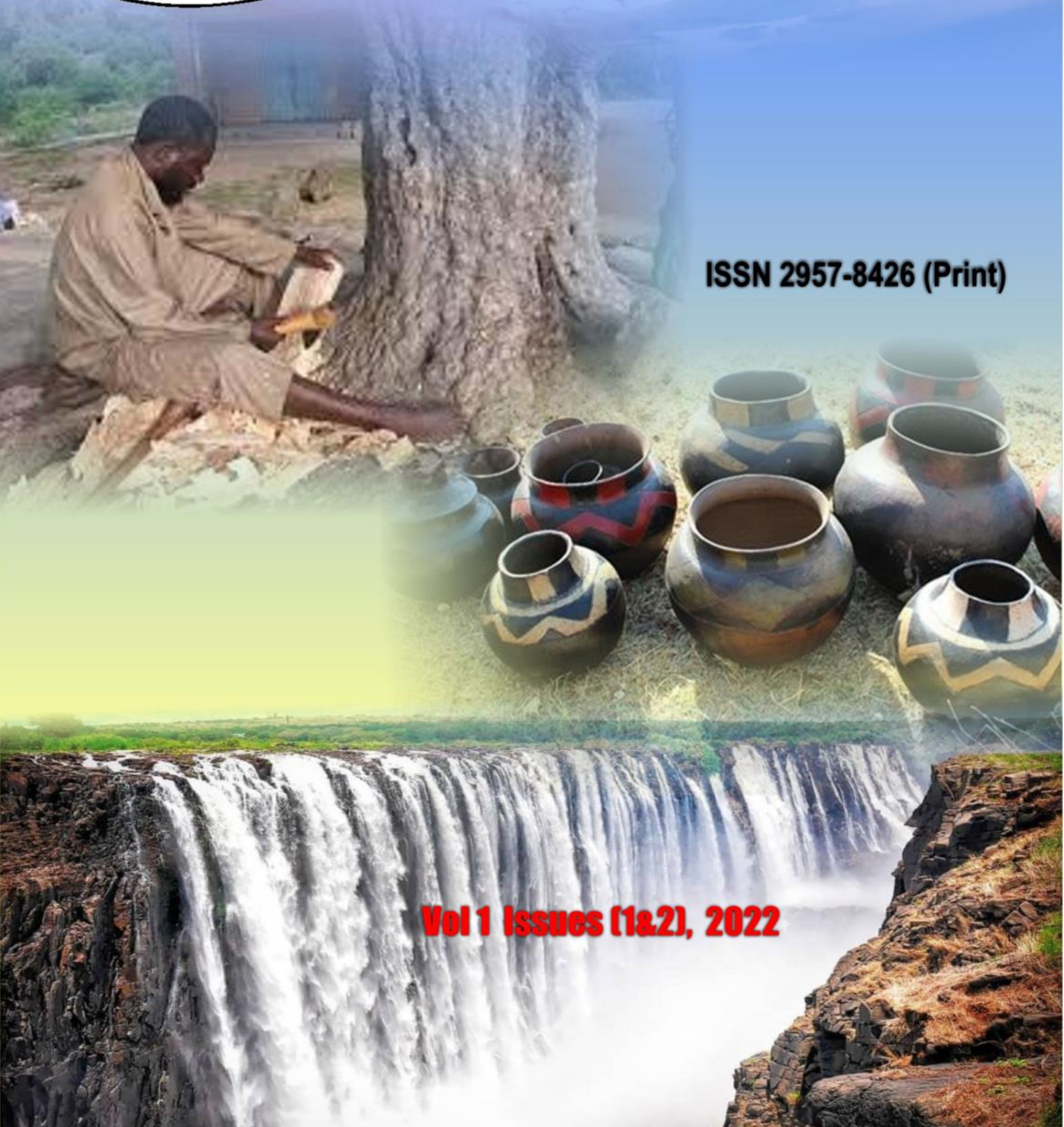
KUVEZA NEKUUMBA

THE ZIMBABWE EZEKIEL GUTI UNIVERSITY
JOURNAL OF DESIGN, INNOVATIVE THINKING AND PRACTICE



ISSN 2957-8426 (Print)

