal and water supply are key services, which urban local authorities provide. With limited resources for maintenance, water supply and sanitation infrastructure fell into disuse with inevitable deterioration of services. As a result, the quality of water supply and sanitation services was seriously compromised. The dilapidated state of infrastructure throughout the country was a major contributing factor in the severe cholera outbreak during the 2008 to 2009 season (IFRRCS, 2010). A total of 98,600 cases were reported and 4,300 deaths recorded by June 2009 (IFRRCS, 2010).

Urban wastewater treatment receives less attention than water supply (UN, 2001).Water increasingly becoming a scarce resource in arid and semi-arid countries, there is a need to consider any source of water that might be used economically and effectively to meet increasing demands for water. Whenever good quality water is scarce, water of marginal quality has to be considered for use in agriculture and groundwater recharge (Fetter and Holzmarcher, 1974)

1.2 Problem Statement

In Zimbabwe, no performance measurement of wastewater management systems at a national scale has been done, hence the need to carry out a study to assess the status of wastewater management systems in Zimbabwe. The increased growth of cities and towns is resulting in demand for more and better options for the treatment and disposal of faecal waste especially in areas without public services. The unhygienic means that of using pit latrines have failed to serve the rapid urban population growth, which has affected the urban areas. Access to sanitation by most of the households remains poor and people are vulnerable to a high incidence of diarrheal disease and typhoid. The improvement, even development of onsite sanitation is made more difficult because of weak pro-poor conditions within the sector.

With the annual growth rate in urban areas predicted twice as high as that of the projected total population, 60% of the world's population will be urban dwellers by the year 2030 (UNDESA, 2006). As the population increases in urban areas, so does the production of wastewater and the number of people vulnerable to the impacts of severe wastewater pollution. The lack of capacity to manage wastewater not only compromises the natural capacities of aquatic systems to assimilate pollutants but causes loss of a whole array of benefits provided by our waterways. Zimbabwe has been experiencing perennial diarrheal diseases, with a cholera epidemic having been experienced during 2008/9. With the growth rate of urbanization having been forecast by CSO (2013), more wastewater is likely to be generated in urban areas of Zimbabwe. Presently, Zimbabwe has a big problem of open defaecation in urban areas because of lack of basic sanitary facilities (IPS, 2012). Contagious diseases will continue as long as the government fails to provide clean water and address the sewerage problems experienced by most cities and towns in the country (JMP, 2013). Upon this background, the research sought to carry out a performance measurement for urban wastewater management systems in Zimbabwe.

1.3 Justification

In order to improve service delivery in local authorities the world over, standardized and best practices are now being employed to measure performance (van den Berg and Danilenko, 2011). Some of the countries that have improved tremendously in service delivery in Africa include South Africa and Zambia which have set benchmarks for their wastewater treatment systems. An example of a local authority performing satisfactorily in Southern Africa is Ethekwini Municipality in Durban, South Africa (CASE, 2003). It has introduced a system of call centers, where residents can phone if they have sewer blockages or spillage complaints and this has improved the interface between customers and the local authority, trust has been built and customers' willingness to pay bills has improved as a result.

Poor wastewater management is being affected by lack of adequate resources in local authorities, especially those in Africa. Lack of funds to reinvest back in wastewater management has been a result of unwillingness to pay by residents due to poor service delivery.

In Zimbabwe, no performance measurement at a national scale has been done, hence the need to carry out a study to assess the status of wastewater management in Zimbabwe. Comparing of councils will give a clear understanding on the constraints affecting wastewater management in urban councils in the country. Furthermore, there is need to understand the present status of the infrastructure, whether it is coping with the wastewater being generated since there is a growth rate in urban areas of Zimbabwe. The study will also investigate the capacities of local authorities to convey and treat wastewater adequately and safely before discharging to water bodies or irrigation purposes.

1.4 Research Objectives

1.4.1 Main objective

The main objective of the study was to assess the extent of the technical constraints for improved wastewater management in urban areas of Zimbabwe through performance measurement.

1.4.2 Specific objectives

1. To establish the coverage and challenges of basic sanitary facilities in urban areas of Zimbabwe.

2. To investigate the effects of lack of preventative maintenance in collection of sewage in urban areas of Zimbabwe.

3. To determine the amount of wastewater generated compared to that treated in urban areas of Zimbabwe.

2. LITERATURE REVIEW

2.1 Introduction and background

Many cities in developing countries currently have no sewerage or other adequate sanitation systems (JMP, 2013). In those that do have a sewerage system, it typically serves only a small minority of the population. This lack of adequate sanitation systems is already an enormous problem and is certain to become much larger. The urbanisation of developing countries is proceeding at an astonishing rate (Whittington *et al.*, Undated). Rapid urbanisation in developing countries will create huge new demands for infrastructure services such as water, sanitation and electricity. Sanitation planning for cities in developing countries has not kept pace with the implications of these demographic and financial changes. Sanitation is still not taken seriously enough in the environmental sector; water supplies are improving but sanitary conditions , in which improvements are equally necessary, are lagging far behind (Mulenga *et al.*, 2004). With few exceptions, neither donors nor national governments have looked carefully at the economies of investments in improved sanitation systems or at households' demand for sanitation services. This is in part because in both industrialised and developing countries, the public provision of wastewater collection and treatment has been heavily subsidised by government. The primary justification of such has been on public health grounds, that the health benefits obtained from a clean, sanitary urban environment accrue to all the city's inhabitants, and thus the costs of such a public service should be shared by all citizens. Individuals are not permitted to make their own decisions on whether or not to dispose of their waste in a hygienic fashion because the consequences of poor waste disposal affect not only themselves but others as well, and that this externality can be dealt with by collective action. Sanitation is a primary key driver for improving public health as it aims to reduce people's exposure to disease by providing a clean living environment (NWP, 2006). Poor sanitation has serious consequences for health (UNICEF and WHO, 2000). Children under the age of five die each year from diarrhoeal diseases which are associated with polluted water, poor sanitation and poor domestic hygiene (Murray and Lopez, 1996).

Sanitation deficiencies can take a number of forms which includes: an absolute lack of sanitation facilities; sanitation facilities being provided but in poor condition so that they are inconvenient, unpleasant and unhygienic; some people have limited access to existing sanitation facilities; sanitation facilities have been provided but suffer from poor operation and maintenance; solutions to local problems result in environmental problems elsewhere in that sewage is collected but ends up being discharged as raw sewage in water bodies thereby polluting the natural aquatic environments. Good sanitation is a prerequisite for healthy cities, protecting people from a range of excreta-related diseases (Taylor *et al.*, 2003). These diseases are likely to be chronic in so many areas and have the potential to reach epidemic proportions in the absence of adequate household waste disposal arrangements. 88% of diarrhoeal diseases is attributed to unsafe water supply, inadequate sanitation and hygiene, and improved sanitation reduces diarrhoea by 32% (WHO, 2004).

Sanitation, along with clean water, is a primary driver for improving public health. It reduces people's exposure to diseases by providing a clean living environment. It is a crucial element in breaking the cycle of infection-disease-recovery-infection, resulting from unsafe disposal of human waste containing pathogens (WHO, 2005).

In 2011, it was estimated that 64% of the world's population relied on improved sanitation facilities, whilst 15% continued to defaecate in the open (JMP, 2013). Since 1990, almost 1.9 billion people had gained access to an improved sanitation facility. However, the world remains off track to meet the Millennium Development Goal number 7, namely, that of reducing the proportion of people without access to sanitation from 51% in 1990 to 25% by 2015. The greatest progress has been made in Eastern Asia, where sanitation coverage has increased from 27% in 1990 to 67% in 2011. In Southern Africa, Zimbabwe is well ahead of other countries in terms of access to sanitation facilities. Countries such as Zambia, Mozambique, and Tanzania have low sanitation coverage. In the year 2011, there was an overall increase of access to safe sanitation in Zimbabwe from 91.8% in 2009 (GoZ, 2009) to 93.4% in 2011 (GoZ, 2011). The JMP has 96% as the figure for access to sanitation in Zimbabwe in 2011. This was slightly higher than the 93.4% surveyed by the GoZ because of varying definitions of what is termed as improved sanitation.

Wastewater or sewage is the byproduct of the many uses of water. There are the household uses such as showering, dishwashing, laundry, and flushing of toilets. Additionally companies use water for many purposes, including processes, products, cleaning and rinsing of parts (EPA, 2007). The wastewater pollutants have to be removed to protect the environment and protect public health (EPA, 2003). If the pollutants are left untreated, they can negatively affect the environment and result in fish kills, foul odours and waterborne diseases such as cholera and typhoid.

In developing countries, only a small proportion of the wastewater produced by sewered communities is treated (UNEP, 2002). In Latin America, less than 15% of wastewater collected in sewered cities and towns is treated prior to discharge (PAHO, 2000). The reason for the lack of wastewater treatment is that of financial incapacity and the ignorance of low-cost wastewater treatment processes and of the economic benefits of treated wastewater reuse (Mara, 2004). Currently the global burden of excreta-related diseases is very high and over half of the world’s rivers, lakes and coastal waters are seriously polluted by untreated domestic, industrial and agricultural waters (UNEP, 2002), and they contain very high numbers of faecal bacteria (Ceballos *et al.*, 2003). Effective wastewater treatment has to be recognized as an environmental and human health imperative (Beach, 2001). Due to wastewater effects, there is a need for cost-effective, efficient, monitored and consistent wastewater management and treatment programs to improve living standards of nearby communities, protect against diseases and infections, and preserve ecosystems and wildlife. Only through comprehensive and expeditious procedures can safe water and sanitation for all be achieved before the targeted deadline of 2015 for all member nations to meet the Millennium Development Goals.

The volume of wastewater generated influences the technology choice of treatment and, where larger volumes are involved, disposal systems must be selected and sized accordingly. The existing ones may become inappropriate if water use increases greatly and may need upgrading or replacing (Cairncross and Feachem, 1983).

2.2 Legal and Regulatory Framework

Performance assessments of water utilities in Zimbabwe are governed by legislation. The water utilities providing wastewater services in Zimbabwe are the council institutions and ZINWA. The two have different legislations which they operate under. Council managed water utilities operate under the Urban Councils Act complimenting it with the Water Act of 1998. ZINWA operates under the ZINWA Act of 1998 which was extracted from the Water Act of 1998. Chapter 29:15 of the Urban Councils Act governs the management of urban areas in Zimbabwe. The Urban Councils Act is a large document with a very thin clause on wastewater, which does not give details on how wastewater management should be done. There was no clear stipulation on who should regulate wastewater management in urban areas up to 2012 when the final draft of the National Water Policy was approved.

Other countries such as South Africa and Zambia have Sanitation Acts which are specific to sanitation. These clearly stipulate the institutional arrangements that should be in existence in urban areas and their roles in the management of services. The ZINWA Act of 1998 is an organizational piece of legislation which mostly refers to catchment management rather than to water management in towns. The ZINWA Act does not clearly stipulate the role of ZINWA as far as the management of urban wastewater systems is concerned.

2.3 Challenges of Improved Sanitation Coverage

2.3.1 Coverage of Toilets

The coverage of toilets denotes the extent to which individuals have access to an individual or community toilet in a service area within the jurisdiction of a local authority (GoI, 2008). The toilets include those in the category of residential, commercial, industrial and institutional properties.

Urbanization holds the opportunity for improving the access to improved water and sanitation facilities which could result in dramatic declines in diarrheal diseases and other infectious diseases (Schirnding *et al.*, 1991). Improved sanitation means facilities that protect users from contact with faeces and that are not shared with other households (Adubofour *et al.*, 2013). According to a study done by Schirding (1991) in South Africa, increased risk of death from diarrhea was associated with the absence of a flush toilet, non-availability of piped water, and household overcrowding.

By 2008, over 2.6 billion people lacked toilets with a flushing system and different forms of decent sanitation. For the majority of the people a toilet represents a life changing dream, a better health dream, higher incomes, more education, higher social status, a cleaner living environment and a better chance for children to celebrate their fifth birthday (Lane, 2008). The world is far from meeting the sanitation target of the Millennium Development Goals. Sanitation is the most off-track and neglected UN MDG target. To provide about 77% of the global population with flush toilets and other decent forms of toilets, it will take until about 2049 (UN, 2011). Of the 2.6 billion people who lacked decent sanitation, 1.1 billion people practised open defecation, meaning they did not use any facility at all (UN, 2011). The rapid urbanization is straining the already stressed urban sanitation systems of many countries the world over. Slums in most cities and towns are not usually connected to the city's sanitation infrastructure and the situation becomes deplorable. This neglect concentrates the people and their waste in unfriendly environments and seriously compromises their health (Adubofour *et al.*, 2013).

Apart from the issues of behavior change, the availability of water is one of the major drivers of safe sanitation. The lack of political will and commitment to ensure the availability of a package of basic services such as water and sanitation to the urban poor is resulting in a lack of infrastructure investment (Kapur, 2007). This has been supported by Adubofour (2013), that without a corresponding increase in the provision of water supply and sanitation facilities, there will be an intense pressure on existing facilities which are already under pressure, leading to their further deterioration and environmental conditions that put the residents at risk of various diseases and increases poverty.

However, in a study done in Botswana, Zambia and Ghana by Faechem (1983), the provision of superior water and sanitation facilities may not protect residents from infection if the overall level of faecal contamination of the environment is high.

In a study done in Ghana, almost half of the houses in developing areas have flush toilets that empty into septic tanks in the gardens and 40% depend on pit latrines while a few use the free range system (Yankson and Gough, 1999). Tanzania and Madagascar have low sanitation coverage, with Tanzania having the lowest (10 to 14%) (SADC, 2013). The low coverage of toilet facilities in most cities and towns could be a result of latrines not being considered as improved sanitation in urban areas though the Joint Monitoring Program considers that as improved sanitation since most of them are in slums and squatter camps where services are not offered by councils.

Equation 1 was used to calculate the extent of coverage of toilets in urban areas of Zimbabwe.

$$\boldsymbol{CT = \left(\frac{a}{a+b}\right) x\, 100}$$

…………………………*Equation 1*

Where; CT =coverage of toilets

a =properties with access to individual or communal toilets

b =total no. of properties without individual or communal toilets

2.3.2 Coverage of sewerage network services

The coverage of the sewerage network services denotes the extent to which the underground sewerage has reached out to the individual properties across the service area within the jurisdiction of local authorities (GoI, 2008). The properties include those in the category of residential, commercial, industrial and institutional.

Sewerage includes the core element of physical infrastructure that determines the environmental status of any settlement and as such requires minute planning, development and management (Mara, 2004). The advantages of sewerage are that it can remove large amounts of wastewater and provides great user convenience. The disadvantages though, are the high capital and operating costs and the effluent might still be containing large numbers of germs (USEPA, 2001).

Globally the development of waterborne sewage networks legs behind the evolution of the piped water networks. Most low income countries in Africa have about 40% of their population enjoying private connections to piped water networks and this places a very low ceiling on the potential for waterborne sewage (Morella *et al.*, 2008). Among utilities serving the largest cities, only half are operating sewage networks. However, in middle income countries such as Namibia , South Africa and Senegal, the cities provide a high level of sewerage coverage (WB, 2008). In countries such as Cote d'Ivore, Kenya, Madagascar, Malawi, Lesotho and Uganda, sewer networks reach less than 10% of the population in the service area. Sewerage systems are built to protect public health, but badly managed sewers are becoming a serious health hazard.

Cholera and diarrhea are the major health problems in the absence of sanitation, especially for children. With sewers, infant mortality rates could be reduced and achieving universal coverage could save 326,000 infants per year (PSIRU, 2008). Cess pits and septic tanks do not provide the same benefits due to leakage and contamination and recycling onto fields is not an option in cities. In Jakarta, Indonesia, with a population of 12 million people, 1% is of households is connected to sewers (PSIRU, 2008). Also in Kisumu, the third largest city of Kenya, the sewerage coverage is 10% and residents use pit latrines which increase the chances of cross contamination of groundwater (UN, 2004). Only 3 of the 1,500 cities and towns in the Philippines contain functioning public sewerage systems and these are old and undersized and need major rehabilitation (WB, 2003).

