Wastewater production, treatment, and use in Zimbabwe

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Abstract

Zimbabwe has an average sanitation coverage of 97% in the major urban centers that gives it high leverage in harnessing wastewater as a water resource. The total annual freshwater resources withdrawal in Zimbabwe is estimated at 21.05% of total annual renewable water resources meaning that Zimbabwe is water-stressed in terms of a water intensity use index greater than 20% or per capita water availability of less than 1700m^3/yr. The apportionment of freshwater withdrawals is estimated as: agriculture (79%), domestic (14%), and industry (7%). The severity of water stress or scarcity is more pronounced in the low rainfall areas. Wastewater is therefore a water resource of greater importance in the low rainfall areas but has not been incorporated into the river system outline plans as a resource and it also plays an important environmental role in the high rainfall areas. The safe use of wastewater in agriculture is indispensable to Zimbabwe as a means of augmenting freshwater supplies for irrigation in the drier regions and protecting freshwater sources for potable supplies. There is a lack of a common definition of wastewater use typologies leading to different estimates on the area irrigated using wastewater and lack of proper regulation of the practice. Zimbabwe has regulations to govern the disposal and use of wastewater but proper enforcement is lacking and there is need for comprehensive guidelines specifically addressing the safe use of wastewater in agriculture to be developed. Capacity development is required mainly for the organizations that provide extension services to farmers and other key regulatory institutions. There is good potential for the safe use of wastewater in Zimbabwean agriculture.

Water availability and use

Zimbabwe is a land-locked country located in Southern Africa and covers 39.08 million hectares with an estimated population of 11.6 million as of 2002. Average annual rainfall is 657 mm, but varies with location as shown in Figure 1. Only 37 percent of the country receives adequate rainfall for agriculture (FAO, 2005). Based on average annual rainfall and land area, the internal annual renewable surface water resources produced in Zimbabwe are 11.26km^3/yr. The annual renewable groundwater resources are estimated at 6km^3/yr and overlap 5km^3/yr with internal surface water resources resulting in total annual internal renewable water resources of 12.26km^3/yr (FAO, 2005). Accounted flows for external renewable surface waters are 7.74km^3/yr (FAO, 2005) and the sum of the internal and external renewable waters gives total annual renewable water resources (TARWR) of 20km^3/yr. The total annual freshwater resources withdrawal in Zimbabwe is estimated at 4.21km^3/yr or 21.05% of TARWR meaning that Zimbabwe is water-stressed in terms of a water intensity use index greater than 20% (Kumar and Singh, 2005) or per capita water availability of less than 1700m^3/yr (Falkenmark and Widstrand, 1992). The apportionment of freshwater withdrawals is estimated as: agriculture (79%), domestic (14%), and industry (7%). The severity of water stress or scarcity is more pronounced in the low rainfall areas. Wastewater is therefore a water resource of greater importance in the low rainfall areas but has not been incorporated into the river system outline plans as a resource (Thebe, 2012) and it also plays an important environmental role in the high rainfall areas.