Vol 1 Issues (1&2), 2022

Published by the Zimbabwe Ezekiel Guti University Press
Stand No. 1901 Barrassie Rd,
Off Shamva Road
P.O. Box 350
Bindura, Zimbabwe

Typeset by Divine Graphics
Printed by Divine Graphics

SUBSCRIPTION AND RATES
Zimbabwe Ezekiel Guti University Press Office
Stand No. 1901 Barrassie Rd,
Off Shamva Road
P.O. Box 350
Bindura, Zimbabwe
Telephone: ++263 8 677 006 136 | +263 779 279 912
E-mail: zegupress@admin.uz.ac.zw
http://www.zegu.ac.zw/press

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The *Kuveza neKuumba - Zimbabwe Ezekiel Guti University Journal of Design, Innovative Thinking and Practice* provides a forum for design and innovative solutions to daily challenges in communities.

CONTRIBUTION AND READERSHIP

Planners, engineers, social scientists, business experts and scholars and practitioners from various fields.

JOURNAL SPECIFICATIONS

Kuveza neKuumba - Zimbabwe Ezekiel Guti University Journal of Design, Innovative Thinking and Practice

ISSN 2957-8426 (Print)

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The journal is a forum for the discussion of ideas, scholarly opinions and case studies of multidisciplinary perspectives of design and innovative thinking. The journal is produced bi-annually.

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Urban Expansion and its Impact on Wastewater Management in Masvingo Town, Zimbabwe: Designing for Resilience

GODWIN K ZINGI[1]

Abstract

Rapid urban expansion has had a negative bearing on wastewater management and sanitation in developing countries, hence there is need for robust and efficient on-site sanitation facilities. The study sought to evaluate the urban expansion and its impact on wastewater management in a developing country case of Masvingo Town, Zimbabwe. The study objectives included investigating the impact of rapid urbanisation on the design capacity of the centralised wastewater treatment plant, characterisation of on-site sanitation technologies in newly built areas against the sanitation standards and to identify the impact of on-site sanitation technologies on the environment. Key informant interviews, questionnaires and secondary laboratory data on biological oxygen demand (BOD_5) were used to collect the data. The population equivalence was used to determine the impact of rapid urbanisation on wastewater efficiency. Results indicate that a population equivalence of 282.86 BOD shows a decline in the efficiency of the wastewater facility that is affecting aquatic species along the Shagashe River. From a sample of 96 respondents, results indicate that onsite sanitation facilities are dominant in newly built residential areas, with limited sewerage networks and erratic supplies of water. The city is building resilience around on-site sanitation facilities within the realm of Water and Sanitation.

Keywords: on-site sanitation facilities, population equivalence, Masvingo

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INTRODUCTION

Developing countries are burdened with a multiplicity of problems and wastewater management is increasingly becoming a priority issue (Semadeni-Davies *et al.,* 2008). The management of wastewater systems in developing countries is exacerbated by accelerating urbanisation, inadequate management and disposal of wastewater and the implementation of sophisticated treatment technologies that are highly centralised (Chirisa *et al.,* 2017). Developing countries are at different stages of urbanisation, leading to many challenges in the development of sewer systems and river pollution control. Current wastewater management systems are riddled with a plethora of irregularities that calls for a paradigm shift from the current centralised system to the decentralisation of wastewater treatment management.

Within urban authorities, there is usually a works division with a subdivision dealing with water and sewerage. As urban space continues to expand to accommodate a growing global population, there remains a real need to quantify and qualify the impacts of urban space on natural processes. Storm drains carry runoff from streets, urban centres, industrial sites and open spaces into streams, creeks and rivers. Industrial operations are only one contributor to this problem, but they are known to be a source of heavy metals, oily wastes and other substances. Manufacturing, shipping and storage operations exposed to stormwater can be sources of pollutants. The expansion of global urban areas has resulted in marked alterations to natural processes, environmental quality and natural resource consumption (McGrane, 2016). Safady (2011) observes that expansion of urban space results in an increase of impervious landscape and expansion of artificial drainage networks that can facilitate dramatic changes to the magnitude, pathways and timing of runoff at a range of scales, from individual buildings to larger developments.