The expansion of sewerage network systems has lagged behind the growth of population resulting into the overflow of sewage into drains causing river pollution or creation of cess pools in low lying areas of towns or settlements. Slums and squatter camps have been denied access to regular municipal sewerage systems and this has resulted in imbalances in the coverage of sewerage systems (Adubofour *et al.*, 2013). Also the network capacity increases may not be feasible where water resources are scarce and where economic returns are low as common in fringe or poor areas (Bosch *et al.*, 2001). In many developing countries, excreta is being disposed into the environment leading to the transmission and spread of communicable diseases (Dunsmore, 1986). This can be interrupted by making use of conveyance systems that collect all sewage from residential properties as well as industries.

Most countries are lagging behind in sewerage network services because they lack the policy framework necessary to achieve total sanitation, in Malaysia, there is a Sewerage Act of 1993 (518) and other forms of legislation which have helped it to achieve total sanitation (Din, 2010).

Equation 2 was used to calculate the coverage in sewerable urban areas of Zimbabwe.

$$CNS = (b/a)\ x\ 100 \quad \text{……………………………………….. Equation 2}$$

Where; CNS =coverage of the sewerage network services

a =total number of services in the service area

b =total number of properties with direct sewer connections

2.4 Level of Collection of Sewage and Challenges in Urban Areas

2.4.1 Efficiency in collection of sewage and maintenance of infrastructure

Efficiency in collection of sewage signifies the effectiveness of the network in capturing and conveying it to the treatment plants (GoI, 2008). It is not enough to have a network that is efficient in collecting sewage but also one that treats the sewage at the end of the sewerage network system.

Many cities and towns started building sewer systems more than 100 years ago and many of these have not received adequate upgrades, maintenance and repairs over time. A wide variety of designs, materials and installation practices are used to construct sewer collection systems (USEPA, 2001). Sanitary sewer overflows occur when untreated sewage is discharged from the collection system due to pipe blockages, pipe breaks, infiltration, and inflow from leaky pipes, equipment failures and insufficient system capacity. Trash and sediments build up in sewer lines and block the sewage from flowing to the treatment plant; the blocked flows result in the pressure increasing in the sewer lines leading to overflow of sewage out of manholes and into streets (Mara, 2004). Most of the challenges are a result of poor or lack of maintenance programmes which include cleaning sewer lines, connections, and pumps.

Historically, Zimbabwe's urban water and sanitation services development has been driven by principles of high service levels and standards and universal access for all, making it unique in Africa (GoZ, 2013a). The economic meltdown in the last decade has led to the deterioration of services leading to many water supply and sewerage infrastructure going beyond the state of repair (GoZ and UN, 2010). Little is reaching the wastewater treatment plants because of lack of maintenance of the conveyance systems, some of which were constructed more than 50 years ago. Ten years ago, drugs used in human medical care were detected in ground and drinking water samples in Berlin, confirming low efficiencies in collection of sewage (Heberer *et al.*, 2002).

2.4.2 Staff per 1,000 connections

According to Rodriguez et al. (2004), staff productivity is not easy to assess given that the wastewater in every utility operates as a part of a wider administration. A common basis of estimating efficiency is the number of connections per staff member. The World Bank classifies connectivity of more than 100 connections per staff member as "good" (Shen et al., 1994). Other research done in other parts of the world found rates 171 to198 (Brazil), 226 to 248 (Mexico), 83 (Malaysia) (Stenekes, 1996). It is important to consider staff productivity in the provision of water in urban areas as this will determine the efficiency of a water utility. Some of the ways of increasing efficiency include employee training to prevent contamination from sewer overflows, need for public education on how to prevent sewer overflows, visual inspections of the surface, internal areas of pipelines and manholes, eliminating direct sewer overflow pathways to water sources, incorporating system upgrades by replacing sewer lines including appurtenances, and equipment as new technology becomes available though it might be very expensive.

2.4.3 Maintenance of wastewater systems

The sewer systems at many local authorities are in a state of disrepair due to the ageing infrastructure (Ehrlich *et al*., 2006). Because of the significance of lead time required for measures such as sewer rehabilitation or facility expansion, there is a need to plan ahead to ensure that growth takes place without overloading sewage facilities. Some of the factors which lead to overloading include economic growth, engineering foresight, or effective plant operation. The maintenance include cleaning of sewer lines, pumps and also pipe replacement (Mara, 2004).

2.5 Adequacy of Capacity for Sewage Treatment in Urban Areas

2.5.1 Adequacy of capacity of treatment of sewage

This indicator highlights the adequacy of available and operational sewage treatment capacities of the sewage that is generated in towns and cities (GoI, 2008). Once every 20 years more or less, every operator and city or town is faced with the problem of an overloaded sewage treatment plant (Tow, 1955).

Each wastewater treatment plant has been designed to treat a projected amount of wastewater to a desired level before discharging into water bodies. There are factors which do affect the treatment capacity of the wastewater treatment plants which include the weather, water conservation practices and water requirements for certain uses. During the wet season wastewater treatment plants receive more than they can treat, leading to untreated sewage being discharged into water bodies. Cities and towns that practise water rationing and have water demand management strategies generate less wastewater which can be handled well with the wastewater treatment systems in place.

The consequences of overloading of sewage facilities include, poor effluents discharged into the environment which become a potential health risk and an environmental concern, surcharge of sewers which results in sewer overflows and increased replacement costs as the mechanical equipment are utilized above their design capacity.

Equation 4 was used to calculate the adequacy of capacity of treatment of sewage in urban areas of Zimbabwe.

$$\boldsymbol{ACS = (c/((a+b)x0.72)x\ 100}$$

…………………………..*Equation 4*

Where; ACS =Adequacy of capacity of treatment of sewage

a =total water consumed or billed

b =estimated water use from other sources

c =treatment plant design capacity

0.72 sewer return factor (as agreed by Zimbabwean Town Engineers in Kadoma).

2.5.2 Quality of sewage treatment

Wastewater infrastructure should not be designed only to collect and convey sewage but to be able to treat it to acceptable standards that are not harmful to the environment (GoI, 2008).

Sanitation has become a yardstick of socio-cultural development of cities and towns. Because of the urban sprawl, haphazard developments, and rapidly expanding populations in cities and towns and inadequate or poorly designed malfunctioning sewage treatment facilities, untreated sewage is often discharged into rivers (Maharashtra and Jnnurm, 2012). In a number of instances, the increasing number of housing developments being constructed throughout towns and cities without the requisite expansion of the necessary sewerage infrastructure has caused chronic overloading of systems. This is compounded by the general practices of the home owners expanding the housing units and usually the number of householders living in the unit thereby increasing the flows to the sewerage system. The infiltration of storm water into the sewerage system also contributes to the overloading of sewage facilities, thereby impacting on the treatment of wastewater.

Pollution of water resources is a cause of the untreated sewage discharged into water resources. A solution to this is not only that of bridging the gap between sewage generation and treatment capacity but also calls for the development of facilities to divert the treated sewage for use in agriculture to prevent pollution of water bodies by nutrients (Uddin, 2005).

One out of four urban dwellers does not have improved sanitation facilities and 90% of all wastewater in developing countries is discharged untreated, polluting rivers, lakes and seas (UN, 2010). Rapid urbanization brings along several challenges related to water quality issues and sanitation. The major progress in the use of improved sanitation facilities in the last decades is undermined by the rapid urban population growth. In most low and middle income countries, wastewater is discharged directly into the sea or rivers without treatment. Many wastewater treatment facilities in cities and towns quickly become undersized as the urban population outpaces investments (Tow, 1955). If well managed, wastewater effluent can be a positive addition to the environment and lead to improved security, health and economic development. Reclaimed water is also becoming more common, particularly in the fast growing region of the U.S. (CSS, 2012).

Sewage is a major carrier of disease from humans and toxins from industrial waste. For the health of any community, the safe treatment of sewage is crucial (Townshend, 1995). Wastewater treatment plants are supposed to make the municipal sewage compatible for disposal into the environment in order to minimize the environmental and health impacts of the sewage and to make the sewage fit for recycling and reuse.

In many dry climate regions in Africa and south Asia water is becoming increasingly scarce and during the past decade, there has been growing concern that the world is moving towards a water crisis (Ursula *et al.*, 2000). Losses in tourism income in countries that depend on tourism are a result of discharge of wastewater effluent of poor quality. Peru in 1999 lost US$1000 million in a week when there was an outbreak of cholera due to poor sewage managements (Owili, 2003). The issues of water quantity and quality are of concern. Reuse and recycling of wastewater is being considered as a new source of water in regions where water is scarce. Treated wastewater can be reclaimed to meet non-portable water needs such as irrigation of golf courses and public parks. However, it can also be used for consumption.

Equation 5 was used to calculate the percentages of the wastewater effluent that met minimum requirements.

$$\boldsymbol{QST = \left(\frac{b}{a}\right) x\ 100}$$

……………………………………*Equation 5*

Where; QST =quality of sewage treatment
a =total no. of samples tested in a year
b =total no. of samples that pass the secondary treatment

2.5.3 Extent of recycling or reuse of sewage

The extent of recycling or reuse refers to the percentage of wastewater received at the treatment plant that is recycled or reused after appropriate treatment for various purposes. This only considers water that is directly conveyed for recycling or reuse such as use in gardens and parks, and use for irrigation (GoI, 2008).

Pollution problems of surface water and groundwater being faced by many cities in developing countries can be controlled through effective and feasible concepts based on the cleaner production principles (Nhapi and Gijzen, 2004). The urban water and waste management system could be addressed from a cleaner production angle which has been extremely successful in the industrial sector (Nhapi and Hoko, 2004).

One of the numerous problems being faced by many cities is that of management of wastewater generated which has resulted in serious pollution of downstream water bodies. Nutrients are known to cause eutrophication of water bodies and they require proper control. The most common water reuse applications of municipal sewage effluent include agricultural and landscape irrigation, industrial recirculation of process water, groundwater recharge for non-potable and indirect potable reuse (Kirsten, 2004).

With the increasing pressure on freshwater resources due to expansion of urban population, the increased coverage of domestic water supplies and sewerage network will give rise to greater quantities of municipal wastewater becoming a source, particularly for agriculture (Choukr-Allah and Hamdy, 2005).Recycling of secondary phosphorous from wastewater involves the reuse of sludge in agriculture though there are some several important issues to be resolved such as the content of pollutants in the sludge (Kvamstrom and Nusson, 1999).

The extent of recycling was calculated using equation 6.

$$\boldsymbol{ERS = \left(\frac{b}{a}\right) x\ 100}$$

....*Equation 6*

Where; ERS =extent of recycling for sewage

a =wastewater received at sewage treatment plants

b =wastewater recycled or reused after appropriate treatment

2.6 Performance Measurement or Assessment

Performance assessments are used to set up performance baselines, performance objectives and performance monitoring (van den Berg and Danilenko, 2011). They are also used to make comparisons between utilities, share best practices, help to set priorities, help managers to detect and correct weaknesses. In addition, they assist when carrying out performance evaluation through performance audits and engineering assessments and they are a tool for analysis (Danilenko, 2007).

The key drivers for carrying out performance assessments include the demand for transparent and efficient public services, modernization of the wastewater sector, standardizing programmes, full cost recovery and showing the stakeholders the drive for improvement (Dane, 2009). The international indicator targets used in the study are as shown in Table 2.1.

Table 2.1 Indicators from best performing countries in wastewater management

Indicator	*Value*	*Reference*	*Country*	*Selected Target*
Staff per 1,000 connections	5-9	GofZ	Zambia	8
Blockages per 100 km/annum	17	EBC, 2011	European	120
	14.1	Groves, 2009	New Zealand	
	330	GoSA	South Africa	
Extent of Sanitation Coverage	100%	GoI, 2008	India	100%
Extent of sewerage network services	100%	GoI, 2008	India	100%
Adequacy of capacity of treatment of sewage	100%	GoI, 2008	India	100%
Efficiency in collection of sewage	100%	GoI, 2008	India	100%
Quality of sewage treatment	100%	GoI, 2008	India	100%

The wastewater benchmarks for Zimbabwe as shown in Table 2.2 were set by senior representatives of all the 32 local authorities in Zimbabwe and ZINWA at a workshop in Kadoma; these included the Town Clerks and Secretaries, Town Treasurers, Town Engineers, Town Planners and environmental health officers.

Table 2.2 Wastewater benchmarks of Zimbabwe, 2013

Indicator	*Value*
Coverage of toilets	100%
Coverage of sewerage network services	80%
Efficiency in collection of sewage	95%
Adequacy of treatment of sewage	100%
Quality of treatment	100%

3. MATERIALS AND METHODS

3.1 Introduction

This chapter presents the characteristics of the study area in terms of location, population, and coverage of the sanitation facilities in the study area. The materials and methods used in the research were discussed and these were categorized into sampling design and methods, data collection and data analysis methods used.

3.2 Description of Study Areas

3.2.1 Location and population

Zimbabwe lies north of the Tropic of Capricorn between the Limpopo and Zambezi rivers. It is situated in Southern Africa and is an entirely landlocked country. South Africa bounds the country to the south, Zambia edges it to the northwest, Botswana borders it to the southwest and Mozambique edges it to the east. The country covers a total area of 150,871 sq miles. The country is bordered by Mozambique on the east 1,231 km, South Africa on the South 225 km, Botswana on the west 831 km and Zambia on the north and northwest 797 km from the capital City, Harare. It is part of a great plateau which constitutes the major feature of the geology of Southern Africa. Almost the entire surface of Zimbabwe is more than 300 m above sea level, with nearly 80% of the land lying more than 900 m above sea level and about 5 percent lying more than 1,500 m above sea level (ZIMSTAT and ICF, 2012). The climate of Zimbabwe is characterized by cool, dry, sunny winters and warm, wet summers. Zimbabwe has an area of 390,757 km^2. Zimbabwe has a population density of 33 persons per km^2. According to the 2012 preliminary census figures, the population of Zimbabwe was at approximately 13 million (CSO, 2012). A map of Zimbabwe with urban towns and cities is shown in Figure 3.1.

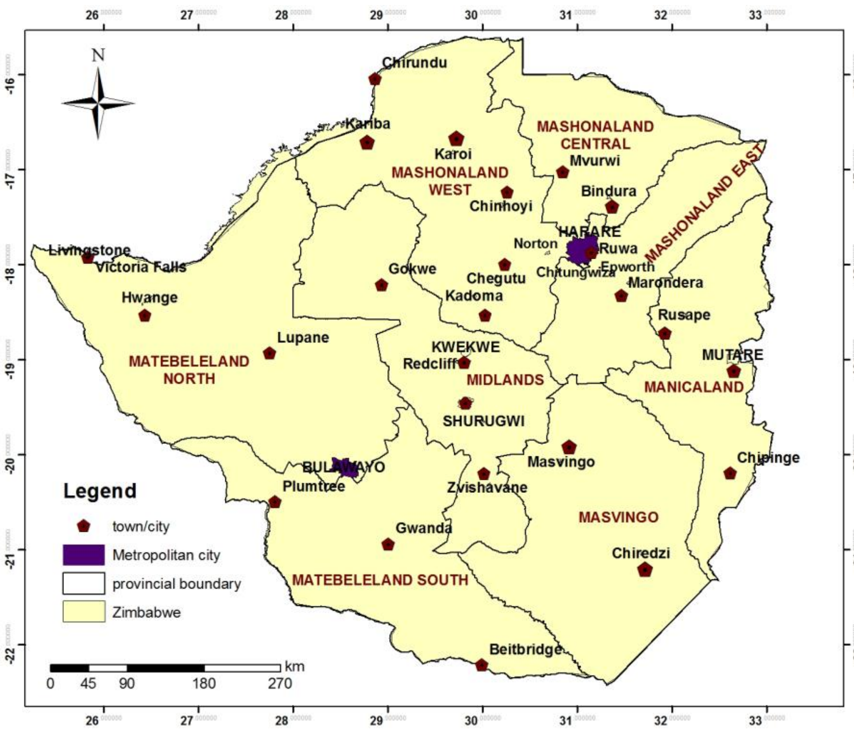

Figure 3.1 Map of Zimbabwe showing urban towns and cities

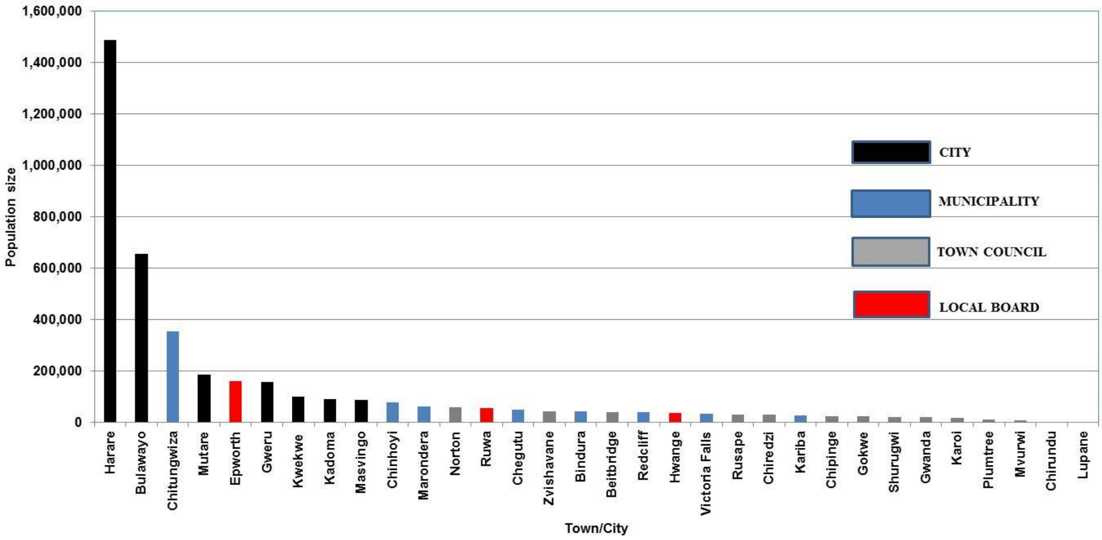

Figure 3.2 Populations of Towns and Cities in Zimbabwe (Adapted from ZIMSTAT 2012)

Zimbabwe has ten provinces, namely Bulawayo Metropolitan, Harare Metropolitan, Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Masvingo, Matebeleland North, Matebeland South and the Midlands. It has 32 urban local authorities comprising cities, municipalities, town councils and town boards. Local authorities are classified and ranked according to their size and levels of development into cities, municipalities, towns and local boards (GoZ, 2013b).