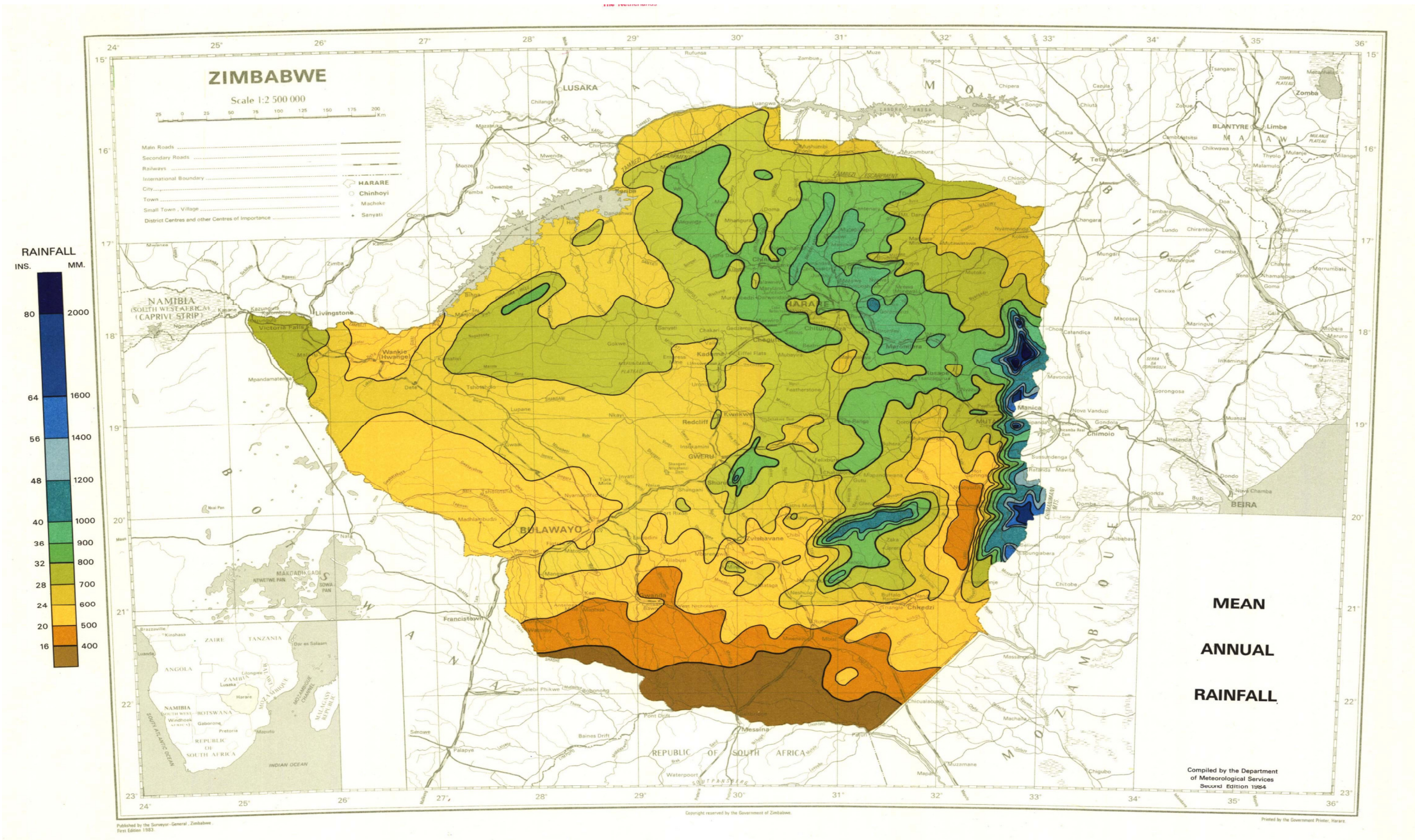

Figure 1. Map of Zimbabwe showing average annual rainfall (Courtesy of the Meteorological Services Department of Zimbabwe)

Wastewater production and treatment

The major towns and cities of Zimbabwe (those that have a population greater than 100000; namely Harare, Bulawayo, Mutare, and Gweru) have a combined water supply estimated at 810000m³/day and generate an estimated 532000 m³/day of wastewater or 66% of gross water supply. Other smaller towns have a combined water supply totaling an estimated 70000 m³/day bringing the national total water supply to an estimated 880000 m³/day and generating an additional 56000 m³/day of wastewater. Conventional sewerage systems are used to collect and convey the sewage to wastewater treatment plants and have inter-connected sewer outfall drains that make it difficult to quantify domestic and industrial effluent separately. Sanitation coverage in urban centers averages 97%.