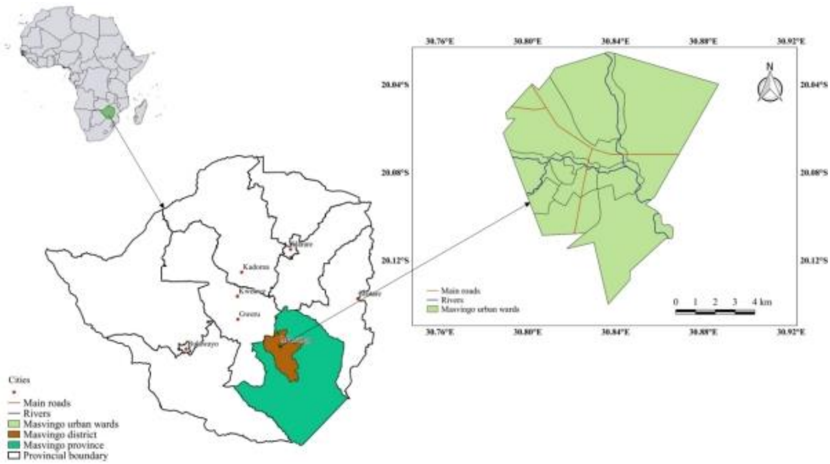
Water resources are under pressure from continuing population growth and urbanisation, rapid industrialisation and expanding and intensifying food production, particularly in developing countries and urban areas. Liao *et al,* (2021) aver that urban populations may nearly double from the current 3.4 billion to 6.4 billion by 2050. This represents a global threat to human health and well-being with both immediate and long-term consequences. The problem of urban sanitation in Zimbabwe, unlike in other parts of Africa, is not primarily one of access to services, but one of disposal of the effluent. An alternative pollution control management approach is suggested based on shifting responsibility from government to the discharge authority. A review of this system is urgently required to create an environment where pollution will be effectively and progressively controlled. Urban wastewater is described as wastewater generated from domestic activities or as a mixture of wastewater generated by household, industrial and rainwater outflows. Urban wastewater is considered a hazardous material that has to be disinfected to support public health and protect the environment.

Due to rapid expansion in most urban spaces, the centralised system of waste management is affected, hence land developers take advantage of the weak regulatory framework and poor regulatory capacity of the local authorities. The current Urban Water Management (UWM) systems evolved from a situation of small populations consuming small amounts of water, the presence of only small-scale industrial activities and, thus, the release of few harmful substances into the environment and the availability of large volumes of fresh water. Consequently, neither water consumption nor the discharge of wastes had significant impacts on the environment. When urban populations increased and, specifically when nearby waste discharges resulted in unhealthy conditions and disease outbreaks, waste needed to be discharged further away from human habitats.

The inability of the City of Masvingo to extend and upgrade its water and sanitation systems and keep pace with the city's growth has led to several complex challenges. The city's ageing sewer network is poorly maintained, overstretched and needs expansion. The water treatment facilities and pipe network also need upgrading and repair but the local authority has limited financial resources. The urbanisation process generally leads to increasing loads of pollutants discharged into the river by human activities, causing serious deterioration of the quality of the water in the Mucheke River and harming the surrounding environment as well as human health (Mapira, 2011). The challenges are compounded by the growing demand for housing in and around Masvingo. Multiple toilet systems are in use, including flush toilets connected to the city's sewer grid, pit latrines and ecological sanitation toilets. Many people still practise open defecation. There is considerable variation between the settlements profiled, ranging from well-maintained, community-managed toilets to poor, neglected and unhygienic systems. Inappropriate planning, incomplete drainage systems, as well as poor construction quality, result in large amounts of pollutant load discharging directly into rivers from the drainage systems. In many places, there is poor or erratic water supply, which leads to open defecation and failure to wash hands. Most of these local authorities have limited resources and are, therefore, unable to provide the basic amenities.

The study assesses the impact of urban expansion on wastewater management in Masvingo through investigating the impact of rapid urbanisation on the design capacity of the centralised wastewater treatment plant. The idea was to determine the characterisation of on-site sanitation technologies in newly built areas against sanitation standards and to identify the impact of on-site sanitation technologies on the environment.