The classification of councils is not according to population sizes as shown in Figure 3. The classification of urban councils in Zimbabwe is governed by Statutory Instrument 50 of the Urban Councils Town Status Regulations of 1997. The following are considered in the classification: the size and population of town, the extent to which a town provides employment opportunities; the total valuation of properties; the extent of use of the town as a district centre for commercial, industrial, mining, agricultural, financial and administrative purposes, centre for state services such as road networks, communication and tourism; standard of marketing and shopping facilities and the range of specialist, professional banking and other services and growth rate. The local authorities are elected bodies that are responsible for the administration of their areas of jurisdiction and for the provision of services and infrastructure to ratepayers. They have the power to levy rates and charges on rate payers in order to raise revenue to cover the cost of council activities (GoZ, 2013b). The 32 urban councils are classified as shown in Table 3.1.

Table 3.1 Classification of councils in Zimbabwe

City Council	***Municipality***	***Town Council***	***Local Board***
Harare	Kariba	Chiredzi	Ruwa
Bulawayo	Chinhoyi	Chipinge	Epworth
Mutare	Chegutu	Rusape	Lupane
Masvingo	Chitungwiza	Karoi	Hwange
Gweru	Victoria Falls	Zvishavane	Chirundu
Kadoma	Gwanda	Plumtree	
Kwekwe	Marondera	Gokwe	
	Bindura	Shurugwi	
	Redcliff	Norton	
		Beitbridge	

3.2.2 Socio- economic activities

At independence in 1980, the Zimbabwean economy experienced a period of gradual growth and relative stability. A diverse economy, dominated by agricultural production was complemented by a strong manufacturing base (Sullivan and Brazier, 2012). However, since the mid-nineties, years of drought and political, economic, and social upheaval brought economic challenges that saw unemployment remaining at 80%. This pushed people into the informal economy, migrating from rural to urban areas (Sigauke, 2002). This resulted in urbanization taking place with lack of upgrading of the wastewater infrastructure and extension of services in new built up areas. Population pressures in towns and cities have led to the mushrooming of informal settlements within the peripheries of towns and cities. For instance, Epworth has become a hub of informal settlers, some of whom work in Harare, Harare South or Ruwa, with over 110,000 people (CSO, 2012). The areas lack sanitation facilities, with pit latrines being the commonly used types of toilets.

3.2.3 Background on wastewater management and legal & institutional arrangements

Wastewater management in urban towns and cities of Zimbabwe is mainly done by local authorities and the Zimbabwe National Water Authority, who have the mandate of supplying water and wastewater services to all residents. However, there are some private organizations providing such services in some towns. For instance, Hwange Colliery is providing more than two-thirds of the population of Hwange town with both water and wastewater services and also Hippo Valley estate in Chiredzi town providing services to majority of the workforce who work at the sugar estate.

Of the 32 cities and towns in Zimbabwe, 30 of them receive water and wastewater services from local authorities and two towns receive services from ZINWA. The towns that ZINWA provides with both water and wastewater services are Hwange and Plumtree. ZINWA also has the mandate to supply both water and wastewater services in all growth points in the country. However, most local authorities have taken over the services from ZINWA and ZINWA is now only supplying councils with bulk potable water.

3.2.4 Types of wastewater systems and state of wastewater systems

Wastewater collected from councils must ultimately be returned to receiving water bodies or to the land or reused (Metcalf and Eddy, 2004). The importance in the treatment processes of the different types of wastewater treatment plants is the performance and reliability in meeting permit requirements in order to protect public health and the environment. Reliability is important where critical water parameters have to be maintained such as in reuse applications. Very sophisticated and expensive wastewater treatment technologies have been developed over the years to cater for deteriorated water quality and many countries have enacted stricter effluent disposal regulations that are difficult to achieve (Nhapi and Hoko, 2004), meaning that less investments will be put towards improving the current treatment facilities.

The most commonly used wastewater treatment processes in Zimbabwe include the extended aeration process, waste stabilization ponds, biological nutrient removal, and the activated sludge process. Major cities such as Harare, Mutare and Bulawayo are using the biological nutrient removal systems, the waste stabilization ponds and the trickling filter systems. For Harare and Bulawayo, the biological nutrient removal systems and trickling filters are partially working whilst some have been decommissioned because of lack of maintenance of the electro mechanical parts. Waste stabilization ponds for most and towns and cities still functional but lack maintenance, but those in Marondera and Ruwa decommissioned. Some towns have biological nutrient removal systems though some partially operational whilst some decommissioned. Those for Marondera and Redcliff are still under construction.

Retrofitting and upgrading of wastewater treatment plants should be of priority because most wastewater treatment plants have equipment which is more than 20 years old and is near the ended of its useful life and would need replacement. Future efforts should be those of modifying, improving and expanding treatment facilities.

3.2.5 Problems in wastewater management

Raw sewage being discharged into water bodies leads to the pollution of most water bodies in Zimbabwe. This has resulted in increases in costs of water treatment chemicals for drinking water. For instance, Harare City alone is using seven water treatment chemicals whilst the City of Mutare is only using one because of pollution. Eutrophication is now common in most urban streams and rivers, thereby having an effect on aquatic systems. Wastewater contributed to, and played a role in the pollution of Lake Chivero in Harare besides non-point sources such as fertilizers from urban agriculture (Nhapi, 2004). Industrial wastewater discharged in towns and cities into water bodies introduces some toxic heavy metals and poisons in water bodies leading to pollution of surface and groundwater sources. Poor wastewater management is also causing cross contamination of water in the distribution networks. For instance, sewer overflows contaminate groundwater sources and potable water through leaking pipes in the water distribution systems.

3.2.6 Sanitation characteristics of the areas under study

According to a study done by the Zimbabwe National Statistics Agency (ZIMSTAT) (2012), it is said that 36% of urban households in Zimbabwe had improved toilet facilities that were not shared with other households. Most of these improved toilet facilities were connected to a sewer system or a septic tank (43%). Figure 5 shows the types of toilet facilities that were used in Zimbabwe in 2009.

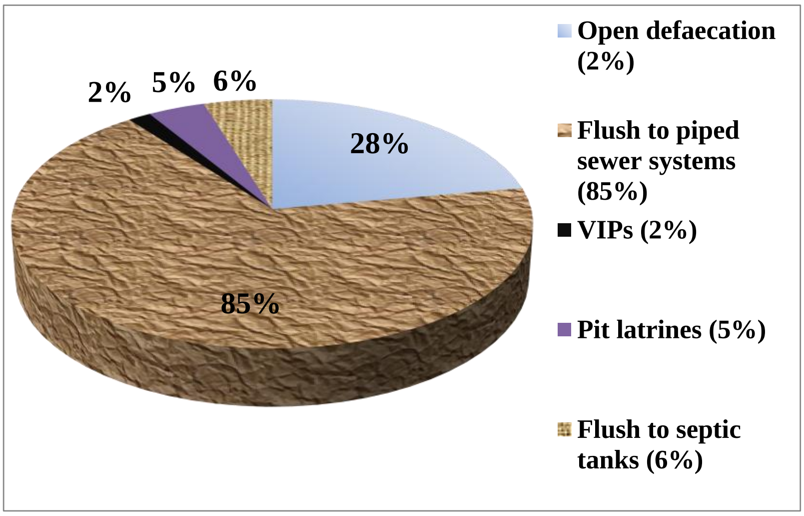

Figure 3.3 Types of toilet facilities used in Zimbabwe, percentage of population (Adapted from ZIMSTAT 2009)

3.3 Research Design

The research was based on both quantitative and qualitative methods. The quantitative method used was that of a structured questionnaire which was conducted and administered by the researcher to the senior management in councils whilst the qualitative methods included focus group discussions, key informant interviews and also field visits and observations.

The research was done for the thirty two urban local authorities so as to get accurate figures representing urban councils in Zimbabwe.

3.3.1 Structured Questionnaire

A structured questionnaire is one whereby all or most of the questions are closed (Phiri, 2007). A structured questionnaire for wastewater was developed by the researcher. It was sent to all the 32 local authorities prior to the workshop which was held in Kadoma. It was then checked and verified by Town Engineers at a workshop in Kadoma. The aim was to collect data of the status of wastewater systems in towns and cities as at December 2012. Some indicators used in the questionnaire were adapted from the Indian Government and were aimed at getting data on the coverage of toilets, coverage of the sewerage network systems, wastewater quality, adequacy of treatment of wastewater systems, extent of cost recovery in wastewater management, extent of reuse and recycling of sewage, efficiency in collection of sewage charges and also efficiency in redressal of customer complaints. The questionnaire that was developed and used in the research is shown in Appendix 1. The information collected in the questionnaire was not all used in this study but some of the information was to support and assist during the interrogation of figures. Some sections had additional information which was also used in the study. The questionnaire was first sent to local authorities and then administered on one-on-one basis by the researcher and the respondents were helped in clarifying issues that the respondents raised in the questionnaire. Pretesting of the questionnaire was done first at City of Harare, Chitungwiza Municipality, Ruwa Local Board and Epworth Local Board before doing the rest. A few adjustments were done to the questionnaires because of the different setups depending on the size of the local authority.

3.3.2 Focus group discussions (FGDs)

After developing the wastewater questionnaire, focus group discussions with Town Engineers and Town Treasurers were done at a workshop in Kadoma. The purpose of the focus group discussions was to verify and make some recommendations if all the indicators in the questionnaire suited the Zimbabwean way of operations in local authorities. Chairpersons from the focus group discussions were chosen and they made presentations on what they felt needed to be changed. After data collection, another workshop was held in Kadoma in order for council officials to validate and endorse the results. Focus group discussions were held and the groups were composed of town engineers, town treasurers, town clerks, environmental health officers and town planners. The purpose of these focus group discussions was to query the results presented and come up with recommendations on what local authorities needed to do in order to improve working skills and provide better services to all concerned stakeholders.

The data was also presented to the Urban Councils Association of Zimbabwe (UCAZ) forums such as the Town Clerk's Forum, the Town Treasurers' Forums and the Town Engineers' Forums. This was a way of clearly explaining the purpose of the study and clarifying some issues and definition of terms to senior managers of local authorities. The data was also presented to the Infrastructure Technical Reference Group which included UNICEF, GIZ, ADB and AusAID. The purpose of the meeting was to go through the indicators and clarify definition of terms. The advantage of these presentations was to revise some indicators to suit Zimbabwean operations.

3.3.3 Key informant interviews

In this study, field visits to wastewater treatment plants were done to triangulate the information and to get some information which could not be gathered through the other methods mentioned. The advantage was that the researcher had a direct contact with the situation and permitted test on reliability of responses to questionnaires. Further clarifications were done in the field by plant operators who have the experience and technical knowledge of the wastewater systems. Some of the ways used to get information from key informants included telephone interviews, personal interviews, and group interviews. The Superintendents of the wastewater treatment systems were interviewed in order to know more about how their systems operated and how they were running and maintaining their wastewater treatment systems. The main purpose was to ascertain the level of knowledge they had, especially when it came to how they measure their wastewater influent and the challenges they encountered during operations. 32 key informant interviews were done for the towns which were not measuring their influent, at the wastewater treatment systems; demonstrations were done on how they could measure using the flow measuring structures in place such as flumes.

3.3.4 Reliability Score

Accuracy of data collected in councils was checked and verified during the data collection. For each main indicator, a reliability score was given depending on the source of the data. The reliability score indicates the accuracy of the data and what needs to be done in terms of data management in order to provide accurate data whenever it is required for different uses. The highest preferred score was a score of 1 and any score besides one showed some challenges in data management and the data needed to be treated with care. The lowest score was a score of 4 and this meant that the data was unreliable and there was not any form of management of the data. Where the data was not readily available and reliable; the approach used to ameliorate this was to define data reliability methods based on calculation methods as is the norm in normal engineering practice.

Reliability score 1 was given a horizontal brick pattern, reliability score 2 shingle pattern, reliability 3 small grid pattern, reliability 4 solid diamond and where the data had no supporting evidence a black colour was used. Figure 3.3 shows the colours of reliability scores.

Table 3.2 Reliability scores

KEY	PATTERN TYPE	RELIABILITY SCORE
	Horizontal Brick	**1**
	Shingle Pattern	**2**
	Small Grid	**3**
	Solid Diamond	**4**
	Black	**Not scored**

The details of the explanations of the reliability scores are given in Appendix 2.

3.4 Data Analysis and Presentation

The performances of the local authorities were assessed based on wastewater indicators adapted from the Government of India for benchmarking of wastewater services (GoI, 2008). The findings were supported by information gathered from key informants, annual reports, financial statements, inception reports, wastewater flows records and water production records. The data was presented by population size of the towns and cities. This entails that in graphical representations, the towns with the highest population were presented first going downwards to the town with the least population. Data was presented in the form of tables, pie charts, and bar graphs. The graphs were colour coded to show the reliability of the data supplied by councils.

Data cleaning was done manually before analysis. Statistical analysis was done using the measures of central tendency. These are ways of representing some important aspects of the data set by a single number. The measures of central tendency used were the mean and the median. The mean was obtained by adding all percentages for all towns per each indicator and divided by the total number of towns that had reliable data available. The median is the central value when all the percentages are arranged in order of size.

Data analysis was done using Microsoft Excel and SPSS. The Pearson's Product Moment Correlation was used in checking for correlations between indicators. It explains if there is a significant relationship between two indicators. If P>0.05means that there is a correlation between indicators. Table 3.2 shows the ranges and interpretations of correlations according to Rumsey (2008).

Table 3.3 Ramsey 2008 Interpretations of correlation coefficients.

Range	*Interpretation*
0 to 0.29	Weak positive correlation
0.3 to 0.69	Moderate positive correlation
0.7 to 0.99	Strong positive correlation
1	Perfect positive correlation
0 to -0.29	Weak negative correlation
-0.3 to -0.69	Moderate negative correlation
-0.7 to -0.99	Strong negative correlation
-1	Perfect negative correlation

4. RESULTS AND DISCUSSIONS

The results obtained after the analysis of data collected from councils indicate that there is little or no effective wastewater management in most towns. Six indicators were used in the assessment of wastewater management in all the towns. Tables 4.1 and 4.2 show summaries of results for wastewater management indicators, showing the levels of reliability of data used. The reliability scores were explained in detail in section 3.3.4.