City wastewater production was estimated using a method slightly modified from the one applied by van Rooijen *et al.* (2010). The method determines wastewater production by multiplying net city water supply (estimated from figures of gross water supply and water supply losses published by the responsible local authority such as the City of Gweru) with a standard return fraction for all water use sectors estimated from literature as it is widely known that only 15-25% of water supply is consumed with the returning as wastewater Qadir *et al.* (2010), as follows;

$$WWG = WS \times (1 - WSLF) \times WRF$$

Where:

WWG is the Volume of Wastewater Generated in m^3/day
WS (gross) is Water Supply Volume in m^3/day
WSLF (physical) is Water Supply Loss Fraction (fraction)
WRF is Water Return Fraction (fraction)

The estimated volume of wastewater treated was obtained from influent flow measurements at wastewater treatment plants. However, the degree of treatment of the wastewater could be failing to meet the effluent quality guidelines due to dysfunctional infrastructure at wastewater treatment plants. The urban councils of major towns and cities having been investing more in the rehabilitation of existing wastewater treatment plants than the construction of new plants with only long-term plans in place for the constructions of larger centralized wastewater treatment plants. Table 1 gives an overview of wastewater production and treatment in Zimbabwe.

Table 1: Wastewater production and treatment in major urban centers of Zimbabwe

City	Population in 2002	Estimated population 2012	Estimated water supply (m^3/day)	Estimated wastewater generated (m^3/day)	Estimated volume of wastewater treated (m^3/day)	Dominant wastewater treatment type
Harare	1850000	2257000	600000	390000	190000	Secondary - Modified activated sludge and trickling filter
Bulawayo	676650	825513	105000	78750	31000	Secondary - trickling filter and modified activated sludge
Mutare	170106	207529.3	55000	33000	30000	Secondary - trickling filter
Gweru	141260	172337.2	50000	30000	10500	Secondary - trickling filter
TOTAL			**810000**	**531750**	**261500**	

Wastewater is collected to semi-centralized wastewater treatment plants using conventional sewerage infrastructure. Combined sewers are not permitted in Zimbabwe (Nhapi and Gijzen, 2002) meaning that storm water drains directly into streams, rivers, and reservoirs in the proximity of the city or town. Some industries discharge partially treated or untreated wastewater into storm drains leading to the direct pollution of streams and reservoirs with industrial effluent.

There are 137 wastewater treatment plants in Zimbabwe and of these, 101 are waste stabilization ponds (Madyiwa, 2006). However, in terms of volumes of wastewater treated, the largest amount of volume is treated by modified activated sludge systems with biological nutrient removal in Harare and Bulawayo as an attempt to conform to effluent discharge regulations. The second dominant type of wastewater treatment in terms of treatment capacity is the conventional trickling filter system.

Urban Councils or Municipalities are responsible for wastewater treatment in Zimbabwe. The major constraint to wastewater treatment in urban centers is lack of financial capacity to overhaul aged wastewater collection and treatment infrastructure rather than lack of technical capacity.

Wastewater use/disposal

Wastewater use or water reuse is an established practice in Zimbabwe that started in the 1950s in Bulawayo at Aisleby Farm, and in 1959 with the reclamation of wastewater from Thorngrove Wastewater Treatment Plant for non-potable use (Gumbo, 1998). Reclaimed wastewater is still used to irrigate public amenities in Bulawayo although the dilapidation of wastewater infrastructure has resulted in reduced areas being irrigated.

Most of the major cities and towns in Zimbabwe including Harare, Bulawayo, and Gweru lie on the edges of the hydrological boundaries or drainage divides. This means that they lie on the main watershed. In Harare in particular, the water supply dams are located downstream of the City in order to increase the catchment yields. Bulawayo is different from Harare in terms of its water supply as it mainly on inter-basin transfers from an adjacent water catchment and augments this supply with groundwater resulting in fewer pollution problems of the water source by wastewater generated in the City.

In 1970, in response to the pollution state of Lake Chivero, the Harare City Council started a major programme of using treated sewage effluent to irrigate pasture. During the late 1970s the lake returned to a minimal pollution condition and the use of sewage irrigation appeared successful (Gumbo, 1997). However, the over-application of irrigation water due to the increase in the volume of wastewater generated over the years, and the limited availability of arable land close to the wastewater treatment plants have reduced the impact of pasture irrigation on lowering the pollution loading of Lake Chivero in Harare. Indirect potable reuse occurs in Harare but is associated with the health risks of drinking water supplies in Harare.