DESCRIPTION OF THE STUDY AREA



Masvingo is located 292 kilometres (181 miles) south of Harare It is divided into suburbs including Mucheke, Rujeko, Rhodene, Target Kopje and Eastvale. The suburbs are divided into high-density, middle-density and low-density suburbs. Mucheke, the oldest township and Rujeko are the most populous high-density suburbs. Mucheke is also the site of the city's main bus terminus as well as the town's stadium of the same name. KMP and Runyararo suburbs are relatively new high and medium-density suburbs, respectively, beyond Mucheke. The city's water supply comes from Bushmead Waterworks at Lake Mutirikwi, where an average of 30 megalitres (ML) is pumped daily to the city. Water quality is excellent and meets both the World Health Organisation (WHO) and Standards Association of Zimbabwe (SAZ) standards. Current supply is at maximum capacity but is failing to satisfy water demand in the ever-growing city. Water demand is estimated at 48 ML per day. However, the city has prioritised the Central Business District (CBD) and the industrial areas in the water supply. Measures put in place by the local authority save water is a ban on the use of hosepipes, which attracts a fine. A water augmentation project is underway to increase water supply to the town. Borrowing powers and a government guarantee are being sought to carry out the project. Sewer in the city flows by gravity to raw sewer pump stations on the banks of the Shakashe RiverIt is then pumped to the Masvingo Sewage Treatment Works to the east of the city for treatment and safe disposal. There are two treatment plants within the premises, *viz*, the Conventional Trickling Filter plant with a capacity of 7.5 ML/d and the Activated Sludge plant with a capacity of 13.5 ML/d, to give a combined capacity of 21ML/day.

LITERATURE REVIEW

SUSTAINABLE DEVELOPMENT GOALS AND WATER MANAGEMENT

The United Nations Sustainable Development Goals (SDGs) provide a global framework for ending poverty, protecting the environment and ensuring shared prosperity. Goal 6 on clean water and sanitation (specifically targets 6.2 and 6.3 on sanitation and water quality respectively) and Goal 3 on good health and well-being, are particularly relevant to sanitation. The SDGs also set out the principles of implementation for states to follow, including increasing financing, strengthening the capacity of health workers, the introduction of risk-reduction strategies and building on international cooperation and participation of local communities. Goal 1 states the need to improve the flow of information and increase monitoring capacities and disaggregation so that it is possible to identify which groups are being left behind.

Wastewater Infrastructure and Urban Growth

When and where sewer infrastructure is located is thought to influence growth patterns and thus the size, location and extension of sewer service areas are critical (He, Okada and Zhang, 2006). Recent examinations of land conversion processes suggest that sewer service area expansion greatly influences urbanisation. One study developed a spatially explicit model that emphasises the role of municipal services and zoning on land use change. They found that when water and sewer service areas were extended, the average probabilities that urban development would occur were very high and there was an increase in the likelihood that development would be high-density. In the Maryland context, the presence of public sewer had a very positive effect on the hazard rate of conversion for developable parcels in Calvert County (Semadeni-Davies *et al,* 2008). Based on estimated hazard ratios, Irwin *et al.* (2003:96) state,

> the mean hazard rate of those parcels with public sewer, holding all other variations constant, was 363% greater than those without a public sewer. Thus, just the provision of public sewer to a parcel increases the hazard rate of conversion by almost fourfold.

Similarly, Shen and Zhang (2007), in their study of the effectiveness of Maryland's Smart Growth policies, found that land inside the sewer service areas of selected counties in the state was more likely to be developed than land outside these areas. These studies suggest that growth is inextricably tied to sewer infrastructure.

Akin to the connection between public sewer infrastructure and urban growth, some of the same land conversion studies have also found that utilisation of on-site septic systems can lead to low-density, sprawl-like development. For instance, Foster

(2001) found that rural and exurban areas in Sonoma County received growth typically at lower densities than those areas close to the urban core. According to the study findings, this lower-density development was the result of the expansion of large lots with on-site septic systems and private residential wells. The installation of on-site septic systems requires that residents set aside enough space to provide adequate drain field size for effective effluent treatment and disposal. These systems also need to be a safe distance from any residential groundwater wells. Large lot sizes are the result. So, while urban development is likely to occur within sewer service areas, the lack of sewer does not necessarily thwart growth, especially the sprawl-like development government planners seek to prevent. This sprawl-like development can even occur within designated sewer service areas. For example, Kookana *et al.* (2020) found that large-lot residential development occurred within the Minneapolis Metropolitan Urban Service Area (MUSA) because of the availability of private septic systems and pre-existing groundwater wells.