Table 4.1 Spearman's correlation coefficient and significance values (p<0.05) for wastewater management indicators

		Coverage of Functional Toilets	Coverage of sewerage network	Efficiency in collection of sewage	Adequacy of capacity for treatment of Sewage	Quality of Sewage treatment	Extent of recycling or re-use of sewage
Coverage of Functional Toilets	Correlation Coefficient	1.000	.734**	.306	.175	.221	-.086
	Sig. (2-tailed)	.	.000	.167	.346	.267	.644
	N	31	31	22	31	27	31
Coverage of sewerage network	Correlation Coefficient	.734**	1.000	.476*	.333	.353	.148
	Sig. (2-tailed)	.000	.	.019	.058	.061	.410
	N	31	33	24	33	29	33
Efficiency in collection of sewage	Correlation Coefficient	.306	.476*	1.000	.468*	.497*	-.032
	Sig. (2-tailed)	.167	.019	.	.021	.026	.880
	N	22	24	24	24	20	24
Adequacy of capacity for treatment of Sewage	Correlation Coefficient	.175	.333	.468*	1.000	.066	.180
	Sig. (2-tailed)	.346	.058	.021	.	.733	.315
	N	31	33	24	33	29	33
Quality of Sewage treatment	Correlation Coefficient	.221	.353	.497*	.066	1.000	.191
	Sig. (2-tailed)	.267	.061	.026	.733	.	.320
	N	27	29	20	29	29	29
Extent of recycling or re-use of sewage	Correlation Coefficient	-.086	.148	-.032	.180	.191	1.000
	Sig. (2-tailed)	.644	.410	.880	.315	.320	.
	N	31	33	24	33	29	33

Table 4.2 Summary of wastewater indicators showing the level of reliability of data used for six indicators

Town/City	Coverage of Functional Toilets	Coverage of sewerage network	Efficiency in collection of sewage	Adequacy of capacity for treatment of Sewage	Quality of Sewage treatment	Extent of recycling or re-use of sewage
Harare	1	1	4	3	2	1
Bulawayo	1	3	4	3	4	2
Chitungwiza	4	3	4	4	4	4
Mutare	1	0	0	0	4	2
Epworth	4	3	0	0	4	4
Gweru	0	0	0	0	3	4
Kwekwe	1	0	0	0	4	4
Kadoma	0	0	0	0	4	4
Masvingo	4	3	4	2	4	4
Chinhoyi	0	0	0	0	4	4
Marondera	1	1	4	0	4	4
Norton	4	3	0	0	0	4
Ruwa	1	1	3	0	2	4
Chegutu	0	0	0	4	4	4
Zvishavane	1	1	4	2	3	4
Bindura	4	4	0	0	4	4
Beitbridge	1	1	4	0	3	3
Redcliff	2	2	4	4	3	4
Hwange LB	0	0	0	0	4	4
Hwange Colliery	0	0	0	0	3	3
Victoria Falls	0	0	0	0	3	4
Rusape	2	2	3	3	4	4
Chiredzi	1	1	4	4	4	4
Kariba	0	0	0	0	4	4
Chipinge	2	2	4	0	4	4
Gokwe	0	0	0	0	4	4
Shurugwi	0	0	0	0	4	4
Gwanda	0	1	0	4	4	3
Karoi	0	1	0	0	4	4
Plumtree	4	3	4	4	4	3
Mvurwi	4	0	4	0	4	4
Chirundu	0	0	0	0	4	4
Lupane	1	0	0	0	4	4

4.1 Extent and Challenges of Urban Sanitation Coverage in Zimbabwe

4.2.1Coverage of toilets

In this study, results showed that in 2012, Zimbabwe had an average toilet coverage of 83.3±21.4%. This figure excludes Ventilated Improved Pit latrines (VIP) and ordinary pit latrines which are not recommended for cities and towns by the Urban Council's Act of Zimbabwe. This is lower than the international target of 100% (GoI, 2008). Fig 4.1 represents the sanitation coverage for all towns and cities of Zimbabwe. According to JMP (2013), Zimbabwe in 2011 had an average coverage of improved sanitation at 96%, based on population whilst the 83.3% is based on properties. The coverage was higher than that of Tanzania at 47%, Madagascar at 49% and Mozambique at 49% in Sub Saharan countries. Other Sub Saharan countries with close to achieving 100% coverage include South Africa at 93%, Malawi at 95%, and Ghana at 91% according to JMP (2013). The JMP definition of improved sanitation is different from that used in Zimbabwe. JMP defines improved sanitation as anything that can separate human faeces from human contact whilst that of Zimbabwe refers to flushing toilet systems in urban areas. Universal access to functional toilets within a reasonable walking distance is key to the improvement of service levels of sanitation facilities. In many Zimbabwean towns, there are inadequate functional toilet facilities.

The coverage of functional toilets of 83.3% indicates that the remaining 16.7% was either representing unimproved sanitation facilities, ventilated pit latrines, pit latrines, and open defaecation, which are not accepted in urban areas of Zimbabwe (GoZ, 2013b). The low coverage of improved toilet facilities could be a result of the low coverage of the sewerage network systems. The result shows that there was a very strong positive correlation ($p=0.000; R=0.734$) between the coverage of toilets and the coverage of the sewerage network services. An increase in the coverage of the sewerage network systems could lead to more improved toilets connections.

The reasons for the use of unimproved sanitation facilities could be lack of enforcement of development control, which has led to the development of slums and squatter camps within the peripheries of cities and towns; parallel development, where the government has allowed residents to stay on their properties before the stands are serviced; lack of sanitation technologies that are simple and affordable to construct; high water table and flood prone areas, water scarcity and topography. It was concluded that the sanitation coverage of toilet facilities in urban councils of Zimbabwe was low compared to the international standard of 100% coverage. It was recommended that councils revisit their policies in line with the Sanitation and Hygiene Strategy of 2011 and the National Water Policy of 2013 of acceptable standards of types of toilets to be used in urban areas of Zimbabwe.

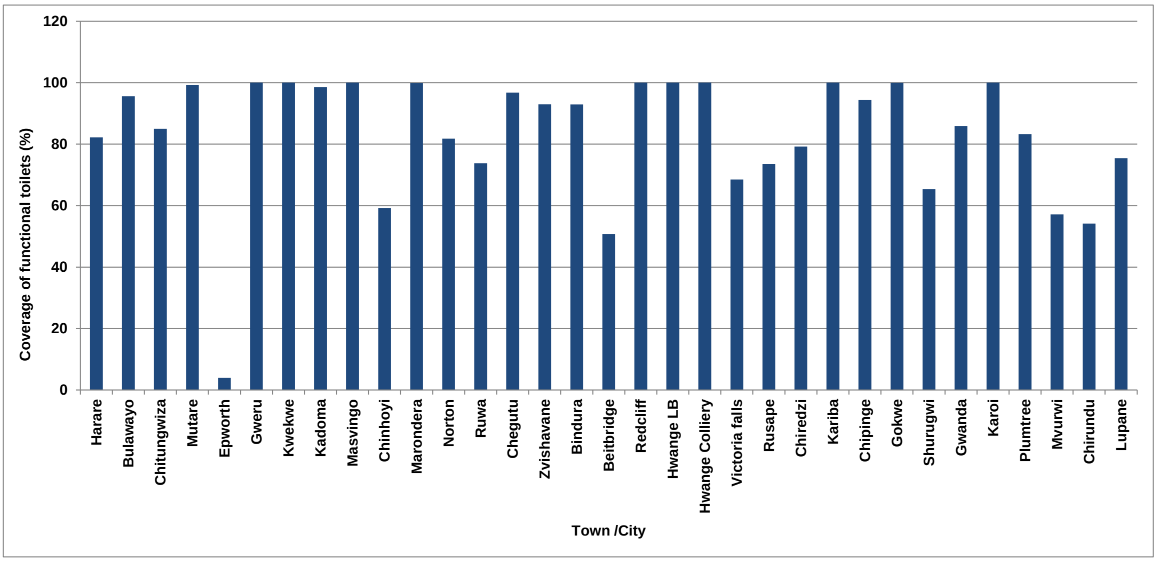

Figure 4.1 Coverage of toilets in urban areas of Zimbabwe

4.2.2 Coverage of sewerage network services

The indicator on coverage of sewerage network services was on average 68.7±27.3%. The sanitation system is being worsened by developments within the peripheries of towns. For instance, in Harare, there were some developments within the peripheries of the town such as Rydale Ridge and Granary with their own treatment plants discharging into Lake Chivero, which is a source of drinking water for Harare. In some Zimbabwean towns, sewage flows through storm water drains and open drains are posing serious public health hazards. Other sanitary on-site facilities such as septic tanks and ecological sanitation were appropriate options used in some towns. The indicator, therefore, does not imply that sewerage is the only option for safe liquid waste management. The international target figure of 100% was considered (van den Berg and Danilenko, 2011).

Figure 4.3 shows other types of onsite and offsite sanitation facilities used in Zimbabwe. The coverage was far more than that of Malawi which had a sewerage coverage of 10% (Manda, 2009). The low coverage of the sewerage network services has an impact on the number of sewer connections in an area. If the coverage is low, it means that there will be less sewer connections. This has resulted in the problem of construction of septic tanks on stand sizes which are less than 1,000 m^2. In Chitungwiza, for example, septic tanks were prominent on 200 m^2, some of which were close to shallow wells providing drinking water. The average figure of 16% of VIPs and pit latrines, coupled with 1.3% of open defaecation confirm the low coverage of sewerage network services. Other reasons for the low coverage in Zimbabwe were those of high water tables and flood prone areas, water scarcity, topography, inadequate and overloaded wastewater treatment plants; lack of simple, acceptable and affordable technologies of wastewater treatment facilities. Figure 4.2 represents the coverage of the sewerage network services in urban towns and cities of Zimbabwe.

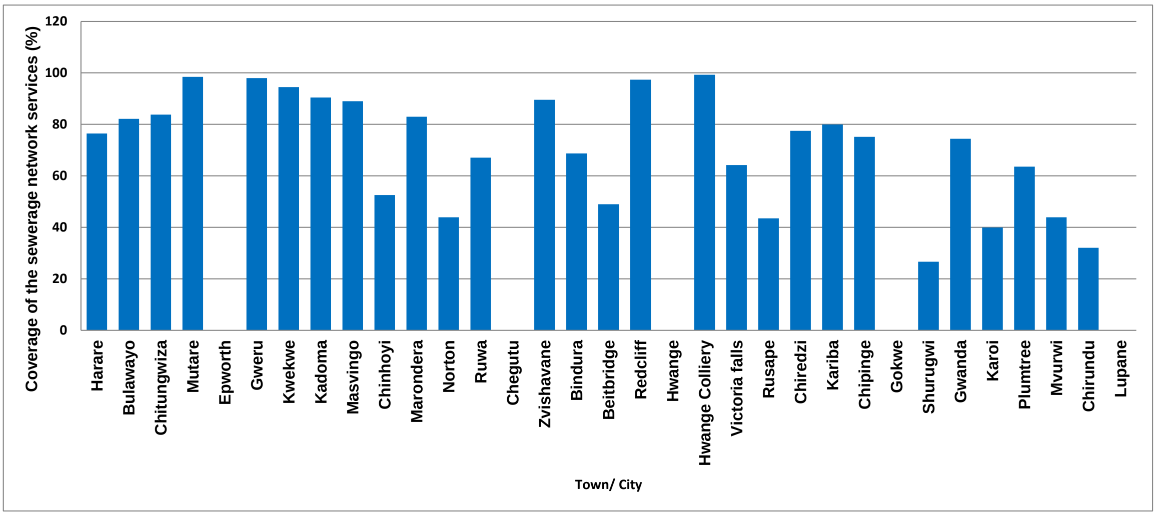

Figure 4.2 Coverage of sewerage network systems in urban areas of Zimbabwe

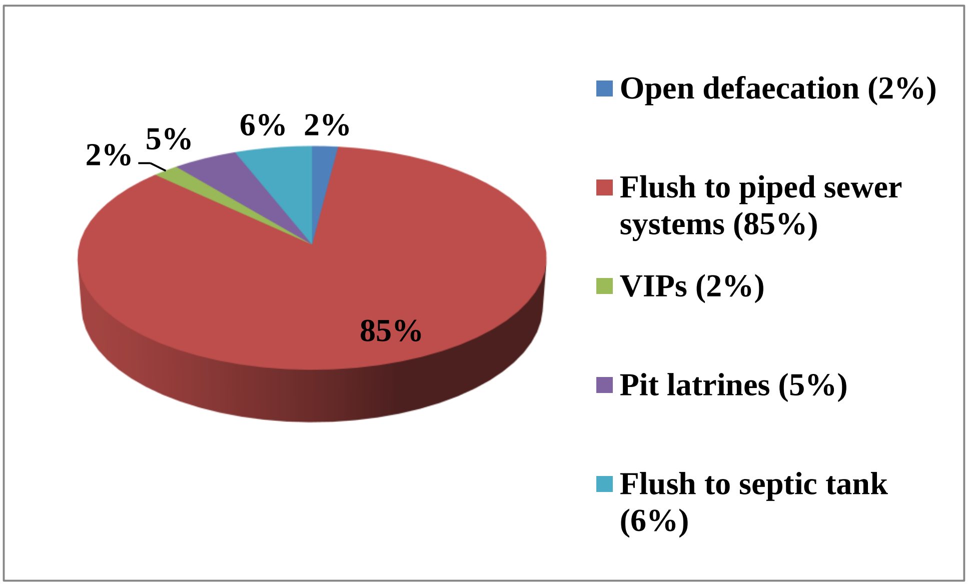

Figure 4.3 Onsite and offsite sanitation technologies

Towns such as Epworth, Chirundu, Gokwe, and Lupane had low coverage of 0% because they are entirely on septic tanks and ventilated pit latrines which are not acceptable to Zimbabwean standards. For Chegutu and Hwange, the property stock was not readily available and with the time limitation of the study, it was not possible to carry out an exercise to establish properties that were connected to the sewerage system and the total numbers in the sewerable areas. It was therefore, concluded that the coverage of sewerage network services in sewerable urban areas of Zimbabwe was low. The recommendations were that Local Authorities use tried and tested low cost technologies that have been used in different settings with success and decentralize treatment and reuse of sewage.

4.2.2 Causes of low sanitation coverage

The causes that resulted in the low sanitation coverage include lack of enforcement of development controls in urban areas, parallel development, lack of simple and acceptable technologies. Because of the past decade of economic meltdown in Zimbabwe, there has been an enormous rural to urban migration of people in search of better living standards and employment. Epworth has been a target by many because of cheap accommodation and its closeness to the capital city, Harare. Many in Epworth live on illegal areas and on private property of the Methodist Church where the council has no control over. As shown in Fig.4.4, many illegal settlers are on rocky and swampy areas which cannot be sewered even if the council formalizes the settlements. Many are therefore relying on onsite facilities such as VIPs and pit latrines.

Rapid urbanization due to population pressure in towns in search of employment opportunities and better living standards by the jobless populace has also led to the development of onsite facilities such as septic tanks on stands below 1,000 m^2. Fig. 4.5 shows a septic tank with a white vent pipe close to the main property on a residential stand which is 200 m^2. Some properties in Manyame Park of Chitungwiza were developed in areas which are below the outfall sewers and they cannot be connected to the existing sewerage systems. The option is that of pumping the sewage but it is expensive and not sustainable in the long run.

The Government of Zimbabwe through the Ministry of Local Government, Public Works and National Housing allowed property owners in urban areas to develop their properties whilst they stay on the same properties before servicing of the stands. This has resulted in the use of unimproved toilet facilities such as the traditional pit latrines, ventilated pit latrines and ecological sanitation toilets. Most councils in urban areas cannot extend sewerage services to the new developed areas because some of the wastewater treatment systems are overloaded and can no longer accommodate new developments. Also funds are not available to develop new wastewater treatment systems. Fig 4.6 shows a property under construction in an unserviced area in Chitungwiza. The owner of the property stayed on the same property before the sewerage services were extended to the area. A pit latrine was being used as a toilet.

Figure 4.4 Illegal developments in unsewerable areas in Epworth (swampy and rocky areas) due to exorbitant rentals in the capital city of Harare

Figure 4.5 Septic tank in a high density area of Chitungwiza (less than 1,000 m^2 stand size).