The major direct wastewater disposal projects through land application are located in Harare and Bulawayo with the City of Harare having three farms namely Ingwe, Pension, and Crowbrough with an estimated total irrigated of 1500ha, while the City of Bulawayo has Aisleby and Good Hope with a total area of about 1000ha. Pasture grass and cereal crops are the main crops grown on these farms. Gweru and Mutare practice agro-forestry through the land application of wastewater to irrigate eucalyptus trees totaling approximately 100ha. Surface irrigation methods are the most common. The wastewater disposal guidelines contained in Statutory Instrument 6/2007 of the Environmental Management Act of Zimbabwe might not be adhered to as wastewater is over-applied on land.

In Bulawayo, there are limited informal wastewater irrigation schemes due to the strict enforcement of Council By-Laws. It has been reported that some farmers in Harare practice informal wastewater irrigation to grow vegetables but the total cultivated area has not been determined.

There are several other formal wastewater irrigation schemes in Bulawayo with the major area being Umguza Irrigation Lots where farmers practice unrestricted irrigation using mainly the sprinkler irrigation method on an area covering approximately 1000ha. It is arguably whether the practice can be classified as indirect reuse as there are no common or universally accepted typologies (Qadir et al., 2010). Wastewater from Bulawayo has widely been known to be stronger than from other cities in Zimbabwe due to the lower per capita water consumption in Bulawayo (Bagg, 1998) meaning that slight dilutions in Umguza River result in wastewater that could be as strong as effluent directly disposed of onto land in Harare. Although, there is another 81ha of formal wastewater infrastructure developed in Bulawayo namely at Luveve Gum Plantation and Khami Prison Farm, the actual area irrigated is under 10ha due to inconsistent wastewater supplies for irrigation.

Farmers are generally not aware of the nutrient value of wastewater and at times tend to over-apply conventional fertilizers. The lack of common definition of wastewater use typologies makes regulation difficult and there are crop restricted imposed on one group of farmers such as at Luveve Gum Plantation that are not enforced at Umguza Irrigation Lots yet the wastewater discharged directly from wastewater treatment plants to Luveve Gum Plantation could be of higher quality than the one indirectly discharged to Umguza Irrigation Lots through Umguza River. Farmers are aware of and concerned by these inequalities. Farmers understand some of the health risks associated with wastewater use but most do not acknowledge possible environmental degradation.

Policies and institutional set-up for wastewater management

The framework and national strategy for wastewater management is governed by several pieces of legislation that are the responsibility of different Government Ministries and Agencies. The Environmental Management Act Chapter 20:27 of 2002 attempted to bring the Public Health Act, The Water Act (Chapter20:24), the Water Pollution Control Act (1976), the Natural Resources Act (Chapter 20:13), and the Urban Councils Act (Chapter 29:15) under one governing framework (Nhapi and Gijzen, 2002). In 2007, Statutory Instrument 6 of 2007 of the Environmental Management Act was gazetted as the Environmental Management (Effluent and Solid Waste Disposal) Regulations, 2007. These regulations generally set for the basic framework for wastewater management in Zimbabwe but the other pieces of legislation remain relevant.

The Public Health Act through Statutory Instrument 638 of 1972 gazetted as the Public Health (Effluent) Regulations sets guidelines for wastewater irrigation with regards to public health. These guidelines forbid the irrigation of root crops such as potatoes and sets restrictions that are not greatly enforced presently in Zimbabwe. The Public Health Act is presently being revised and will likely result in new public health regulations that take scientific evidence into account.

The Water and Sanitation Sector Coordination Mechanisms of the Ministry of Water (2010) outline the following key government ministries in the management of wastewater: Ministry of Water Resources Development and Management; the Ministry of Health and Child Welfare; the Ministry of Transport and Infrastructural Development; The Ministry of Agriculture, Mechanization, and Irrigation Development; the Ministry of Local Government and Rural and Urban Development, the Ministry of Environment and Natural resources Management, the Ministry of Energy, and the Ministry of Women Affairs, Gender and Community Development as key institutions for water and wastewater management.

