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SEWAGE TREATMENT, DISPOSAL AND MANAGEMENT PROBLEMS AND THE QUEST FOR A CLEANER ENVIRONMENT IN MASVINGO CITY (ZIMBABWE)

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ABSTRACT

This study examines the problems of sewage treatment, disposal and management that are bedevilling the city of Masvingo (Zimbabwe). This is done in the light of the current legislation as enshrined in the Environmental Management Act (Chapter 20:27) of 2002. The study was conducted in 2008, based on field surveys and document interrogation (literature review). The city is experiencing an environmental crisis due to the malfunction of its sewage waste treatment works, which are: old, and frequently break down due to power cuts and the shortage of spare parts to repair them. However, this problem is not confined to Masvingo City, as many urban centres in Zimbabwe also experience it due to the prevalent harsh economic conditions. Municipalities are often bankrupt and therefore lack the capacity to execute their mandate efficiently, which undermines the goal of environmental protection. The paper advocates for the forging of links with foreign donors or partners who may be willing to provide funding and technical assistance so that some of the problems can be solved.

Key words SEWAGE, Problems, Environment, Masvingo City

INTRODUCTION

Sewage is liquid waste that is derived from domestic, industrial, commercial and institutional sources (Katyal and Satake, 2001). Within an urban setting, it also includes run-off from the streets. Although only a small fraction of sewage (0.05%) consists of waste material, the discharge of raw sewage into watercourses can lead to serious levels of pollution (Jackson and Jackson, 1998; Moyo, 1997). That is why it is necessary to treat sewage before it is allowed to flow into natural watercourses such as streams and rivers. Sewage treatment seeks to achieve three objectives, which include: to reduce the pathogen content of waste, to decrease its biochemical oxygen demand (BOD) and to reduce its solids content (Jackson and Jackson, 1998).

The treatment is done in three stages, namely: preliminary, primary and secondary (Katyal and Satake, 2001). The goal of the first stage is to remove large objects from the wastewater, which include: wood, bottles, stones and toilet paper. Once the larger objects have been removed, the sewage goes further for primary treatment, which involves the crushing of some solids, which settle down to form sludge (solid waste). Secondary treatment is a biological process that is aimed at restoring wastewater to a condition where it can sustain aquatic life such as fish, frogs and turtles. Three reactor designs are often used for wastewater treatment, according to Jackson and Jackson (1998). They include:

a) Trickling (biological) Filters
b) Activated Sludge Tanks, and
c) Oxidation (stabilisation) ponds.

Although the first two can be used anywhere, the last type is only applicable in warm climates such as the tropics. Sewage treatment processes produce sludge and wastewater whose pathogen populations are so low that they pose little or no harm to aquatic life. After treatment, this water can either be used for irrigation purposes or be directed into natural watercourses such as streams and rivers. The sludge on the other hand can be incinerated or used as manure in surrounding farms (Jackson and Jackson, 1998).

In Zimbabwe, urban waste disposal and management fall under the responsibility of municipalities, industries, institutions and the Zimbabwe National Water Authority (ZINWA). The Environmental Management Agency (EMA), a watchdog of the nation's environment, monitors their daily activities, seeking to ensure that they comply with the country's regulations of waste disposal and management. It has a mandate to sue those that fail to comply with them (Masocha and Tevera, 2003). EMA was established in 2002 following the promulgation of the Environmental Management Act (Chapter 20:27). Its primary goals are:

a) The achievement of sustainable management of natural resources
b) Protection of the environment, and
c) The prevention of pollution and environmental degradation.

However, since its establishment, EMA has not made a significant impact in its goal of environmental protection as many rivers, which pass through urban centres continue to be polluted with little or nothing being done to the offenders. Some of the worst polluters are municipalities, government ministries and para-state organisations such as ZINWA, which reflects the complexity of the pollution problem at local and national levels (Mapira and Mungwini, 2005).

This study has three objectives, which include:

a) Identifying the main problems of sewage waste disposal and management that are confronting the city of Masvingo.
b) Discussing their causes, sources and consequences in the light of the current legislation as enshrined in EMA.
c) Suggesting possible solutions.