Figure 4.6 Property developed before area serviced with sewerage system in Chitungwiza after a government policy which encouraged property owners to stay on the properties before they are serviced with water, sewerage and roads infrastructure.

In Zimbabwe, conventional wastewater treatment systems are used for treating sewage. The biological nutrient removal systems, trickling filters as well as waste stabilisation ponds are used for treating sewage. The BNR systems and trickling filters are expensive systems to construct, run and maintain especially in some African countries which require huge capital for projects of such a magnitude (Gustaf *et al.*, 2005). In the 1990s, Zimbabwe had moved from the waste stabilisation ponds and trickling filters because they required more land even though they were cheap to maintain. BNR systems were seen as being effective in treating wastewater and requiring less land. Fig 4.7 shows a BNR system in Marondera which was abandoned before completion because of lack of funds. Mutare and Redcliff also have uncompleted BNR systems due to lack availability of funds to complete the construction. If the system was completed, it could accommodate a number of suburbs that are not yet connected in Marondera. All towns and cities in Zimbabwe with BNR systems have challenges in maintaining them and therefore all are partially or not working. Simple technologies such as waste stabilisation ponds and constructed wetlands can be used to increase the coverage of sewerage network systems and toilets.

Figure 4.7 Biological nutrient removal wastewater treatment plant in Marondera still under construction after financial resources were exhausted about a decade ago.

4.3 Extent and Level of Collection of Sewage in Urban Areas of Zimbabwe

4.3.1 Efficiency in collection of sewage

The research indicates that, on an average, only 37.4±29.6% of the wastewater generated is collected by the sewerage system in the urban councils of Zimbabwe against an international target of 100% (GoI, 2008). The percentage was based on valid data from records at the wastewater treatment systems. Some towns had no form of any record because most wastewater treatment systems are either not functional or are fully functional. While the coverage of sewage network systems may be important, their effectiveness in capturing the sewage is equally important. The indicator for the efficiency in collection of sewage signifies the importance of the sewage network in capturing and conveying sewage to the wastewater treatment systems. A sewage network system, even if effective and efficient in collection of sewage, has to have a treatment system at the end of pipes. Establishing a more accurate figure was difficult even where the water billed was used in sewered areas because of unknown quantities of water from sources such as boreholes and wells. Basic flow measurements were done in Chipinge, Chinhoyi and Kariba but the figures were suppressed in statistical analysis to avoid abnormal figures since measurements were done during the rainy season. The sewage measured was diluted by stormwater due to stormwater ingress in sewerage network systems. The average of 37.4% excludes towns that are entirely on septic tanks such as Lupane, Gokwe and Epworth. There was a moderate correlation ($p=0.021;\ R=0.468$) between efficiency in sewage collection and the adequacy of capacity of treatment of the sewage. If more sewage is collected and conveyed to wastewater treatment plants exceeding the design treatment capacity, the capacity of the treatment plants to treat sewage might be altered, thereby affecting the quality of the sewage effluent produced. High efficiencies means less sewer overflows into rivers through blockages and leaking pipes. There was also a moderate positive correlation ($p=0.026;\ R=0.497$) between efficiency in collection of sewage and the quality of sewage. However, the relationship was not significant.

This result indicates that the sewerage system has only a limited capacity to collect wastewater or that the entire population for which the system has been designed has not obtained connection to the system. The low coverage by sewers in urban towns and cities could be the reason for the low collection efficiency (GoI, 2005). Fig 4.8 illustrates the collection efficiencies for urban councils of Zimbabwe.

The low efficiency coverage could also have resulted from the operation side of the systems; lack of maintenance which results in sediment built-up in sewer lines, causing overflows in manholes (Sauramba *et al.*, 2009), and ageing infrastructure which could result in leakages. The average blockages per 100 km were 217 compared to the international standard of 215 blockages per 100 km. The blockages were close to the acceptable international figure but this was rather high considering the sizes of the sewerable areas in Zimbabwe. South Africa has an average of 33 blockages per 100 km which is also above the international standard. The actual figures for blockages were difficult to get because some of the blockages were not recorded and these were obtained from council records only. Household interviews could not be conducted because of the limited time of the study. The record keeping systems in councils were not efficient because they mixed complaints for blockages, solid waste, and pipe bursts. In some towns monthly averages had to be estimated with the assistance of council plumbers and superintendents. Fig 4.9 shows the blockages of 21 urban councils of Zimbabwe which provided the data. In 2012, the number of blockages per 100 km reflected that the employees were doubling their efforts, meaning that they were overworking. An average of 2 employees per thousand for urban councils of Zimbabwe reduces labour productivity. The sewer blockages could have been a result of displaced joints in pipes or cracks that allow soil or plant roots to form an initial obstruction (GoA, 2004). It becomes worse when the blockage obstructs solids from the sewage. It was concluded that the efficiency collection of sewage in Zimbabwean urban areas was low and the recommendations made were that council measure wastewater flows on a daily basis since wastewater flows fluctuate depending on the season of the year and time of the day, measuring of water supplied from other sources besides council water supply system and also rehabilitation of the collection system since most sewage was not arriving at the wastewater treatment systems.

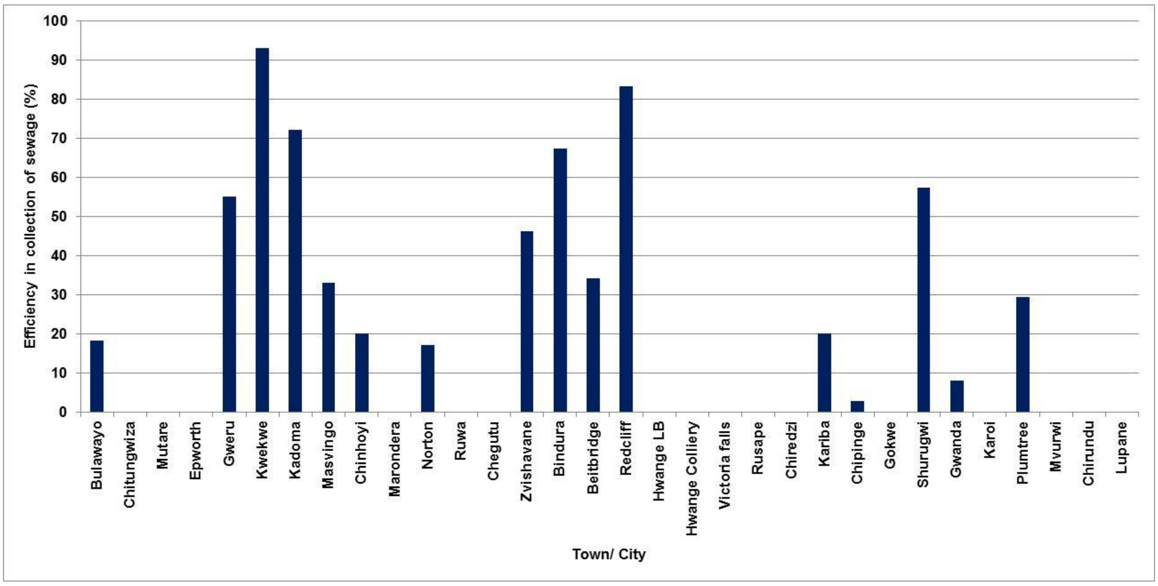

Figure 4.8 Efficiency in collection of sewage in urban areas of Zimbabwe

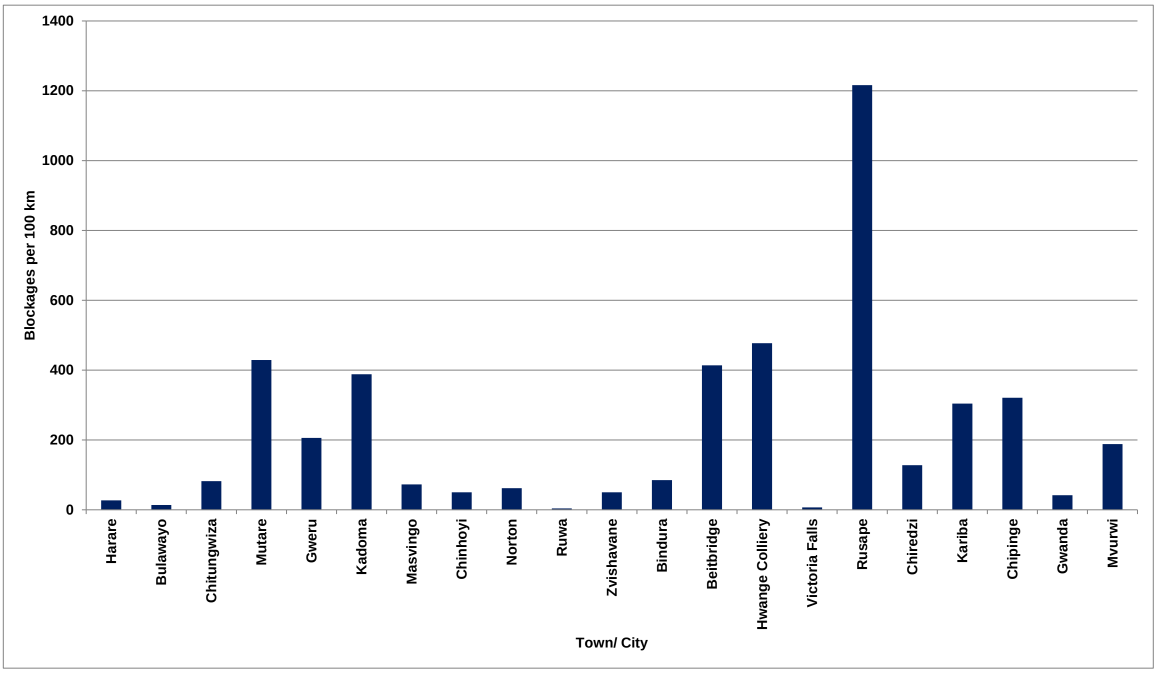

Figure 4.9 Reported sewer blockages per 100 km in urban areas of Zimbabwe

4.3.2 Staff per 1,000 connections of sewage

On average, there were 2 employees per 1,000 connections in the sewerage system against an international target of 8 for water utilities, which is too low for international targets proposed by the Pacific (PWWA, 2012). Labour Productivity refers to the cost of labour input in the daily operation of a utility measured as the ratio of inputs and outputs. The average figure of 2 employees per 1,000 connections in Zimbabwe included all employees with a direct input to wastewater services. Senior management, such as Town Engineers, were included because they have a fraction of their time which they spend in wastewater management. The categories of staff used were engineers, technicians, superintendents, plumbers, general hands, fitters; efficient water utilities recommend 2 employees because some of the work will be hired out. Australian water utilities have staff per 1,000 connections at 1.8 whilst the Pacific has 8 staff per 1,000 connections for water and wastewater sections. Zambian water utilities have staff per 1,000 connections at between 5 to 9, which is within the international targets of 8 staff per 1,000 connections. The low efficiency in the collection of sewage indicates that there is lack of maintenance taking place because of manpower with an employee doubling the load of over 400 connections. The general cleaning of sewers was not possible because employees could be attending to emergencies like pipe leakages and collapse.

Fig 4.4 shows the staff per 1,000 connections in sewage. Chipinge has a large number of general hands who are not only for wastewater management but who work in other departments such as roads and refuse collection. For Chitungwiza, the number is high because they have a large number of revenue clerks exceeding a hundred and also non skilled workers.

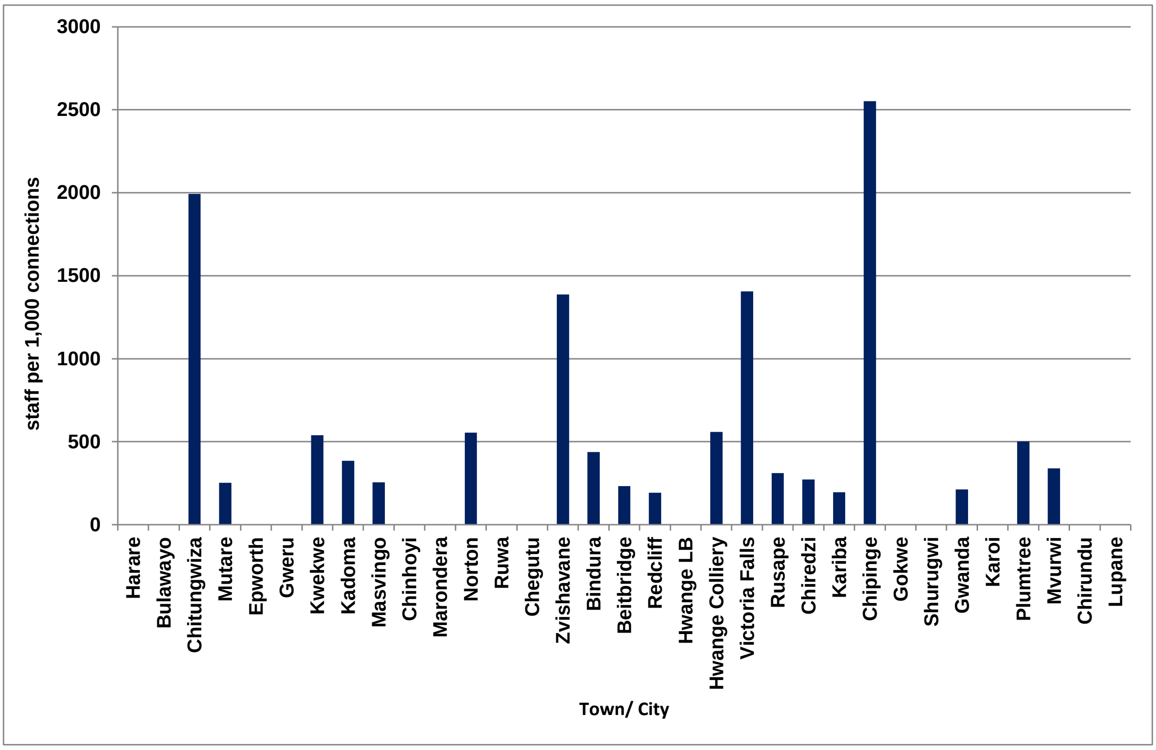

Figure 4.10 Staff per 1,000 connections

4.3.3 Problems associated with low efficient collection of sewage

The problems that could have contributed to the low collection efficiencies include; poor workmanship in construction of sewerage network systems, blockages of sewerage systems by sediments, tree roots, grease and oils, lack of appropriate equipment for maintenance purposes, minimum supervision of employees and ageing of wastewater systems allowing wastewater to seep through into the ground.

Economic challenges and high tariffs have forced some urban residents to hire unskilled and unregistered plumbers to connect them to the sewer systems. Fig 4.11 shows a property in Chitungwiza where unskilled council officials were hired to connect a property to a sewer system and such poor workmanship could have led to low collection efficiencies of sewage in urban areas of Zimbabwe. Shoddy work or poor workmanship causes silt to enter sewerage systems and block the systems, leading to the collapse of some sections of a sewerage system. Some systems are ageing and coming to the end of their lifespan. These become ineffective in the collection and conveyance of the sewage.

This has been a common phenomenon in most councils, hampered with little or no equipment such as jetting machines for general maintenance of infrastructure.

Most infrastructures in towns and cities are ageing. Some towns have wastewater systems that are between 50 to 100 years old. Councils are not replacing and upgrading the wastewater systems and this has reduced the collection efficiencies of sewage. Most sewer lines have outlived their life spans and need replacement. Rapid population growth in towns and cities has resulted in overloading of wastewater systems. With the current power outages the country is experiencing, most residents use firewood for cooking. Sand is being used for cleaning pots, thereby finding its way into sewerage systems.

Figure 4.11 Poor workmanship in sewer connections can cause silt to enter and block sewerage network systems

Common blockages are caused by fats, oils, grease, tree roots and other foreign objects. When hot fats, oils and grease are discharged into the sewerage network systems, they easily get solidified before being transported for long distances and thereby result in blockages. Some foreign objects like tree roots, logs and rocks also result in pipe blockages.

Lack of maintenance has resulted in overflows of sewage through manholes into river systems and non-replacement of pipes has resulted in the leaking of sewage and pollution of groundwater systems. With an average blockage of 217 per 100 km per annum against an international standard of 120 blockages per annum, it shows very little is being done in the area of maintenance. The blockages are far less than those of South Africa which averages 330 blockages per annum (GoSA, 2012). The routine and general maintenance of sewer lines includes cleaning or flushing of sewer lines, pumps and pipe replacement.

