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Full Length Research Paper

Design of a waste management model using integrated solid waste management: A case of Bulawayo City Council

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The purpose of this research paper was to design a waste management model for Bulawayo City Council (BCC) based on integrated solid waste management system. The increasing solid waste generation in the city of Bulawayo is evidenced by increased number of illegal dumping of waste in the urban communities. In this paper, a model that identifies cost-effective and efficient combinations of scientific and engineering tools to manage solid waste and also incorporating the key performance indicators (KPIs) or metrics for solid waste management services has been designed. Literature on different types of waste management models, quantitative analysis of waste at Ross camp, direct observations made in the city locations and policy documents of the Zimbabwean Government (EMA acts), founded the development of this model. The design shows a clear depiction of the environmental management acts (EMA) and the municipality by-laws. Performance measurement which is very critical in waste management has been incorporated. Model design focus was on waste type which is a determinant of the waste receptacles, collection, transportation and disposal methods have therefore been depicted in the model. The model provides easy access to data for the formation and implementation of effective solid waste management policies, strategies and programs to achieve sustainable waste management.

Key words: Environment, Integrated Solid Waste Management (ISWM), solid waste.

INTRODUCTION

Solid waste streams can be appropriately characterized by their sources, by the types of waste produced, as well as by generation rates and composition but this approach might be difficult for Bulawayo City Council as it is struggling to do so. Figure 1 is a depiction of the current waste management model for Bulawayo City Council. The waste management system shows that from the waste stream, some waste end up at illegal (informal) sites and some at legal sites. The formal involves a scenario, whereby once solid waste is produced on site; it is temporarily stored in waste bins or any other suitable containers or at transfer points awaiting collection. The municipality's solid waste management section collects the wastes from the temporary storage facilities and transports them to its specially designated dumpsite. The second stream is illegally disposed and it accounts for solid wastes that do not find their way into the municipal solid waste collection system (Figure 2). Some of the wastes are illegally buried in the ground, or burnt at source or dumped in open spaces, streams, or roadsides. Both streams handling have leakages that have direct and indirect impacts on the biophysical and social environments. The current system (Figure 1) is inadequate in ensuring an integrated solid waste management system which should take into consideration waste generation; waste handling and sorting, storage; and processing at the source, collection, sorting, processing and transformation; transfer and transport; and disposal (Edward, 2004).

Zimbabwe, in particular Bulawayo City has been affected by an ineffective waste management system