SEPTIC SYSTEMS AND SEWER SERVICE

Developing countries always lack proper sanitation systems due to rapid urbanisation. Decentralised onsite wastewater treatment systems could provide an improvement in sanitary conditions in these countries. The simplest of such systems are septic tanks, which provide the first and very important pre-treatment. The quiescent condition inside the tank allows a portion of suspended solids (SS) to settle and floatable solids to rise and provides storage space for biological processes to occur. In some developing countries, septic tanks have become a required component in their sanitation systems and appropriate authorities monitor the operation and maintenance of the septic tanks to manage the quality of the effluent. The effluent must meet regional standards if discharged onto land or sewer systems (Semadeni-Davies *et al.*, 2008). However, in some other developing countries, the septic tank effluent quality is not regulated and the effluent could be discharged into sewers or leached into the ground. This causes serious environmental problems. The main objective of this study was to evaluate the current performance of onsite sanitation in some areas in Vietnam and Thailand to promote them as onsite sanitation systems in developing countries. A septic tank provides the primary treatment of wastewater from a dwelling.

Impact of Population Growth on Sewer

The state of sanitation and the inadequacy of sewerage management pose a health hazard to residents. In 2005, a study by Astaraie-Imani, Kapelan and Butler, 2013) indicated that about 50% of all preventable illnesses in Kenya are water, sanitation and hygiene-related. In Eastleigh, the sewerage system is designed as a combined system of both sewer line and storm water drainage running concurrently. The Nairobi Water and Sewerage Company is the body bestowed with the responsibility to manage the sewer line while the Nairobi City Council is responsible for the maintenance of the stormwater drainage. This poses a major health problem to the residents of the city. The sewer line was laid in 1943 to serve an estimated population of 36 616. The sewer line is nine inches wide, efficient to serve the neighbourhood that had a sparse population living in single housing units. However, due to the rapid population growth, the Nairobi North Region Sewerage Technical Officer indicated that the sewer line only has 65% capacity to be effective and efficient. The company attributes this moderate percentage to rapid population growth and physical developments in the area. Initially, the sewer line in Eastleigh had been laid to serve as a low-density area as per the infrastructure size. However, the change of use in certain areas of the neighbourhood has led to overstretching of the sewerage system and the results have been frequent bursts of the sewer line and spillover of the wastewater in unplanned areas, posing a health risk to residents. Moreover, the sewer has experienced illegal development along the way, which has been closely linked to population growth and weak enforcement of the city bylaws. This has continually hampered the efforts by the company to offer high-quality regular preventive sewerage services. In addition, in most areas of the neighbourhood, the storm drain covers have been vandalised, posing an imminent danger to road users and consequent blockage of the sewer line.

On-site Treatment System

On-site treatment systems can be adopted when the individual houses are far apart over a large area and where there are no centralised systems. This can also be a preliminary option in newly developing localities. However, it is emphasised here that the option of an on-site treatment system should be considered mostly as an interim solution and not a permanent wastewater treatment/management option. If improperly designed or maintained, or left unattended, on-site treatment systems can result in severe environmental hazards. Various on-site wastewater treatment systems are available. Selecting the most appropriate option requires a thorough analysis of all factors including cost, cultural acceptability, simplicity of design and construction, operation and maintenance, hydrogeological conditions and local availability of materials and skills. DWTS is an on-site sanitation system that treats wastewater (both black and grey water) mostly at community scale or even larger scale. Waste water management systems can be either conventional centralised systems or decentralised systems. Centralised systems are usually planned, designed and operated by government agencies, which collect and treat large volumes of wastewater for entire communities. On the other hand, DWTS systems treat wastewater of individual houses, apartment blocks or small communities close to their origin. Typically, the DWTS is a combination of many technologies within a given geographical boundary, one of the multiple onsite sanitation systems comprising low-cost collection systems and dispersed siting of treatment. It may also be noted that any city or town can have a combination of centralised, decentralised and on-site wastewater treatment systems, to meet the overall city sanitation requirements.