4.4 Adequacy of Current Capacity of Treatment of Sewage in Urban Areas of Zimbabwe

4.4.1 Adequacy of treatment of sewage

The average adequacy of treatment capacity of urban councils of Zimbabwe was determined to be 161.5% against an international target of 100% (GoI, 2008). The indicator highlights the adequacy of available and operational sewage treatment capacity. What it meant was that the design capacity of the treatment plants was much less than the potentially generated sewage, basing on the 2012 water consumption levels. However, the result was affected in that water supplies were suppressed due to water unavailability in most towns and also most of the capacities have been lost especially for towns with unmaintained waste stabilization ponds such as Rusape, Plumtree, Chiredzi and Karoi. With the growing population in towns, most Zimbabwean towns have inadequate capacity for treatment of sewage that is generated in their areas. The figures used were also in question as much was relied upon billed figures when the reality is that most towns had more than 50% of household meters not working. The functional capacities were the best to use but it was beyond the scope of this study to determine them. The water consumption figures for Zimbabwe of an average of 135 L/capita are higher than those of international standards, thereby affecting the capacities of the treatment plants. Fig 4.13 shows the adequacy of treatment of sewage. The average indicates that most of the wastewater treatment systems are overloaded. 14 of the urban councils are overloaded. There is a moderate correlation ($p=0.021; R=0.468$) between the adequacy of capacity of treatment of sewage and efficiency in collection. The relationship is not a strong and significant relationship in that the ability of a sewage network system to collect and convey sewage to the treatment plant does not mean that there will be adequacy of treatment of sewage.

The result was far exceeding the benchmark set by town council officials of Zimbabwe for the adequacy of treatment of sewage of 100%. Taking the 75th percentile, 25% of councils are capable of reaching 240%. This means that 25% of councils are prone to overloading and the wastewater treatment systems must be upgraded and expanded to accommodate new developments.

With a total population of about 4,062 million and a daily consumption of per capita water of 135 L in all urban areas of Zimbabwe, the water requirement was 200, 4 x 10^6 m^3/year, excluding Epworth and Lupane which did not have waterborne infrastructure; the wastewater generated was 144, 3 x 10^6 m^3/year. The design capacity of wastewater treatment systems in urban areas was 206, 7 x $10^6 m^3$/year. The results showed that the wastewater treatment systems had the capacity to treat more sewage. Of all the 32 councils, 14 councils had overloaded wastewater treatment plants. For towns such as Plumtree and Rusape, the waste stabilization ponds could have reduced capacities due to the excessive proliferation of weeds.

Overloading of wastewater treatment plants alters the treatment processes in the wastewater treatment system and thus resulting in raw sewage discharge into river systems (GoA, 2004). Raw sewage discharge into river systems has the potential of causing environmental effects to aquatic systems, and public health harm. The BNR systems rely on intensive power for them to operate. When there were problems of power cuts, most wastewater was bypassed through wastewater treatment systems into river systems untreated. The BNR systems were the more affected than waste stabilization ponds which required less electricity or none. The probable causes of overloading included; wastewater generated in urban areas due to rapid urbanization, storm water ingress through manholes, more water supplied through use of boreholes, wells and possibly springs, lack of maintenance of wastewater treatment systems, and the overestimated water consumption.

It was concluded that 14 towns had overloaded wastewater treatment systems and the recommendations were that councils manage the demand for water and postpone the need for new investments and also determine the operational capacities of wastewater treatment plants.

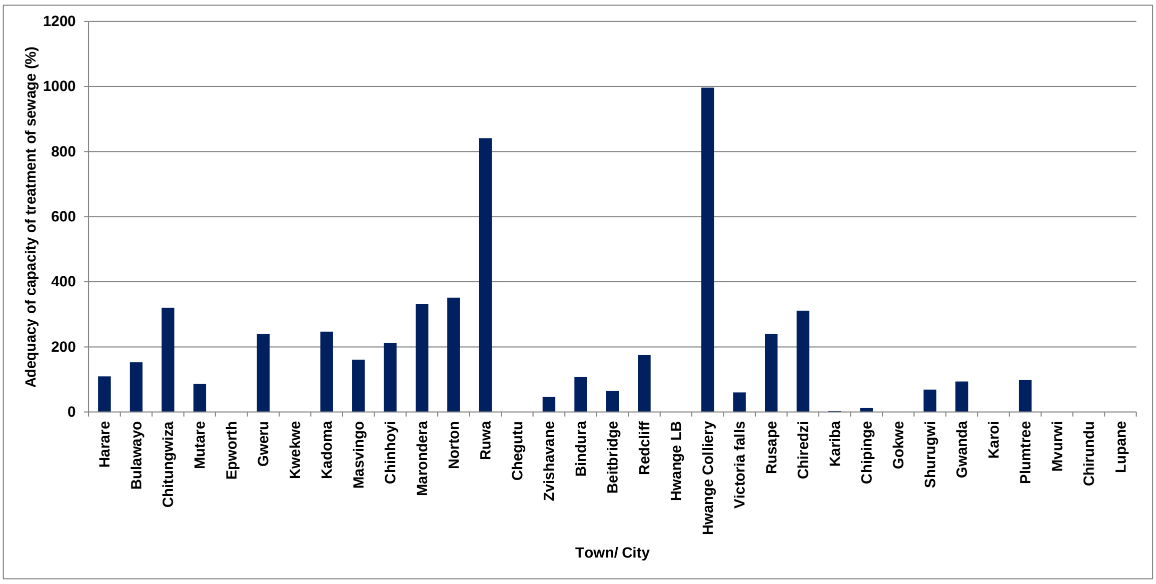

Figure 4.12 Adequacy of capacity of treatment of sewage in urban areas of Zimbabwe

4.4.2 Extent of recycling or reuse of sewage

The average figure for the extent of recycling and reuse in Zimbabwe was determined to be 2.9%, which was far less than the international target of 20% (GoI, 2008). In wastewater management, sewage can be reused after appropriate treatment to acceptable standards. Treated effluent can be used for watering of public parks, watering of school grounds, watering of gardens and pasture irrigation. Figure 4.15 represents the averages for the councils recycling and using wastewater in Zimbabwe. Six councils: Plumtree, Gwanda, Beitbridge, Harare, Mutare, Hwange, and Bulawayo and one water utility company (Hwange Colliery) were having some form of recycling and reuse. Chitungwiza used to pump its sewage to Imbga Farm but at the time of the study, no sewage had been pumped to the farm for almost a decade. The sewage effluent was used for pasture irrigation before the land reform in Zimbabwe. It was noted that all sewage treatment ponds in Zimbabwe were designed with accompanying pieces of land for effluent reuse. However, the shortages of land for housing has seen the encroachment of urban developments on the set aside pieces of land. The summary of the wastewater reuse is shown in Table 4.15.

The result was also far below the benchmark of 10% set for Zimbabwe by council officials. Proper maintenance of conventional wastewater treatment systems and waste stabilization ponds could produce better quality treated effluents that could be used for agricultural and irrigation purposes.

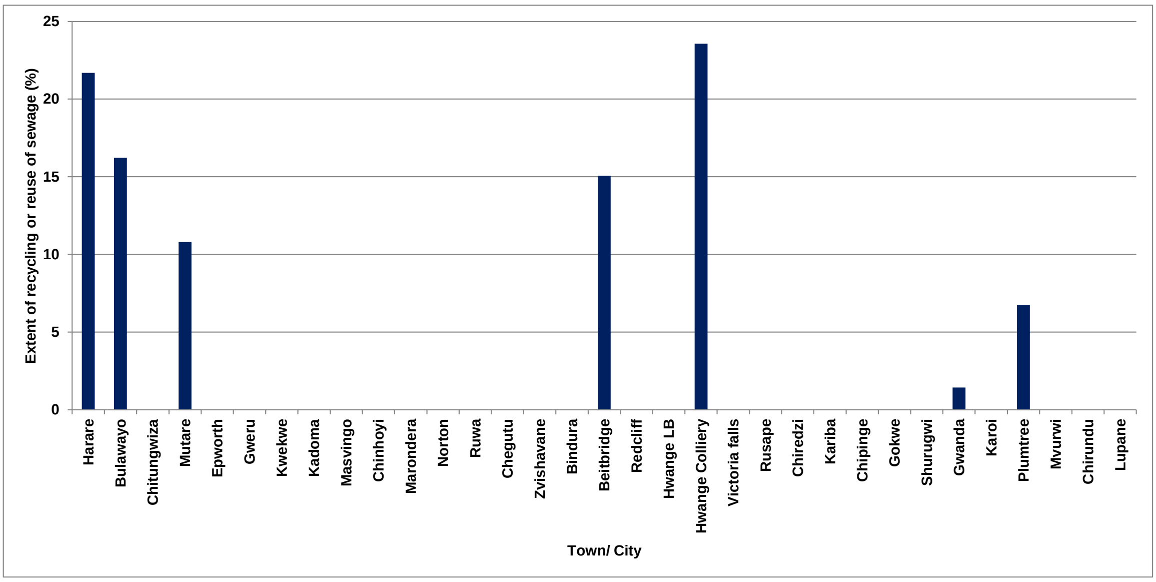

Figure 4.13 Extent of recycling or reuse of sewage in urban areas of Zimbabwe

Zimbabwe is failing to fully utilize the wastewater for non-potable uses to reduce usage of fresh water in order to protect the scarce water resources. Wastewater irrigation has, however, become a common practice in developing countries of Asia and Africa and also in water scarce regions of the developed world like Australia (Mekala *et al.*, 2008). The emergence of a global water crisis has seen the necessity of a sustainable approach to water management (Hurlimann, 2007). Public acceptance is seen as a key reason why water recycling technology is accepted or rejected (Stenekes *et al.*, 2006). Some countries are using wastewater for groundwater recharge to improve the scarce water resources (Aiken and Kuniansky, 2002). The potential to use wastewater is there (Jimenez and Asano, 2008), but there is still a controversy between the defenders of strict water quality standards for an absolute protection of public health and the defenders of a pragmatic stance recognizing existing wastewater reuse practices and promoting non-potable water uses with less restrictive water quality standards (Angelakisa *et al.*, 1999).

The failure to recycle and reuse wastewater by most councils could have been that (i) most irrigation land for pastures in most councils was used for other developments such as housing schemes, (ii) lack of marketing of sewage, especially after the land reform in the last decade in Zimbabwe, (iii) the negative perception new farmers had about using wastewater for irrigation purposes and (iv) lack of maintenance of wastewater treatment systems and recycling equipment. Fig 4.16 show gardens under irrigation in Chiredzi and Zvishavane.

Table 4.3 Use of recycled water in urban areas of Zimbabwe

Name of Council	***Nature of recycling***	***Description of reuse***
Harare		Irrigation of pastures
Bulawayo	Reclaimed water used for watering public parks and school grounds	Irrigation of pastures, tree plantations
Beitbridge		Irrigation of pastures
Hwange Colliery	Reclaimed water used in cooling towers	
Gwanda		Irrigation of pastures
Plumtree		Irrigation of pastures
Chiredzi		Irrigation of gardens
Zvishavane		Irrigation of gardens

Figure 4.14 Informal irrigation of gardens using wastewater effluents in Chegutu town

With little or no wastewater recycling or reuse taking place in most council, it was concluded that wastewater reuse was not seen as a way of augmenting water demands for agriculture and the industries in Zimbabwe. The recommendation was the need to market and raise awareness of farmers on the benefits and safe handling of wastewater in irrigation and develop a wastewater reuse strategy.

5.CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions were drawn from this study:

1. According to the policies and legislation of Zimbabwe, the sanitation coverage of toilet facilities in urban local authorities was low compared to the international standard. Urban Councils' bylaws of Zimbabwe do not allow the use of improved ventilated pit latrines in urban areas thereby contributing to the reduction of the urban sanitation coverage.

2. The coverage of the sewerage network services in sewerable urban areas was low compared to the international standard. The government allowed property owners to stay on their properties before services were extended to most urban areas because of housing challenges in the country. Funds for servicing were either channeled to salaries or eroded by the inflationary environment the country experienced in the last decade.

3. Efficiency in collection of sewage in urban areas was low compared to the international standard. Sewage was however being collected but most of it did not arrive at the wastewater treatment plants because of blockages and leaking pipes.

4. Staff per 1,000 connections of sewage was low, far from the international standards. The staff directly related to sewerage operation and maintenance was low or not dedicated for the section in most councils.

5. Fourteen urban councils had overloaded wastewater treatment systems.

6. Wastewater reuse was not seen as a way of augmenting water demands for agriculture and industries in Zimbabwe as most sewage in most towns was being discharged as raw sewage into rivers and streams.

5.2 Recommendations

1. There is need to review policies and legislation in line with the Sanitation and Hygiene Strategy of 2011 and the National Water Policy of 2013 on acceptance standards of toilets to be used in urban areas of Zimbabwe in order to increase the sanitation coverage of toilets facilities.

2. Local authorities to use tried and tested low cost technologies that have been used in different settings with success and decentralize treatment and reuse of sewage.

3. Wastewater flows arriving at the wastewater plants to be measured on a daily basis since wastewater flows fluctuate depending on the season of the year and time of the day. Water from other sources, especially groundwater sources, must be measured. Routine maintenance of is required inorder to reduce sewer overflows through blockages and leakages.

4. Councils to increase human resources directly related to sewerage operation and maintenance in order to improve service delivery. In-house training of general hands and deploying them to the sewerage section of councils can go a long way to improve service delivery.

5. The demand for water has to be managed and the need for new investments be postponed. The operational capacities of wastewater treatment systems have to be determined, so as to expand the existing systems or develop new ones.

6. There is a need to market and raise awareness of farmers on the benefits and safe handling of wastewater in irrigation as a substitute for scarce fresh water for irrigation and also develop a wastewater reuse strategy.

REFERENCES

Adubofour, K., Obiri-Danso, K. and Quansah, C., 2013. Sanitation survey of two urban slum Muslim communities in the Kumasi metropolis, Ghana. Environment and Urbanization, vol 25(1): p. 189-207.

Aiken, G.R. and Kuniansky, E.L., 2002. U.S. Geological Survey Artificial Recharge. U.S. Geological Survey, Sacramento, California.

Angelakisa, A.N., Monteb, M.H.F., Bontouxc, L. and Asanod, T., 1999. The status of wastewater reuse practice in the Mediterranean basin: need for guidelines. Physics and Chemistry of the Earth, vol 33, issue 10: p. 201–217.

Beach, M., 2001. Water, Pollution and Public Health in China. The Lancet, vol 358: p. 735.

Bosch, C., Hommann, K., Rubio, G.M., Sadoff, C. and Travers, L., 2001. Water, Sanitation and Poverty: Poverty reduction Strategy.

Cairncross, S. and Feachem, R., 1983. Environmental Health Engineering in the Tropics. John Wiley & Sons, Chichester.

Carden, K., Winter, K. and Armitage, N., 2009. Sustainable urban water management in Cape Town, South Africa: Is it a pipe dream?, 34th WEDC International Conference. Carden, Winter & Armitage, Addis Ababa.

CASE, 2003. Municipal Cost Recovery in four South African Municipalities. p. 12.

Ceballos, B.S.O., Soares, N.E., Moraes, M.R., Catão, R.M.R. and Konig, A., 2003. Microbiological Aspects of an Urban River Used for Unrestricted Irrigation in the Semi-arid Region of North-east Brazil. Water Science and Technology, vol 47, no. 3: p. 51-57.

Choukr-Allah, R. and Hamdy, A., 2005. Wastewater treatment and reuse as a potential water resource for irrigation. page 2.

CSO, 2012. Census 2012: Preliminary Report, Zimbabwe National Statistics Agency, Harare.

CSS, 2012. U.S. Wastewater Treatment Factsheet, Michigan, pp. 1-2.

Dane, P., 2009. EBC’s benchmarking programme for water services: the art of benchmarking, Hennef, pp. 1-24.

Din, I.A.K.M., 2010. Towards Sustainable Sewerage Development - Sharing Malaysia's Experiences For Replication, Kuala Lumpur.

Dunsmore, D.J., 1986. Safety measures for use in outbreaks of communicable diseases. World Health Organization, Geneva.

Ehrlich, R.L., Philbrick, K.P., Steele, M.S. and Jacobson, J.A., 2006. Wastewater Capacity Management Plans. p. 1-46.