In terms of Zimbabwean law in the form of Urban Councils Act, Chapter 29.15 and Regional Town and Country Planning Act, Chapter 29.6; all households are compelled to have an acceptable sanitation system before an occupation certificate is issued (Nhapi, 2004) and this has led to the high sanitation coverage in Zimbabwe urban centers. However, the challenges in maintain wastewater infrastructure mean that water is channeled away from the households and industries but could fail to get adequate treatment before re-entering the water courses or being used irrigation.

Zimbabwe has regulations contained in the Public Health (Effluent) regulations and the Environmental Management (Effluent and Solid Waste Disposal) Regulations as national guidelines for the safe use of wastewater. However, a recent policy review of regulations done under an on-going study in Bulawayo has shown policy inconsistencies and is recommending the development of separate guidelines that focus on wastewater use in agriculture with clearly defined terms of different typologies of wastewater use to ensure adequate regulation or enforcement of standards. The development of separate standards that specifically addresses wastewater use in agriculture will contribute to meeting the objectives of the Workshop of Wastewater Use in Agriculture held in Harare in 1994 (WHO, 1994). There are presently no mechanisms for quality control of wastewater-irrigated produce/products due to the non-traceability of agricultural produce. Farmers at Umguza Irrigation Lots in peri-urban Bulawayo pay for the wastewater that they use for unrestricted irrigation (Thebe, 2012), while most of wastewater irrigations have free wastewater supplies as they are a means of direct wastewater disposal.

Research/practice on different aspects of wastewater

Firstly, it is worthy to go beyond the past five years to understand wastewater research in Zimbabwe. Understanding these works will ultimately lead to the development of sustainable wastewater management practices and will result in meaningful current and future research. The greatest works on the management of wastewater in Zimbabwe that have laid the foundation for sustainable wastewater management were done in Harare during the period 1997 to 2006 and include three major PhD projects of Madyiwa (2006), Nhapi (2004), and Gumbo (2005) as well as several projects done under the auspices of the Department of Soil Science and Agricultural Engineering, the Department of Biological Sciences, and the Department of Civil Engineering at the University of Zimbabwe. Also of note among these works are the books by Hranova (2005) and Moyo (1997). A few studies were also done in Harare and Bulawayo but none have been long-term projects. Most of the later studies were short-term studies to determine the effect of using the wastewater and probable health risks.

Land application and the agricultural use of wastewater sludge and subsequent effect on soil and water quality is documented for Zimbabwe, especially studies in the Harare area (Snyman, 2007). However, it is abundantly clear from the studies in Harare that there is over-application of wastewater rendering guideline values on chemical quality of wastewater ineffective and therefore leading to the reported negative impacts of wastewater use. The major drivers of wastewater research in Harare were the concerns over the pollution of Lake Chivero, Harare's main water supply dam. The major output of these works was to highlight the importance of proper wastewater irrigation to minimizing the pollution of Lake Chivero and indicating that adequate planning and management strategies were necessary for the safe use of wastewater in agriculture. Harare is inadvertently and unnecessarily practicing indirect potable water reuse when potable water supplies are not limited but are polluted by the improper management of wastewater.

In spite of all these major efforts, Zimbabwe does not have wastewater irrigation guidelines based on local research, lacks a proper definition of wastewater use systems for agriculture, and there has been no study to link irrigation systems on the availability and quality of wastewater used for irrigation and consequently possible health and environmental risks that could arise and how they could be mitigated. There has been a general lack of similar studies in a different setting where wastewater supplies are not highly abundant and freshwater resources are scarce such as Bulawayo. The impacts of wastewater use are potentially different and could lead to the revision of national laws and regulations, and also ensure proper adherence to guidelines across the country.