A public toilet, a kind of common toilet installed in stations and on streets, is open to everyone. In contrast, a community toilet has limited users such as residents. These common toilets are controlled by local governments, residents or private sector organisations. A common toilet normally has two sections: one is for males and the other is for females. In addition, another section special to persons in a wheelchair (unisex) is sometimes provided. In general, an on-site common toilet includes a special sewage treatment facility such as a septic tank. The flow rate of sewage to be treated is derived from the total number of users based on how many toilet bowls are installed and how frequently they are used. The toilet is equipped with a water supply unit, a ventilator and a lighting device.

Mobile toilets are temporarily installed in places where there is no toilet, such as shelters during natural disasters, venues for events and construction sites, or where the number of existing toilets is inadequate. A mobile toilet box has a tank for storing excreta in its lower part. If the tank is full, a vacuum tanker collects the stored sewage. Each toilet has a single room or multiple rooms with a hand washing unit, which is selected according to the flexibility of installation sites and ease of transport by a truck. In addition, there is a mobile flush toilet that is equipped with a water tank and a pedal. Stepping on the latter activates a manual pump to cause washing water to flow. The box is made by assembling fibreglass-reinforced plastic (FRP) side panels, so its weight is light. Local governments keep these toilets to prepare for disasters and events, or rental companies lease them. The mobile toilet features easy installation work on the ground.

In a conventional water flush latrine, the excreta is normally flushed with 10 to 14 litres of water from a cistern. In a pour-flush latrine, as the name suggests, excreta is hand flushed by pouring about 1.5 to 2.0 litres of water. These pour-flush leaching pit latrines were first developed in India in the mid-1940s with a single leach pit and squatting pan placed over it. When the pit in use gets filled up, another pit is dug and the squatting slab is removed and placed over the new pit. The first pit is covered with earth and the excreta is allowed to digest. After one or two years, the digested excreta is used as manure. In the late fifties, a modified design of the system was developed. In this system, the leach pit is kept away from the seat, instead of placing it underneath the pan. In a single pit system, desludging has to be done almost immediately after the pit has been filled up to enable its re-use. This involves handling fresh and undigested excreta containing pathogens which is a health hazard. A single leach pit is appropriate only if it is dislodged mechanically by a vacuum tanker. To overcome this shortcoming, the twin-pit design was introduced and in this case, when one pit is full, the excreta is diverted to the second pit. The filled-up pit can be conveniently emptied after

1.5 to 2 years when most of the pathogens die off. The sludge can safely be used as manure. Thus the two pits can be used alternately and perpetually. With simple care, a pour-flush water-seal latrine is a very satisfactory and hygienic sanitation system, hence it can be located inside the house since the water-seal prevents odour and insect nuisance.

RESEARCH METHODOLOGY

SAMPLING

The study adopted the descriptive and experimental research design. The size of the sample was drawn from the population. Sampling is the process of selecting of a subset of individuals from the population to estimate the characteristics of the whole population.. When the units being sampled (households) are not the same as the elementary units (people), to derive the average values and confidence intervals for variables describing people a different set of formulas must be used. To target the 96 sampling units in which pre-tested questionnaires were distributed, four clusters were identified, that is industrial SME (24), Clip Sham heights (24), Vic Range (24) and Garikai Housing Hooperative (24). A pre-tested open-ended questionnaire was randomly distributed targeting 30 key informants on wastewater treatment including 10 health workers, 10 officials from the engineering department and 10 officials from Zimbabwe National Water Authority (ZINWA). The questionnaire targeted key informants to obtain information on the impact of rapid urban expansion on wastewater treatment. Questionnaire was constructed from the WHO (2014) and sanitation legislation (Urban Zouncils Act, RTCP Act and the Public Health Act.

QUALITY CONTROL

A structured questionnaire is used to collect quantitative data. This type of questionnaire is designed in such a way that it collects intended and specific information. It can also be used to initiate a formal inquiry, supplement data and check data that have been formerly accumulated and also validate the hypothesis. This involves giving the questionnaire to the same group of respondents at a later point in time and repeating the research and hen comparing the responses at the two-time points. Thus, to reduce memory effects, the time between the first test and the retest was increased.