EPA, 2003. Land Capability Assessment For Onsite Domestic Wastewater Management. p. 1-16.

EPA, 2007. Handbook on Wastewater Management for Local Representatives. p. 1-148.

Fetter, C.W. and Holzmarcher, R.G., 1974. Groundwater recharge with treated wastewater, pp. 260.

Flores, A., Buckley, C. and Fenner, R., 2008. Selecting Wastewater Systems for Sustainability in Developing Countries, Edinburgh, pp. 1-10.

Fürhacker, M., 2009. Challenges and solutions for waste and wastewater reuse. p. 1-5.

GoA, 2004. Guidelines for Sewerage Systems, Sewerage System Overlows. In: NRMMC (Editor). Commonwealth of Australia, Melbourne, pp. 1-62.

GoI, 2005. Status of Water Supply, Sanitation and Solid Waste Management in Urban Areas. In: NIUA (Editor), New Delhi.

GoI, 2008. Handbook on Service Level Benchmarking. In: Urban-Development (Editor), New Delhi, India.

GoSA, 2012. The Green Drop Handbook: Towards Improved Municipal Management. Department of Water Affairs, Republic of South Africa, pp. 8.

GoZ, 2009. Multiple Indicator Monitoring Survey. Printflow, Harare.

GoZ, 2011. Zimbabwe Economic and Trade Revival Facility. Printflow, Harare.

GoZ, 2013a. National Water Policy. In: M.o.W.R.D.a. Management (Editor). Printflow, Harare.

GoZ, 2013b. The Urban Councils Act. In: M.o.L.G.R.a.U. Development (Editor). Printflow, Harare.

GoZ and UN, 2010. Country Analysis Report for Zimbabwe. Printflow, Harare, pp. 4-5.

Gustaf, O., Nielsien, M., Jensen, A. and Yuan, Z., 2005. Instrumentation, Control and Automation in Wastewater Systems. IWA Publishing, London.

Heberer, T., Reddersen, K. and Mechlinski, 2002. From municipal sewage to drinking water: fate and removal of pharmaceutical residues in the aquatic environment in urban areas. Water Science and Technology, vol 46 no. 3: p. 81-88.

Hurlimann, A.C., 2007. Is recycled water use risky? An Urban Australian community's perspective. Environmentalist: p. 84.

IFRRCS, 2010. Zimbabwe - Cholera: Emergency Appea, International Federation of Red Cross and Red Crescent Societies, Harare.

IPS, 2012. More Toilets in Zimbabwe, Better Livelihoods, INTER PRESS SERVICE (IPS), Harare.

IWSD, 2012. Guidelines for Urban Hygiene Promotion, Harare, pp. 6.

Jimenez, B. and Asano, T., 2008. Water Reuse, An international Survey of Current Practice, Issues & needs. IWA, London.

JMP, 2013. Progress on Sanitation and Drinking-water, World Health Organization, Geneva.

Kapur, D.S., 2007. What is ailing sanitation sector in India? WaterAid India, India, pp. 1 & 2.

Kirsten, E., 2004. A Review of Water Reuse and Recycling, with Reference to Canadian Practice and Potential: 2. Applications. 39: p. 13.

Kvamstrom, E. and Nusson, M., 1999. Reusing Phosphorus: Engineering Possibilities and Economic Realities. vol 33.

Lane, J., 2008. Improving sanitation is achievable. UN-Water, Geneva, Switzerland, pp. 1.

Maharashtra and Jnnurm, U., 2012. City Development Plan for Pune, Pune, pp. 13.

Manda, M.A.Z., 2009. Water and sanitation in urban Malawi: Can the Millennium Development Goals be met? A study of informal settlements in three cities, IIED, London.

Mara, D., 2004. Domestic Wastewater Treatment in Developing Countries. Earthscan. Earthscan, Chicago, p. 22 pp.

Mekala, G.D., Davidson, B., Samad, M. and Boland, A.M., 2008. Wastewater Reuse and Recycling Systems: , A perspective into India and Australia. International Water Management Institute (IWMI), Colombo.

Metcalf, L. and Eddy, H.P., 2004. Wastewater Engineering Treatment and Reuse. McGraw-Hill, New York.

Michael , J., Paul and Meyer, J.L., 2001. Streams in the Urban Landscape. 32: pp. 333-365.

Morella, E., Foster, V. and Banerjee, S.G., 2008. Climbing the ladder: The State of Sanitation in Sub-Saharan Africa, The World Bank, Washington.

Mulenga, M., Manase, G. and Fawcett, B., 2004. Building Links for Improved Sanitation in Poor Urban Settlements, Southampton.

Murray, C. and Lopez, A., 1996. Global Health Statistics: A compendium of Incidence, Prevalence and Motality Estimates for Over 200 Conditions, Cambridge, MA, USA. 2.

Nhapi, I., 2004. Options for Wastewater Management in Harare. Taylor & Francis Group.

Nhapi, I. and Gijzen, H.J., 2004. A 3-step strategic approach to sustainable wastewater management. Water SA 31.

Nhapi, I. and Hoko, Z., 2004. A cleaner production approach to urban water management: Potential for application in Harare, Zimbabwe. Physics and Chemistry of the Earth, : p. 15-18.

Nsiah-Gyabaah, 2003. Urbanisation, Environmental Degradation And Food Security in Africa, Brong Ahafo., pp. 1-25.

NWP, 2006. Smart Sanitation Solutions. Netherlands Water Partnership.

Owili, M.A., 2003. Assesment of Impact of Sewage Effluents on Coastal Water Quality in Hafnarfjordur, Iceland, The United Nations University, Reykjavik.

Phiri, L.B., 2007. AN assessment of the quality of water services in low-income areas of Malawi, A casestudy of Mtandile-Mtsiliza in the City of Lilongwe, University of Zimbabwe, Lilongwe, 35-38 pp.

PSIRU, 2008. Sewerage Works,Public investment in sewers saves lives, Public Services International Research Unit, London.

PWWA, 2012. Pacific Water and Wastewater Utilities Benchmarking Report pp. 1-126.

SADC, 2013. SADC Gender Protocol, pp. 1-2.

Sauramba, J., Majiwa, M. and Richards, T., 2009. Rapid Appraisal of Water Supply and Sanitation Services in Zvishavane Town Council, Harare.

.

Schirnding, Y.E.R.V., Yach, D., Blignault, R. and Mathews, C., 1991. Environmental determinants ofacute respiratory symptoms and diarrhoea in young coloured children living in urban and peri-urban areas ofSouth Africa. vol 79: p. 457-460.

Shrestha, D. and Cronin, A.A., 2006. The Right to Water & Protecting Refugees. 24: p. 12-14.

Sigauke, N., 2002. Improving Urban Livelihoods: Epworth Sustainable Livelihoods Benchmark Study. p. 27.

Stenekes, N., Colebatch, H.K., Waite, T.D. and Ashbolt, N.J., 2006. Risk and Governance in Water Recycling Public Acceptance Revisited. Science, Technology, & Human Value, vol 31 no. 2: p. 107-134.

Steven , J., Burian, Stephan , J., Nix, R.E. and Durrans, R., 2010. Urban Wastewater Management in the United States: Past, Present, and Future. p. 33.

Sullivan, M. and Brazier, A., 2012. Rural-Urban Linkages, Zimbabwe, Harare.

Taylor, K., Parkinson, J. and Colin, J., 2003. Urban sanitation: A guide to strategic planning. ITDG Publishing, London.

Templeton, M.R. and Butler, D., 2011. An introduction to Wastewater Treatment. Ventus Publishing, London.

Tow, H.A., 1955. Problems of Overloading Treatment Sewage Plants, Sewage and Industrial wastes Calif.

Townshend, A., 1995. Sewage Treatment. Academic Press, Auckland.

Uddin, N., 2005. Status of Sewage Treatment in India, Central Pollution Control Board, Dehli.

UN, 1949. United Nations Universal Declaration of Human Rights 1948, Geneva, pp. 5-6.

UN, 2001. Human Development report 2001, Geneva

UN, 2004. Kisumu City Development strategies, United Nations Human Settlements Programmme, Kisumu.

UN, 2010. Water quality and sanitation. UN-Water Decade Programme on Advocacy and Communication, Geneva, pp. 1-4.

UN, 2011. The Millennium Development Goals Report 2011, Geneva.

UNDESA, 2006. World Urbanization Prospects, United Nations Department of Economic and Social Affairs, New York.

UNEP, 2002. Global Environment Outlook 3, Earthscan. p. 23.

UNEP and UN-Habitat, 2010. Sick Water? The central role of wastewater management in sustainable development, Arendal.

UNICEF and WHO, 2000. Global water supply and sanitation assessment 2000 Report, Geneva.

Ursula, J., Blumenthal, D. and Mara, D., 2000. Guidelines for the microbiological quality of treated wastewater used in agriculture: recommendations for revising WHO guidelines. World Health Organization, Geneva.

USEPA, 2000. The quality of our nation's water. 841-S- 00-001.

USEPA, 2001. Source Water Protection Practices Bulletin Managing Sanitary Sewer Overflows and Combined Sewer Overflows to Prevent Contamination of Drinking Water. p. 1-5.

van den Berg, C. and Danilenko, A., 2011. The IBNET Water Supply and Sanitation Performance Blue Book. World Bank, Washington DC.

WB, 2003. Urban Sewerage and Sanitation, Lessons learned from case studies in the Philippines. p. 1-20.

WB, 2008. AAfrica Infrastructure Country Diagnostic, Climbing the ladder: The State of Sanitation in Sub-Saharan Africa. p 1-11.

Whittington, D., Lauria, D.T. and Wright, A.M., Undated. Improved Sanitation Services: A case Study of Kumasi, Ghana.

WHO, 2004. World Health Organisation, Water, Sanitation and Hygiene Links to Health Facts and figures.

WHO, 2005. Water and Sanitation Collaborative Council and World Health Organisation, Sanitation and Hygiene Promotion, Programming Guidance.

WHO, 2011. Access to Improved Sanitation and Wastewater Treatment. European Environment and Health Information System.

Yankson, P.W.K. and Gough, K.V., 1999. The environmental impact of rapid urbanization in the peri-urban area of Accra, Ghana. Danish Journal of Geography: p. 89-100.

ZIMSTAT and ICF, 2012. Zimbabwe Demographic and Health Survey 2010-11. In: Z.S. Agency (Editor). Printflow, Maryland, pp. page 1.

APPENDICES

Appendix 1: Structured Questionnaire

Ref	Data Item	Comment	Unit	Response	Reliability Score	Frequency of Measurement
2.1	**Coverage of functional toilets**		**%**			
	Definition: This indicator denotes the extent to which citizens have access to a functional toilet (whether individual or community) in a service area. The toilets would include those in the category of residential, commercial, industrial and institutional properties. The service area implies a specific jurisdiction in which the service is required to be provided. Coverage excludes peri-urban toilets.					quarterly
2.1.1	a. Total number of properties with access to individual or community functional toilets within walking distance (<100 m) in the service area	The total number of functional toilets (as against households) should be assessed. A property may have multiple tenants. A property is considered unique if it is recorded as a unique property in the municipal records. Municipal records should be up-to-date, and preferably backed up by a cadastral map.	#			
2.1.2	b. Total number of properties without individual or community toilets within walking distance	Only the total number of properties without access to individual or community toilets should be assessed.	#			
	Coverage of toilets = [a/(a+b)]*100		%			

	Additional information					
2.1.3	c. Total Number of Properties in the City		#			
2.1.4	d. Properties with toilets		#			
2.1.5	e. Households dependent on functional community toilets	Shared communal toilets not desirable for new projects and existing ones should be phased out within 10 years.	#			
2.1.6	f. Total Number of Properties with access to toilets		#			
2.1.7	g. Total number of households on communal toilets within 100 m walking distance		#			
2.1.8	h. Properties with sewer connections		#			
2.1.9	j. Properties with onsite sanitary disposal facilities (septic tanks and VIP toilets)	VIP toilet only allowed for peri-urban settlements and septic tanks allowed only where approved.	#			
2.2	**<u>Coverage of sewage network services</u>**		%			
	Definition: This indicator denotes the extent to which the sewerage (or sewage collection network) has reached out to individual properties across the service area. Properties include those in the categories of residential, commercial, industrial and institutional. The service area implies a specific jurisdiction in which service is required to be provided (excluding peri-urban areas).					quarterly

2.2.1	a. Total number of properties in the service area	The total number of properties (as against households) should be assessed. A property may have multiple tenants. A property is considered unique if it is recorded as a unique property in the municipal records. Municipal records should be up-to-date, and preferably backed up by a cadastral map.	#			
2.2.2	b. Total number of properties with direct connection to the sewerage network	Only properties with access connection to the sewage network should be included. Properties that connect their sewerage outlet to storm water drains or open drainage systems should not be considered. However, this may include one or more properties with access to decentralised/standalone sewage networks, which have treatment and safe effluent disposal facilities, which has been set up and operated according to laid down environmental standards.	#			
	Coverage of sewage network services = [b/a]*100		%			
2.2.3	c. Additional information on on-site facilities	Number of properties connected to sanitary on-site facilities.	#			
2.3	**<u>Efficiency in collection of sewage</u>**		%			

	Definition: This indicator is measured as the quantum of wastewater collected as a percentage of normative sewage generation in the ULA. Wastewater generation is linked to the quantum of water supplied through piped systems, and other sources such as boreholes, where they are very extensively used. Data should be collected daily for an entire month, so as to measure the quantities per month. While daily variations may be normalised, monthly variations may exist on account of seasonal variations. Data should be aggregated from multiple points across the town.					monthly
2.3.1	a. Total water consumed/billed	Data on the total quantum of water supplied to the distribution system (consumed/billed water)	m^3/year			
2.3.2	b. Estimated water use from other sources	An estimate of water drawn from other sources such as private boreholes. Data that will drive this estimate include the number of properties with access to boreholes or other sources of water, spatially spread across the city, and the quantity of water supplied in those areas. Alternately, data may also be collected from sample surveys.	m^3/year			
2.3.3	c. Wastewater collected	The quantum of wastewater measured at the inlet of treatment plants. The quantum of untreated sewage at outfalls, leading into rivers, lakes or other water bodies should not be included in the quantum of sewage collected.	m^3/year			
	Collection efficiency of sewage networks = [c/ ((a+b)*0.72)]x100		**%**			

2.3.4	d. Additional information on septage collection	Volume of sewage delivered by vehicles at the treatment works.	m^3			
2.4	**Adequacy of capacity for treatment of sewage**		%			
	Definition: Adequacy is expressed as EMA effluent standards green category or secondary treatment (that is, removing oxygen demand as well as solids, normally biological) capacity available as a percentage of normative wastewater generation, for the same time period.					annually
2.4.1	a. Total water consumed/billed	Data on the total quantum of water consumed/billed to consumers	m^3/year			
2.4.2	b. Estimated water use from other sources	An estimate of water drawn from other sources such as private boreholes. Data that will drive this estimate include the number of properties with access to boreholes or other sources of water, spatially spread across the city, and the quantity of water supplied in those areas. Alternately, data may also be collected from sample surveys.	m^3/year			
2.4.3	c. Treatment plant capacity	Total functional capacity of all wastewater treatment plants that can meet secondary treatment standards.	m^3/year			

	Adequacy of treatment capacity = [c/ ((a+b)*0.72)]x100					
	Additional information					
2.4.4	d. Septage disposal	Quantum of septage disposed safely, using treatment plants or sludge drying beds.	tonnes			
2.4.5	e. Volume of sewage actually treated at the Primary Treatment Plant		m^3/d			
2.4.6	f. Volume of sewage actually treated at Secondary Treatment Plant		m^3/d			
2.4.7	g. Total Volume of Waste Water collected and Treated at Sewage Treatment Plants		m^3/d			
2.4.8	h. Installed Capacity of Primary Treatment Plant		m^3/d			
2.4.9	i. Installed Capacity of Secondary Treatment Plant		m^3/d			
2.4.10	j. Total Installed Capacity (Primary + Secondary Treatment)		m^3/d			
2.4.11	k. Total Waste Water Generated		m^3/d			
2.4.12	l. Volume of sewage actually treated at Secondary Treatment Plant		m^3/d			
2.4.13	m. Volume of treated waste water reused after Secondary Treatment		m^3/d			