STUDY AREA AND RESEARCH METHODS

Masvingo is a medium-sized city with a population of 69 993 according to the 2002 population census (CSO, 2002). It is the capital of Masvingo, one of Zimbabwe's ten provinces and is well linked to all major urban centres in the country (Nyanda Urban Development Project, 1982). Although it has a weak industrial base, the city has experienced phenomenal spatial and demographic growth over the last decades (Scott, 1991). It is the oldest modern urban settlement, having been established on the 13th of August in 1890, 8km south of the present site (Bulpin, 1968). Water scarcity at the original site forced it to relocate to the confluence of the Mucheke and Shagashi rivers where it has survived up to the present day (Nyanda Urban Development Project, 1982). Today, more than a century later, the city has grown spatially in virtually all directions. The two rivers now play a significant role in the disposal of the city's sewage waste, which is a cause for concern from an ecological perspective (Tarutira, 2008).

This study is based on secondary and primary information that was collected in 2008. Secondary information was derived from a survey of the available literature on the problems of sewage disposal and management. It involved document

interrogation (literature review) of various sources such as books, journals, city master plans and municipal reports. Field surveys were conducted in June. They involved visits to the city's sewage treatment works, industrial, residential, commercial and institutional areas where observations were made in order to obtain first-hand information about the nature of the problem. Three sewage treatment works serve the entire city. They include two municipal plants and the Teacher's College system, which broke down several years ago and has been discharging raw sewage into the Shagashi River adjacent to the campus (Figure 1). This has led to the proliferation of the water hyacinth weed (*Eichhornia Crassipes*) around the bridge area (Mapira and Mungwini, 2005).

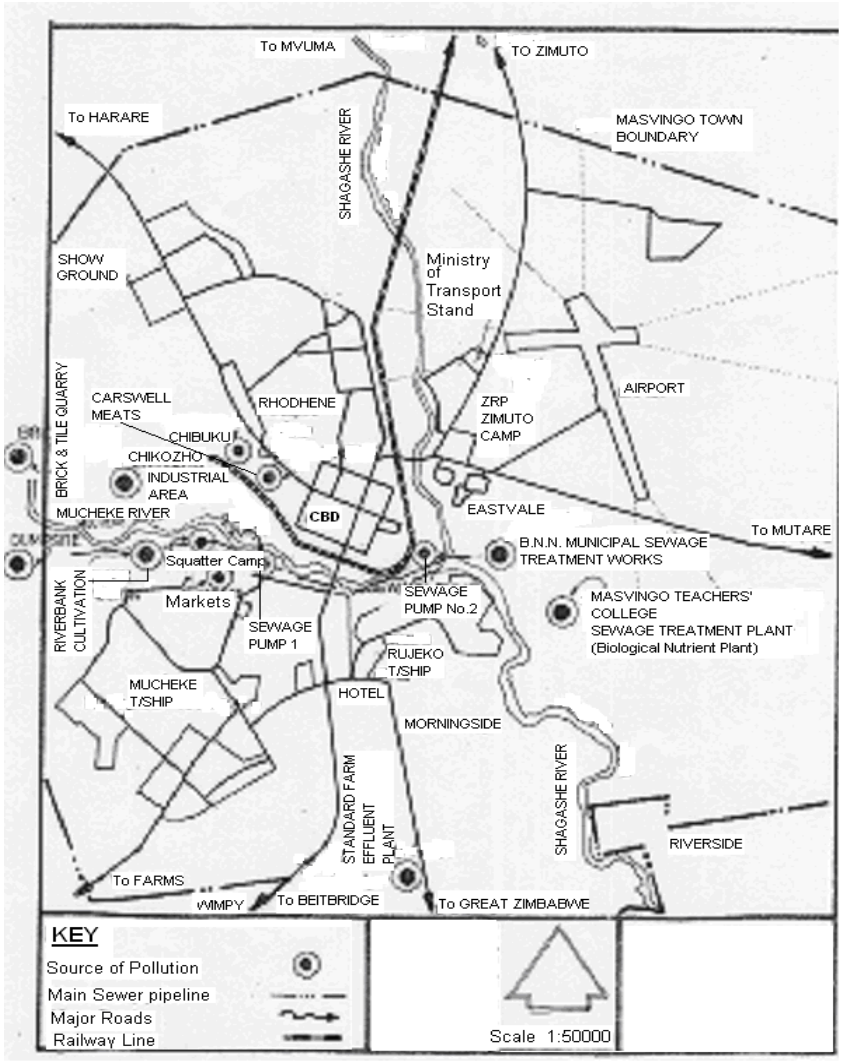

Figure 1: Sources of River Pollution in Masvingo City

RESULTS AND DISCUSSION

Recent studies on river pollution within the city of Masvingo identify the major causes and sources of the problem (Mapira and Mungwini, 2005; Chiwira, 2006). They include:

a) The municipal sewage works treatment system.
b) The Teacher's College's broken down sewer reticulation system.
c) Industries including abbatoirs, tanneries, butcheries and bus garages such as Mhunga, Magwizi, Mapundu and Musasiwa.
d) Household garbage from residential areas.
e) The squatter settlement along the banks of the Mucheke River near the city's main bus terminus, and
f) Stream-bank cultivation, which is rampant in the city.

THE CITY'S SEWAGE TREATMENT WORKS

As a major cause and source of river pollution in the city, the municipal sewage works treatment system calls for some investigation. The sewage works cater for the whole urban community, which includes: domestic, industrial, commercial and institutional land-uses. They are located in the northeast of the city, not far from the Mutare highway (Figure 1) and comprise two separate but complementary entities namely: the conventional trickling bio-filter and the biological nutrient removal (BNR) plants. The trickling plant was commissioned in 1976 with a capacity to treat 7.5 mega-litres of wastewater per day (Tarutira, 2008). It generates nutrient-rich effluent that has been used in the irrigation of pastures and crops within the surrounding commercial farming areas such as the Standard and Carswell Meat Farms (near Stopover), 11km from the plant where animal husbandry is practised.

The growth of the city over the years has exerted much pressure on the plant so that it is failing to cope with the increased volume of sewage waste. Although the city council is aware of this problem, the prevailing negative political and economic environment, undermine the implementation of alternative solutions (Bond and Manyanya, 2006). The plant comprises seven inter-related components, which include:

a) A Screen
b) Grit Removal Channels
c) Sedimentation Tank
d) Anaerobic Digesters
e) Trickling Filter Unit
f) Humus Tanks
g) Sludge Drying Beds.

The screen carries out preliminary treatment by removing large solid objects and heavy mineral particles. Grit removal channels also perform a similar function as they eliminate inorganic substances such as sand, glass, metals and ashes from the wastewater. The sedimentation tank separates solid from liquid waste at the bottom so that it can be disposed and eventually dried to produce manure for the farming community.

Primary or anaerobic digesters are used for the oxidation of raw sludge using micro-organisms, such as bacteria. Oxidation ponds produce methane and algae and can be used to raise fish even though there is a health risk associated

with pathogen transfer if human beings consume them (Jackson and Jackson, 1998). The trickling filter unit is an aerobic secondary treatment device, which is used to oxidise settled sewage through the use of micro-organisms. Humus tanks separate the final effluent from secondary sludge, which is then conveyed to disposal areas such as irrigation farms or pastures. Sludge drying beds perform two main functions, namely: sludge treatment and drying. Once the sludge has dried, it can be sold to consumers in the farming community as sludge cakes or manure. In order for sewage treatment to succeed, all the above components should operate efficiently. However, frequent electric power cuts and the breakdown of some parts in recent years have impacted negatively on the operation of the plant (Tarutira, 2008).

Sometimes raw sewage directly flows into the nearby Shagashi River thereby posing health risks to downstream communities such as Morningside, the Teacher's College and Great Zimbabwe University. A major symptom of river pollution is the growth and spread of the water hyacinth weed, which clogs the entire river section for several kilometres. When livestock (cattle, sheep and goats) feed on the weed, they expose themselves to pathogens such as the tuberculosis germ, which thrives in untreated sewage (Jackson and Jackson, 1998). Since these animals are sometimes slaughtered, the consumption of their meat exposes human beings to risks of pathogen transfer.

Downstream communities also depend on the Shagashi River for fish and water for domestic purposes such as drinking and washing thereby endangering their health (Mapira and Mungwini, 2005). Builders who occasionally quarry for sand in the river (which they use in the construction of houses in the nearby Rujeko C low-income residential area) also face a similar risk. In addition, the polluted river generates a strong odour, which is unhealthy for the surrounding communities. This is quite evident at the Shagashi River Bridge near Masvingo Teacher's College (Mapira and Mungwini, 2005).