STATISTICAL ANALYSIS

The regression analysis technique was used for the modelling and analysis of numerical data. Data from the Likert scale was coded into SPSS version 16.0 for regression analysis. To establish the internal consistency of the scale, we conducted a reliability analysis, calculating Cronbach's alpha coefficient for each of the factors and the overall scale.

POPULATION EQUIVALENT

Population equivalent (PE) is a measure of important parameters for characterising domestic wastewater. PE reflects the equivalence between the polluting potential of a municipal area in terms of the biodegradable organic matter and a certain population, which produces the same polluting load. The formula for the calculation equivalent based on BOD is

The pollutants per capita values can be used to estimate the present and future pollution loading of wastewater produced by a population. These are also useful to estimate the equivalent population of an urban or industrial wastewater flow. By expressing wastewater pollution in terms of per capita values, the concept of pollution will be more understandable for citizens and policy-makers. The secondary data collected by the Masvingo City laboratory on the 20 August (Year) was used to calculate the population equivalence to determine the capacity of the centralised wastewater treatment plant in the face of rapid population growth.

RESULTS

THE ON-SITE SANITATION FACILITIES IN THE FACE OF URBAN EXPANSION

Table 1 indicates that septic tanks are significantly ($p<0.05$) site facility relative to the number of individual housing unit per household, whilst the Fossa Alterna is the least dominant within the newly built residential areas. Housing units with an average of 9-12 individuals have access to onsite sanitation facilities. Septic tank facilitates biological treatment of wastewater in unconnected residential areas such as Runyararo West Treasure Consultancy, Victoria Range, Garikai and Klipshap Range. These findings are in line with Maira (2011) who observed that a septic tank is significantly present in small-scale decentralised units for grey and blackwater. Pit latrines and septic tanks are common on-site sanitation facilities used in Sub-Saharan Africa. This shows the resilience of the households to cope and adapt to the lack of a centalised waste management system in the face of rapid urban expansion. The ecological toilets have been adopted mainly in Victoria Range, which is unconnected to the centralised system. Ecological sanitation is a viable sanitation alternative to conventional sanitation. Key informant from the City of Masvingo noted that the Eco San project in Victoria Range was facilitated by the Shelter for Dialogue Foundation in Zimbabwe and is more convenient where access to water is limited and more effective than wet methods. Blair toilets and Fossa Alterna are pronounced in New Klipsham residential areas under construction. This is because it is regarded as stop gap measure pending completion of the structure. These housing units are inhabited by caretakers. On-site sanitation systems are more widely employed in low-income and rural areas of the world.

Table 1: Distribution of on-site sanitation facilities

		On-Site Sanitation Facilities				
		Septic Tanks	Blair Toilet	Ecological Sanitation Toilet	Fossa Alterna	Total
Number of individuals per housing unit	0-4	8	4	2	1	15
	5-8	11	10	3	0	24
	9-12	20	7	14	5	46
	13-15	4	1	3	3	11
Total		43	22	22	9	96

The Characteristics of the On-site Sanitation Facility

Table 2 shows that most respondents indicated that onsite sanitation facilities were durable, whilst current legal acceptance was the least frequent from the respondents. Somensite systems do not meet the structural standard within the Urban Councils' Act and Building Standard Act and are rarely inspected by the Masvingo Department of Engineering. Housing units within the range of 200m^2 are dominated by eco-sanitation facilities that require no water to operate. The ecosan facilitates recycling nutrients, hence boosting soill fertility. One key informant from the Environmental Management Agency (EMA) notes that eco san toilets is effective in the destruction of pathogens than the pour-flush mechanism. Housing units with dimensions of 800m^2 to 1 600m^2 are dominated by septic tanks that require water to dispose of effluent. Klipsham residents adopted septic tanks with appropriate effluent treatment and disposal facilities. The on-site sanitation facilities can mitigate against the occurrence and emergence of pathogenic infections, especially in dry toilets that are more effective in destroying pathogens than wet methods. The toilet is elevated to ensure that water does not enter collection tanks even during flooding. Provision is also made for the cleansing water to go into the collection tank separately to ensure the drying of faeces The results also shows that one of the characters of the onsite sanitation facility is low maintenance costs.