2.5	**Quality of sewage treatment**		**%**			
	Definition: Quality of treatment is measured as a percentage of wastewater samples that pass the specified secondary treatment standards, that is, treated water samples from the outlet of STPs are equal to or better than the standards laid down by the SAZ/EMA SI 6/2007 Standards for effluent disposal. While the samples are collected at the STP outlet and results should be computed per STP, this indicator should be reported at city/urban local authority level.					monthly
2.5.1	a. Total number of wastewater samples tested in a year	Sampling (quantity, periodicity, point of sample collection, *etc*.) should be taken as per good industry practices and laid down norms by EMA and the Standards Association of Zimbabwe.	#			
2.5.2	b. Number of samples that pass the specified secondary treatment standards in a year	Within the total valid samples, the number of samples that pass the specified secondary treatment standards, along all key parameters.	#			
	Quality of treatment capacity = [(b/a)*100]		%			
	Engineers highlighted need for weighting of different parameters	Noted and to be finalized at 2nd workshop early 2013.				
	Additional information					

2.5.3	c. Septage disposal	Quantum of septage disposed safely, using treatment plants or sludge drying beds.	tonnes			
2.6	**Extent of recycling or reuse of sewage**		**%**			
	Definition: The percentage of wastewater received at the treatment plant that is recycled or reused after appropriate treatment for various purposes. This should only consider water that is directly conveyed for recycling or reuse, such as use in gardens and parks, use for irrigation, etc. Water that is discharged into water bodies, which is subsequently used for a variety of purposes, should not be included in this quantum. While measurements are done at STP inlets and outlets, the indicator should be reported at the city/ULA level as a whole.					annually
2.6.1	a. Wastewater received at STPs	This should be based on the actual flow measurement, the quantum for which should be measured daily. Daily quantities should be aggregated to arrive at monthly quantum.	m^3/year			
2.6.2	b. Wastewater recycled or reused after appropriate treatment	This should be based on the actual flow measurement by functional flow meters, the quantum for which should be measured daily. Daily quantities should be aggregated to arrive at the monthly quantum.	m^3/year			
	Extent of sewage recycled or reused = [(b/a)*100]		**%**			

2.7	**<u>Efficiency in satisfactory response/reaction to customer complaints</u>**		**%**			
	Definition: The total number of sewage-related complaints redressed within 24 hours of receipt of complaints, as a percentage of the total number of sewage-related complaints received in the given time period.					monthly
2.7.1	a. Total number of sewage-related complaints received per month	The total number of all sewage-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 ward offices, collection centres, drop boxes, online complaints on the website, etc.	# per month			
2.7.2	b. Total number of complaints redressed inside 24 hours within the month	The total number of sewage-related complaints that are satisfactorily redressed within 24 hours, within that particular month. Satisfactory resolution of the complaint should be endorsed by the person making the complaint in writing, or by a senior official, as part of any format/proforma that is used to track complaints.	# per month			
	Efficiency in satisfactory response/reaction to customer complaints = [(b/a)*100]		%			

	Additional information					
2.7.3	Average time to complete repair works		days			
2.8	**Efficiency of cost recovery in sewage management**					
	Definition: The extent of cost recovery is expressed as wastewater revenues as a percentage of wastewater expenses, for the corresponding time period.					annually
2.8.1	a. Total annual operating expenses	Should include all operating expenses (for the year) such as electricity, chemicals, staff and other establishment costs, outsourced operations/staff related to wastewater collection and treatment, and O&M expenses. Should include interest payments and principal repayments.	USD			
2.8.2	b. Total annual operating revenues	Should include all wastewater-related revenues billed for the year including taxes/surcharges, user charges, connection charges, sale of sludge, sale of recycled water, etc.	USD			
	Cost recovery = [(b/a)*100]		**%**			
	Additional information					
2.8.3	Regular Staff and Administration		USD			
2.8.4	Outsourced /Contract Staff Costs		USD			
2.8.5	Electricity Charges /Fuel Costs		USD			
2.8.6	Chemicals Costs		USD			

2.8.7	Repairs/Maintenance Costs		USD			
2.8.8	Contractor Costs for O&M		USD			
2.8.9	Others (Specify)		USD			
2.8.10	Total Annual Operating Expenses		USD			
2.8.11	Arrears at the beginning of previous year		USD			
2.8.12	Revenue demand from user charges - sewerage only		USD			
2.8.13	Revenue demand from taxes - sewerage only		USD			
2.8.14	Revenue demand from other sources (eg. connection costs/donations etc.)		USD			
2.8.15	Total Revenue Demand of the previous year (Current Demand of previous year)		USD			
2.8.16	Total Revenue Demand of the previous year (Current Demand of previous year)		USD			
2.8.17	Collection against arrears		USD			
2.8.18	Collection against current demand		USD			
2.8.19						
2.8.20	Senior Management (Sanctioned)		#			
2.8.21	Senior Management (Working)		#			
2.8.22	Engineers (Sanctioned)		#			

2.8.23	Engineers (Working)		#			
2.8.24	Clerks/Accountants (Sanctioned)		#			
2.8.25	Clerks/Accountants (Working)		#			
2.8.26	Labourers/Cleaners (Sanctioned)		#			
2.8.27	Labourers/Cleaners (Working)		#			
2.8.28	Total (Sanctioned)		#			
2.8.29	Total (Working)		#			
2.9	**<u>Efficiency in collection of sewage charges</u>**		**%**			
	Definition: Efficiency in collection is defined as current year revenues collected, expressed as a percentage of the total billed revenues, for the corresponding time period.					annually
2.9.1	a. Current revenues collected in the given year	Revenues collected for bills raised during the year. This should exclude collection of arrears as inclusion of arrears will skew the performance reflected. Collection efficiency is in fact an indicator of how many arrears are being built up, and therefore only current revenues should be considered.	USD/annum			
2.9.2	b. Total revenues billed during the given year	The total quantum of revenues related to sewage services that are billed during the year. This should include revenues from all sources related to sewage such as taxes, charges, surcharges, etc.	USD/annum			

	Collection efficiency = [(a/b)*100]		**%**			
2.10	**<u>Maintenance coverage ratio</u>**		**%**			
	Definition: Maintenance coverage ratio is defined as current year maintenance expenses, expressed as a percentage of the total annual wastewater management expenses.					annually
2.10.1	a. Maintenance expenses in the given year	Maintenance-related wastewater management expenses recorded in a particular year, excluding salaries, running costs and capital repayments	USD/annun			
2.10.2	b. Total maintenance expenses within a given year	The total costs of running the wastewater management function. This should include costs for all functions related to wastewater management such as VAT, electricity charges, purchase of chemicals, etc.	USD/annun			
	Maintenance coverage ratio = [(a/b)*100]		**%**			

2.11	**General but non-indicator information**					
	Septage management					
2.11.1	Does the ULA practice septage management?		Yes/No			
2.11.2	Septage sucking machines available within ULA		#			
2.11.3	Private Septage machines licensed by ULA		#			
	Connection Costs for Sewerage Connections					
2.11.4	Residential - General		USD			
2.11.5	Residential - Urban Poor		USD			
2.11.6	Institutional		USD			
2.11.7	Commercial		USD			
2.11.8	Industrial		USD			
	Sewerage Tariff Structure - Flat Rate Tariff					
2.11.9	Residential - General		USD/month			
2.11.10	Residential - Urban Poor		USD/month			
2.11.11	Institutional		USD/month			
2.11.12	Commercial		USD/month			
2.11.13	Industrial		USD/month			

	Sewerage Tariff Structure - Volumetric Tariff						
2.11.14	Residential - General		USD/m^3				
2.11.15	Residential - Urban Poor		USD/m^3				
2.11.16	Institutional		USD/m^3				
2.11.17	Commercial		USD/m^3				
2.11.18	Industrial		USD/m^3				
	Performance of sewerage network						
2.11.19	Length of sewerage network in the city		km				
2.11.20	Average number of blockages reported in a month over the financial year		#/month				
2.11.21	Average number of blockages per 100 km in a month		#/100 km				

Appendix 2: Reliability score sheet

Indicator	Rationale	Reliability Classes			
		1	2	3	4
		Highest/preferred level of reliability	Intermediate level	Fair level	Lowest level
2.1 Coverage of functional Toilets	Universal access to functional toilets within a reasonable walking distance is key to improvement in service levels of sanitation facilities. In many Zimbabwean towns, there is inadequate access to functional toilet facilities. Therefore, it is important to measure this parameter.	Calculation based on the actual number of properties and the count of properties with or without functional toilet facilities, measured through a field survey. These data should be periodically updated on the basis of data regarding provision of toilet facilities and new properties being developed (from the building plan approval department). Field surveys throughout the city should be carried out	Not applicable.	Not applicable.	Estimation based on the total number of properties with toilets on the premises or with access to a community toilet at walking distance and without such facilities as a percentage of the estimated number of properties, to arrive at the indicator of service coverage.

		at least once in two years.			
2.2 Coverage of sewage network services	In some Zimbabwean towns, sewage flows through open drains/storm water drains, posing serious public health hazards This indicator, however, does not imply that sewerage is the only option for safe liquid waste management. An appropriate mix of options including sanitary on-site facilities (e.g. septic tanks, ecological sanitation) may be considered depending on the town's context.	Calculation based on the actual number of properties and the count of properties with a direct connection, measured through a field survey. These data should be periodically updated on the basis of new sewage connections taken (from the sewage department), and new properties being developed (from the building plan approval department). Field surveys throughout the city should be carried out at least once in five years.	Not applicable.	Estimation based on the total number of connections as a percentage of the estimated number of properties, to arrive at the indicator of service coverage.	Estimation based on the layout maps
2.3 Efficiency in collection of sewage	While the performance indicator for coverage provides an idea of infrastructure available for access to sewerage	Sewage production is based on billed water. Estimates are available for water consumed from other sources.	Sewage production is based on 'Reliability Class 2 for measuring NRW. Periodic measurement of	Sewage production is based on Reliability Class 3 for measuring NRW. Sewage intake is estimated on the basis of	Sewage production is based on Reliability Class 4 systems for measuring NRW. There are no meters at sewage

	networks, the effectiveness of the system in capturing the sewage may not be adequate. Therefore, the performance indicator related to collection efficiency signifies the effectiveness of the network in capturing and conveying it to the treatment plants. Thus, it is not just adequate to have an effective network that collects sewage, but also one that treats the sewage at the end of the network	Measurement of wastewater collection occurs at all inlets of STPs by flow assessment methods. Process control automation provides accurate data, for both water production and distribution and for sewage intake and treatment.	wastewater collection is based on flow assessment methods at the STPs. There are no estimates for water consumed from other sources.	flow or treatment plant capacity. No estimates are available for water consumed from other sources.	treatment plants (STPs), influent is estimated on the basis of treatment plant capacity. No estimates are available for water consumed from other sources.

2.4 Adequacy of capacity for treatment of sewage	Most Zimbabwean towns have inadequate capacity for treatment of sewage that is generated in their cities. This indicator will highlight the adequacy of available and operational sewage treatment capacity.	Water consumption is based metering Reliable estimates are available for the quantity of water consumed from non-municipal sources. STP system capacity is assessed through rigorous testing and commissioning procedures (after which there have been no modifications to the plant). In case any modifications to the STP have been carried out, system capacity is reassessed through measuring peak throughput.	Water consumption is based on 'B' category systems for NRW. Sound engineering estimates of functional wastewater treatment capacity are available, on the basis of reliable operational data that are maintained. There are no estimates for water consumed from other sources.	Water consumption is based on 'C' category systems for NRW. There is no estimate of wastewater treatment capacity that is actually functional and in operation, nor for water consumed from other sources.	Water consumption is based on 'D' category systems for measuring NRW. There is no estimate of wastewater treatment capacity that is actually functional and in operation, nor for water consumed from other sources.
2.5 Quality of sewage treatment	For sustainable sewage management, it is not just enough to have the infrastructure to collect and convey the sewage,	The sampling regimen is well documented and practiced completely. The council/utility has its own laboratory equipment or	The sampling regimen is well documented and practiced on most occasions. The council/utility has its own	Not applicable.	There is an absence of a sampling regimen and of required laboratory equipment. Irregular tests are carried out. Not all

	or the installed capacity to treat it. It is important that the effluent that is discharged back into water bodies, or used for other purposes such as irrigation, meets the laid down environmental standards. It is therefore important to monitor this indicator.	easy and regular access to accredited testing centres. There is periodic independent audit of wastewater quality. All parameters are assessed.	laboratory equipment or easy and regular access to accredited testing centres. Only a few key parameters are assessed.		parameters are tested.
2.6 Extent of recycling or reuse of sewage	For sustainable water management, it is desirable that sewage is recycled or reused after appropriate treatment. Effluent water can be directly reused in a number of areas such as used in parks and gardens, supplied for irrigation purposes for farmland on the city periphery, etc. To maximise this reuse, it is important that this indicator is measured and	Based on data from flow measurement at STP inlets and outlets (that is, points of supply of recycled water). Data should be measured daily, and aggregated for monthly totals.	Not applicable.	Not applicable.	There are no meters at STP inlets or points of supply of recycled water. Estimates are based on observation and STP capacity.

	monitored.				
2.7 Efficiency in satisfactory response/reaction to customer complaints	It is important that in essential services such as sewage, the utility has effective systems to capture customer complaints/grievances, escalate them internally for remedial action and resolve them. While some councils/utilities have put in place systems to capture complaints, much more work needs to be done to put in place back-end systems for satisfactorily resolving those complaints in time. As sewage treatment is an essential service, the benchmark time for redressal is 24 hours.	There are multiple mechanisms by which consumers can register their complaints such as by telephone, in person , in written form or e-mail. Complaints are segregated into different categories, and are collated through a computer network or other systems, and tracked on a daily basis. The status of redressal of complaints is maintained. Consumers endorse complaints being addressed on the municipal proforma.	There are multiple mechanisms/means by which consumers can register their complaints such as by telephone, in person or by writing or e-mail. However, systems do not exist for aggregating, sorting and tracking the complaints. Data available for some months have been used as a trend to report the figures for some other months.	There are multiple mechanisms/means by which consumers can register their complaints such as by telephone, in person or by writing or e-mail. All complaints received are assumed to be resolved quickly.	Complaints data are not maintained at all city levels

2.8 Efficiency of cost recovery in sewage management	Financial sustainability is a critical factor for all basic urban services. In services such as sewerage management, some benefits are received directly by the consumers, and some benefits accrue indirectly through a sustainable environment and public health benefits. Therefore, through a combination of user charges, fees and levies, all operating costs should be recovered.	In case of multi-function agencies such as municipal corporations, the budget heads related to wastewater are clearly separated. Cost allocation standards for common costs are in place. An accrual-based double entry accounting system is practiced. Accounting standards comparable to commercial accounting standards with clear guidelines for recognition of income and expenditure are followed. Accounting and budgeting manuals are in place and are adhered to. Financial statements have full disclosure and are audited regularly and on time.	Budget heads related to wastewater are segregated. Key costs related to wastewater are identifiable, although complete segregation is not practiced. Key income and expenditure are recognised, based on accrual principles. Disclosures are complete and on time.	Not applicable.	There is no segregation of budget heads related to wastewater from the rest of the functions of the agency. A cash-based accounting system is practiced. There are no clear systems for reporting unpaid expenditure. Disclosures and reporting are not timely. Audits have a time lag and are not regular.
2.9 Efficiency in	For a utility, it is not just	Collection records are	There is a clear	Not applicable	There is no segregation of

collection of sewage charges	enough to have an appropriate tariff structure that enables cost recovery objectives, but also efficient collection of revenues that are due to the utility. It is also important that the revenues are collected in the same financial year, without allowing for dues to get accumulated as arrears. It is therefore critical to monitor this indicator.	maintained for each billing cycle. Collections are clearly identified against the specific bill which has been issued. Overall accrual principles of accounting are followed, and therefore deposits and advances are not included in income and expenditure, respectively. The accounting code structure also enables monitoring of billing and collections for each administrative district within the council.	segregation of current year revenues collection versus arrears collection. However, revenue collection is not matched against the specific bill issued. Overall accrual principles of accounting are followed, and therefore deposits and advances are not included in income and expenditure, respectively.		arrears versus current year revenue collection. A cash basis of accounting is followed. The accounting code structure does not enable clear segregation of water revenues.