The BNR Plant was commissioned in 1998 in order to complement the conventional trickling filter system, which was by then overloaded and failing to cope with the increasing volumes of wastewater from an expanding urban community. The plant has a capacity to treat over 13.5 mega-litres of raw sewage per day. It is intended to treat wastewater so that it can either be used for irrigating pastures at the Standard Farm or be recycled back into the Shagashi River. Sludge that is removed from the plant is used as manure in surrounding irrigation farms. However, it is not recommended for the production of carrots due to pathogens such as the tuberculosis germ (Tarutira, 2008). The BNR plant reduces high BOD from wastewater so as to biodegrade substances. Phosphates are taken up with sludge while nitrogen is released into the air. Phosphates and nitrates are some of the most harmful substances in wastewater since their presence leads to *eutrophication* (Katyal and Satake, 2001).

The BNR plant is highly sophisticated and requires a normal economy if it has to function properly. However, it is no longer operating due to frequent power cuts, shortage of oil and spare parts (Tarutira, 2008). Consequently, the city has to depend entirely on the overloaded and ageing trickling plant thereby compromising its standards of sewage treatment and disposal. Raw effluent is often released directly into the Shagashi River when the city experiences power failures due to load shedding strategies (Chiwira, 2006). The BNR plant comprises eight units, which include:

a) The Screen
b) Grit Removal Channel
c) Skimming Tank
d) Bio-reactor

e) Return Activated Sludge (RAS) substation
f) Clarifiers
g) Thickeners
h) Cascade

The first two units (The Screen and Grit Removal Channel) perform the same functions as in the trickling plant. Hence there is no need for another explanation. The skimming tank is a small unit that traps some waste components of sewage, which may have by-passed the head works and tend to float over the surface of the tank. They include: plastic wastes, condoms, coagulated oils and greases, which interfere with subsequent sewage treatment processes (Tarutira, 2008). The bioreactor removes pollutants through the use of bio-chemical reactions. It is a fairly sophisticated device comprising an anaerobic basin, aeration zone and anoxic basin. The RAS substation delivers sludge back to the bioreactor. It performs two functions, namely: supplying active microbes and polishing/creating the desirable anaerobic conditions for fermentation. The RAS is a key component of the plant and no life can be sustained without it.

Clarifiers are secondary sedimentation tanks that are designed to separate solid from liquid wastes. They thicken the accumulated solids content at the bottom of the tank and help to maintain suspension. Scum removal is achieved, separating it from the final effluent that is made to flow back into the Shagashi River. Thickeners also play a significant role as they handle solids generated from the bioreactor and scum from the clarifiers. Once thickened, these solids are conveyed to a nearby woodlot gum plantation for irrigation purposes. The cascade is the last stage of the BNR plant. Effluent from the clarifiers passes through it on its way to disposal channels such as rivers and streams. EMA regularly draws samples of water for laboratory testing downstream of the cascade in order to determine whether the plant complies with conditions of effluent disposal such as suspended solids (SS), total dissolved solids (TDS), electrical conductivity (EC), alkalinity, heavy metals, biochemical oxygen demand (BOD) and several other parameters. However, since the BNR plant is no longer operational due to the prevailing economic hardships, its role in the treatment of sewage is now insignificant.

CURRENT LEGISLATION AND THE PROBLEM OF RIVER POLLUTION

The nation's current legislation as enshrined in the Environmental Management Act (Chapter 20:27) states that pollution is an offence that is punishable by the law. The penalty for the offence may be in the form of a fine, imprisonment or both. It also states that any individual or organisation wishing to dispose of wastewater into a public stream, surface or underground water should apply for a permit to the Water Pollution Control Unit of EMA, which authorises or rejects such disposal. EMA usually requires individuals or organisations to take certain measures or steps in order to prevent pollution. It determines effluent quality standards using a scale that comprises four categories (Table 1), namely: Blue (environmentally friendly), Green (low hazard), Yellow (medium hazard) and Red (high hazard).