Table 2: Characteristics of an Onsite Sanitation Facility

Count

		Characteristics of Onsite Sanitation Facility						
		Durability	current legal acceptance	Control Exposure to Pathogens	Water For Operation	Operation and Maintainance	Protects Nearby Water Sources	Total
Dimensions of Housing Units	200	8	2	4	2	5	4	22
	400	4	1	1	2	2	1	10
	800	7	1	3	6	5	3	25
	1600	9	4	3	5	1	13	39
Total		28	8	11	15	13	21	96

Population Equivalent

The population of Masvingo City for 2022 is estimated 110 000 people. Therefore, since research conducted on wastewater by German scientists, the average BOD for one person was found to be 54g BOD/day (McGrane, 2016) According to historic data from the WWTP, the plant receives an average of 21 ML/day of water, hence the theoretical BOD is calculated as shown below:

54gBOD/day = 54 000mg/day

21Ml/day = 21 000 000l/day

The value of theoretical BOD deviates from the experimental average value by 11.3%. The results indicate that rapid population growth is outstripping the capacity of the centralised system to manage waste, hence there is need to adapt to on-site sanitation facilities. A key informant from EMA noted that there is glaring evidence that effluent being discharged into the Mucheke and Shagashe Rivers is a leading factor in the depletion of aquatic life. Such findings are in line with Desire *et al.* (2021) who observed that in Shangai, China, urbanisation is a trigger by increased load of pollutants derived from anthropogenic factors leading to poor wastewater quality parameters and threatening public health.

DISCUSSION

The limited construction and maintenance of drainage networks in newly built areas have to led to the adoption of on-site sanitation facilities as an urban resilience strategy in the face of Rrapid urban expansion. The population equivalence of 282.86 BOD shows that the wastewater treatment plant is overburdened by the amount of sewage generated per individual, thereby affecting the treatment efficiency of the centralised system. Given the background of volatile economic situations, coupled with poor planning and construction of urban drainage systems, the onsite sanitation facilities have been adopted to cope with and adapt to system failure of the centralised system to extend drainage networks to newly built areas. On-site sanitation systems are more widely employed in low-income and rural areas of the world The septic tank treatment technologies have been designed to contain exposure to pathogenic hazards. The technical sanitary excrete disposal facility is designed to contain faeces so that the infectious pathogens are isolated from the new host. Onsite sanitation facility such as the ecosan, facilitates nutrient recycling, as it helps to conserve water and soil fertility. Human excreta is regarded as a resource rather than a waste' This is line with sustainability and resilience in the face of rapid urbanisation. The re-use of excreta (untreated or treated to differing extents) as a fertilizer and the re-use of wastewater (including sullage water) for many purposes, but especially for irrigation, may also contribute to the incidence of excreta-related diseases (Eerikäinen *et al.,* 2020). Given that a well-functional sewage system requires access to and adequate water supplies, dry toilets facilitate sanitary conveniences in the face of erratic water supplies, this being in line with SDG Number 6 on Water and Sanitation. However the pit latrines and Fossa Alterna are used mostly in urban areas..

Order and groundwater contamination are risk factors for infectious diseases, hence there is a need to come up with standardised sanitation conveniences supported by legislation. The regulatory standards enshrined in the Regional Town and Country Planning Act, Urban Councils Act and the Housing Standards Act are rarely applied except in housing units that range from 800m^2 to 1 600 m$^{2.}$ Currently, urban authorities lack a sanitation master plan and an act of Parliament to guide the operationalisation of onsite sanitation facilities. The building inspection usually caters for the housing plans, hence little consideration for the septic tanks or eco sanitation toilets.

CONCLUSION

The centralised sewer system is overburdened by rapid urbanisation, leading to the deterioration of the waste treatment efficiency of the sewer plants. Moreover, lack of a sewerage network due to high maintenance and operational costs, have led to the emergence of on-site sanitation facilities as a buffer against the challenges associated with the centralised sewer system. The onsite sanitation facilities have had a positive bearing on sustainability and resilience against a background of vulnerability. There is need to consider sanitation provisions and flexible technology solutions that promote the sustainability of the on-site sanitation facilities. Inspections are rarely done, since there is no sanitation master plan or legal provision to monitor the on-site sanitation facilities.

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