Since early 2011, a medium-term project is being carried-out in peri-Bulawayo with funding and support from IWMI Theme 3 on Water Quality, Health, and Environment. The study is titled "Impact of irrigation systems on wastewater quality and availability, and the contamination of irrigated crops and soils" and aims to address the short-comings stated above. The expected date of completion of the study is June 2013. It is important to note that there is poor water delivery to formal irrigation schemes in Bulawayo and understanding the irrigation systems could result in improvements in that regard. This study recognizes the knowledge of farmers in formal irrigation schemes and has a participatory approach that will result in institutional strengthening of concerned farmer organizations. The study has also done a comprehensive policy and regulations review and it is set to result in the integration of these policies and regulations and afford wastewater irrigation policy recognition. Recommendations have been made to the Public Health Advisory Board on the Review of the Public Health Act to take local scientific evidence into cognizance and contributions have been to the on-going Irrigation policy formulation. The study details wastewater irrigation systems and proposes a typology for these to enable proper regulation. The positive impacts of wastewater irrigation are highlighted in the study and the value of wastewater and its use for irrigation is demonstrated as part of an integrated urban water management plan that could minimize unnecessary indirect potable reuse of water.

Status and need for the knowledge and skills on the safe use of wastewater

The Questionnaire to Support the Individual's Capacity Needs Assessment on the Safe Use of Wastewater in Zimbabwe was distributed to eleven institutions or Departments (including three different Departments at the main University) at national level in Harare. Two institutions did not respond. The questionnaire was also distributed to seven institutions in Bulawayo but only six responses were obtained.

Bulawayo is the second largest city in Zimbabwe and faces water scarcity. There are greater drivers to use wastewater for irrigation in Bulawayo and there are formal wastewater irrigation schemes that were established in the 1950s that utilize wastewater for irrigation.

The scores used were taken from those that were used in Ghana and are as follows:

Poor/Very Low = 1
Basic/Low = 2
Good/High = 3
Excellent/Very High = 4

The average scores on current knowledge and skills of pertinent staff of the responding organization on the safe use of wastewater in agriculture were 2.53 and 2.51 at national level and in Bulawayo respectively. This indicates generally that knowledge and current skills is in the basic to good category for most of the key institutions interviewed. The Governmental agency responsible for providing agricultural extension services to the farmers (AGRITEX) had the lowest score in this front at national level and in Bulawayo. This indicates that knowledge transfer to farmers is generally poor and could be contributing to poor farming practices. The Department of Irrigation within the Ministry of Agriculture also provides advisory farmers and exhibits better knowledge and skills but has limited manpower to deliver extension services to all farmers and would do well to collaborate with AGRITEX. All scores below 2.5 on current knowledge and skills indicate areas requiring greater attention such as setting health-based targets and economic and financial considerations. Some institutions do not cover some of the aspects stated in the questionnaire and this lowered their average score on current knowledge and skills.

The average scores on importance of the subject were high with the Ministry of Water Resources Management and Development (3.92) and the Department of Irrigation (3.5) scoring the highest at national level. Other institutions had their scores weighed down by their non-participation in some of the subject areas such as the Departments at the University of Zimbabwe. Institutions in Bulawayo generally placed high to very high importance on all issues with the Department of Irrigation (3.96), ZINWA (3.88), and AGRITEX (3.71) leading the way indicating the importance of wastewater as a resource in this drier region of Zimbabwe.

Conclusion

It has been reported that Zimbabwe faces water stress and the pollution of water bodies by wastewater. The safe use of wastewater for agriculture plays an important part in addressing these challenges. Zimbabwe has a highly developed sanitation system in urban centers with average sanitation coverage of 97%. However, the lack of financial capacity by the Urban Councils is hampering adequate wastewater conveyance to the wastewater treatment plants and the proper treatment of wastewater. This presents significant health and environmental risks. It is therefore necessary to consider wastewater irrigation as part of an integrated urban water management strategy and to integrate wastewater into river system outline plans as a water resource for irrigation. The capacities of the key institutions responsible for wastewater management and disposal require strengthening and comprehensive policies and guidelines have to be developed to ensure the safe use of wastewater in Zimbabwean agriculture. The proper use of wastewater could result in water resources available for irrigation increasing by about 10% from current estimates of freshwater withdrawals. There is apparently no need for potable reuse of water in Zimbabwe or the indirect use of wastewater for potable purposes as the wastewater can be adequately used for irrigation with proper planning. Existing freshwater should be protected from pollution for potable supplies with proper water demand management strategies being used to control water supply and the volume of wastewater generated.

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