Table 1 Classification of Effluent Standards for Disposal (mg/L)

Parameter	Blue Sensitive	Blue Normal	Green	Yellow	Red
BOD mg/L	<15	<30	<50	<100	<120
DO % saturation	<75	<60	<50	<30	<15
Sulphate (as SO4)	<100	<250	<300	<400	<500
Alkalinity	.0	.0	.0	.0	<500
Nitrite mg/l NO2	<3	<3	<5	<8	<10
Turbidity NTU	<5	<5	.0	.0	.0
Potassium mg/l K	.0	.0	.0	.0	<500
Phosphates Total as P	<0.5	<0.5	<1.5	<3	<5

Source: EMA (Masvingo Branch) 2002

As a routine, EMA monitors pollution levels along the Mucheke and Shagashi Rivers. It draws water samples from several points such as Standard Farm, Shagashi River upstream of Raw Pump Station ER2 and BNR. Results of water samples drawn from the Standard Farm (Table 2) over a period of time indicate that sulphates and nitrates are in the Blue category. However, phosphates and potassium are in the Red category while BOD levels range from Blue to Red. The occasional direct flow of raw sewage effluent into the Shagashi River due to problems such as power cuts and the breakdown of some components of the sewage treatment works, compromises the city's desire to maintain a clean river system throughout the year. Indeed, as previous studies have shown, evidence of *eutrophication* have manifested themselves at various sections of the Shagashi River in the form of the water hyacinth weed, which thrives along the channel between May and October every year (Mapira and Mungwini, 2005; Chiwira, 2006). The proliferation of the weed reflects nutrient enrichment in the form of nitrates and phosphates that are derived from the city's mal-functional sewage treatment system. However, once the rain season is in full swing between November and April, the weed disappears, as the increasing discharge of the river tends to dilute the pollutants. Pollution levels within the Shagashi and Mucheke Rivers thus, follow a cyclical pattern that is linked to seasonal variations in river discharge.

Table 2 Effluent Pollution Levels at Standard Farm (2001-2005).

Parameter	03/11/01	08/09/04	15/01/05	16/09/05
DO % Saturation	34	17	66.5	-
PH	7.30	7	9.13	7.15
Sulphates mg/l SO4	-	24	3	30
Nitrates mg/l NO3	1.0	1.4	1	1.8
Phosphates mg/l P	7.91	13.23	4.24	6.41
BOD mg/l	232	16.6	-	-
COD mg/l	68	88	-	84
Potassium mg/l K	20.5	-	16	19

Source: EMA (Masvingo Branch) 2006

For the purposes of litigation, in 2005, the Pollution Control Unit of EMA devised a fee structure for offenders (Table 3). The penalties compel the culprits to reduce their pollution levels as a means of safeguarding the environment. They are valid for a year and are liable to revision so as to take into account the annual rate of inflation. They are also charged according to the magnitude of the pollution caused. Although EMA has been in operation since 2002, it has not prosecuted any of the offenders even though the evidence of pollution is abundant in several parts of the city (Mapira and Mungwini, 2005). This, to some extent, reflects the ineffectiveness of EMA, which seems to turn a blind eye on the offenders. The scenario poses a threat to the public and undermines the goal of protecting the urban environment and its natural watercourses. Although Masvingo used to be renowned as one of the cleanest urban centres in the SADC region, the continuous disposal of raw sewage into its main rivers damages its image at both local and national levels (Munganasa, 2008). Article 36 of the Environmental Management Act (Chapter 20:27) gives EMA the mandate to ensure that the following actions are avoided:

a) The disturbance of ecosystems and loss of biological diversity.
b) Pollution and degradation of: land, air and water.
c) The disturbance of landscapes and sites that constitute the nation's cultural heritage.

It goes further to recommend the recycling of waste and to dispose it in a responsible manner.

Table 3:MunicipalWaste Environmental Fees

Levels/Categories of Pollution	Penalty/ Fees in Z$
Blue	30 257.00
Green	60 514.00
Yellow	90 772.00
Red	121 029.00

Source: EMA (Masvingo Branch) 2006

However, over the years, little or nothing has been done in the city to execute these duties as previous studies have shown (Mapira and Mungwini, 2005; Chiwira, 2006). The city of Masvingo draws its water from Lake Mutirikwi, 30km to the south east of the settlement (Mapira and Mungwini, 2005). The lake derives most of its water from the Mutirikwi River whose main tributaries are Popoteke and Shagashi Rivers. The pollution of any of these rivers has serious implications on the water quality of the city. Since the Shagashi River feeds Lake Mutirikwi, any effluent disposed into it has a direct cost implication to the city, as a higher demand for water treatment chemicals is inevitable (Tarutira, 2008). River pollution also compromises the health of livestock, fishermen and downstream communities in general (Mapira, 2007).

ECOLOGICAL CONSEQUENCES OF THE PROBLEM

Some ecological consequences have emerged from the pollution of the Shagashi and Mucheke Rivers with negative impacts on the rivers, their immediate environments and surrounding ecosystems including:

a) The contamination of river water, which now displays a dark, oily and greasy colour and throws a thick and unpleasant odour. This has led to the shortage of safe drinking water along the polluted sections.
b) Proliferation of the water hyacinth, which now clogs some sections of the river channels.
c) Disappearance of aquatic life for several kilometres downstream. Some of the creatures that have disappeared over the years include: crocodiles, crabs, fish, frogs and turtles.
d) Contamination of the rivers is likely to lead to an outbreak of water borne diseases such as cholera, dysentery, diarrhoea and typhoid especially in the Morningside area. Some of these cases have been observed among squatters who live along the banks of the Mucheke River (Mapira and Chinooneka, 2007).
e) People who swim and wash their clothes in the river expose themselves to serious health risks due to the high pathogen content of the polluted water.
f) Livestock, which feed on the water hyacinth weed, are prone to disease vectors such as red worms. They also expose themselves to the tuberculosis germ.

Unless drastic measures are taken to control pollution levels along the two rivers, they will continue to pose serious health risks to their surrounding communities thereby undermining the city's goal of environmental protection.

POSSIBLE SOLUTIONS

The problems of waste disposal and management in Zimbabwe have attracted much research and debate in the past (Bagg, 1992; Moyo, 1997; Mapira and Mungwini, 2005 and Mapira, 2007). However, little has been done to address them apart from the enactment of laws such as the Environmental Management Act (Chapter 20:27). The legislation has not been supported by tough punitive action on the ground apart from a few cases (Mapira, 2007). Issues of environmental pollution do not seem to be high on the nation's priority list (Mapira and Mungwini, 2005). There is also a need to make penalties more deterrent so that potential offenders feel threatened (Chiwira, 2006).

The traditional (passive) approaches have proved to be ineffective in discouraging potential offenders/polluters. Failure to prosecute them can be interpreted as approval of their actions. This sets a bad precedence for the city as a whole. If culprits are not punished in time laws, which seek to protect the environment, may not be taken seriously as previous studies have shown (Mapira and Mungwini, 2005; Mapira, 2007). There is also a need to adequately fund monitoring

activities and awareness campaigns so that the general public is well informed on issues that affect their environment. Once this is done, some of them will lobby for change among offenders thereby safeguarding the environment.

The harsh economic conditions currently prevailing in Zimbabwe also undermine efforts to adequately address the problems. Power cuts and the lack of spares prevent sewage treatment works from operating efficiently. For example, the BNR plant has ceased to operate due to frequent power failures and the shortage of spares and oil (Tarutira, 2008). There is need for the country to mend its relations with western nations so that donor aid and technical assistance can be resumed in various sectors of the economy. However, this cannot be accomplished without addressing the political questions, which call for dialogue among political parties within the country (Bond and Manyanya, 2006).

CONCLUSIONS

This paper has examined the problems of sewage treatment, disposal and management within the city of Masvingo. It has exposed their main causes and ecological consequences within the context of the existing legislation. It shows that the city's main source of water, Lake Mutirikwi is under threat due to the persistent pollution of the Shagashi and Mucheke Rivers. The city's sewage treatment works are failing to cope with the increasing volumes of sewage as the city grows both spatially and demographically. At the same time, the prevailing economic problems undermine any efforts to ameliorate the situation. Frequent electrical power cuts and shortages of spare parts undermine the efficient operation of the sewage treatment works. Although EMA has been in operation since 2002, its impact has hardly been felt on the ground as river pollution continues without any offenders being prosecuted. This scenario sets a bad precedence since failure to act can be interpreted as approval of the culprits' actions. The paper argues that at national level, issues of environmental protection should be prioritised beyond the mere enactment o f laws. Tough punitive action should be seen on the ground in the form of severe penalties against offenders. At the same time, the country should mend its relations with western countries so that it can attract funding and technical support in order to restore the lost clean city status of urban centres such as Masvingo.

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