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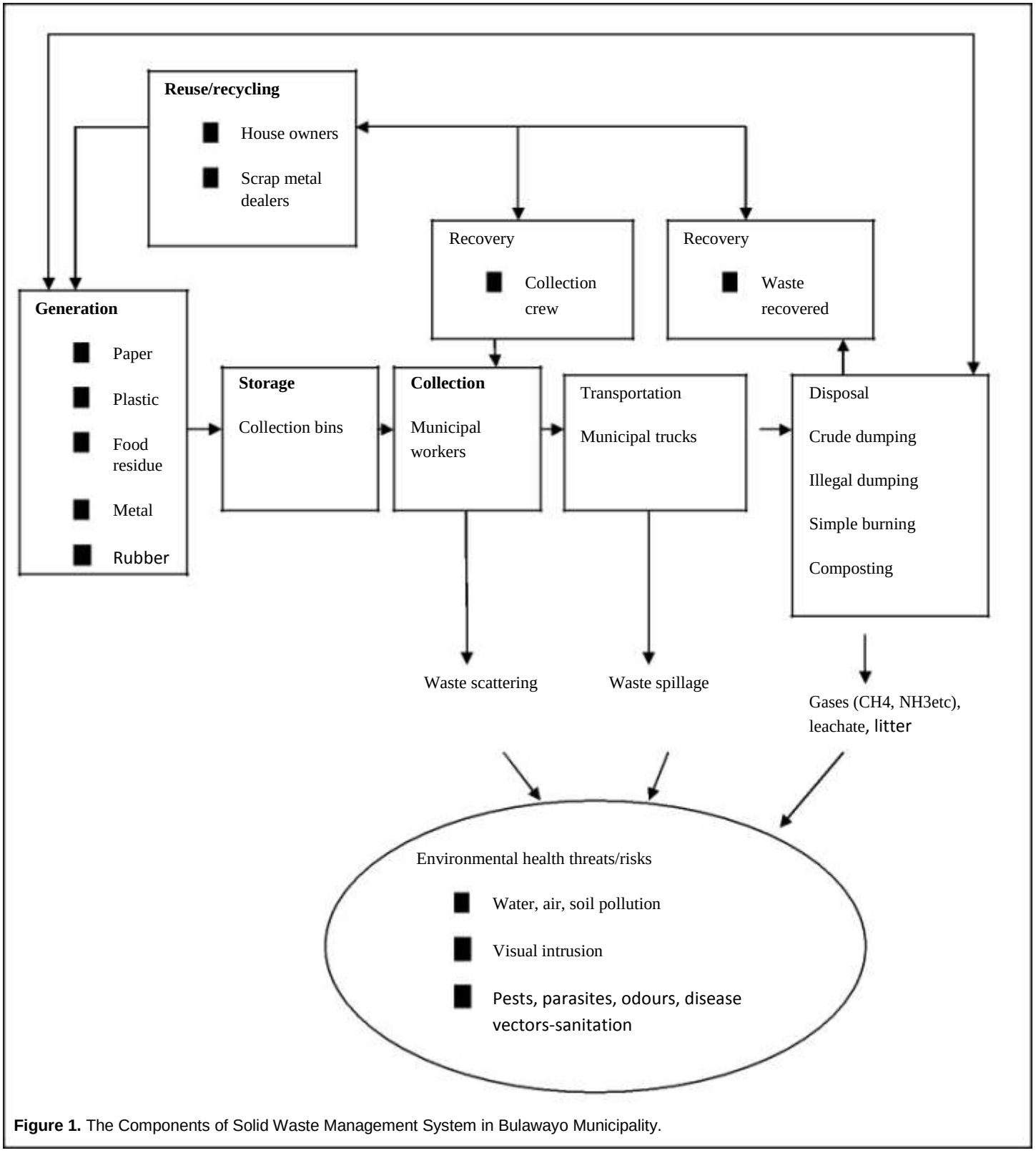

Figure 1. The Components of Solid Waste Management System in Bulawayo Municipality.

which is visible by the levels of waste which is dumped in open spaces. The research other concern was the lack of disciplin e in the way waste was dumped carelessly and the lack of commitment for waste management by the communities. The main purpose of this paper is to design a waste management model for the city councils and other organizations involved in the management of waste. The characterization of waste into different types

Figure 2. Illegal Dumpsite next to a Market (Mpopoma, 2011).

will make it easy for the waste management agents to understand the main generators of waste and how it can be stored, collected, transported and finally disposed of. The model is designed on the basis of different waste types generated from different sources of the community. The different sources considered are the different residential areas. In this study, waste characterization starts at the source to determine the type of waste receptacle, waste collection method, transportation and the best disposal method. The paper also recommends how the city council or any organization involved in waste management can improve the management of waste by including performance measures in the waste management system.

REVIEWED LITERATURE

The necessity for Waste Management cannot be over emphasized especially in modern society but it has existed for millenniums. In “Waste Management”

Bilitewski et al. (1994) reports that from 9.000 to 8.000 B.C. people learnt to dispose of their waste outside their own settlement to avoid odor, wild animals and nuisances of vermin (NIMBY SYNDROME). Waste management is nowadays far more complex than it was some thousand years ago. The complexity arises not only because of the huge quantities of residuals produced by the modern society, but also because of differences in the composition of the waste. Presently various municipalities fail to supply adequate waste management service to their communities (Godfrey, 2006). This is shown by the increase in uncollected waste in high density suburbs. In various places liter is scattered and also waste accumulates in non-designated places. One of the main causes of poor service in most of the municipalities is lack of proper planning although staff, equipment and poor access to certain places are also given as reasons (Godfrey, 2006). The United Nations Development Program survey of 151 mayors during the International Colloquium, in 1997, identified insufficient solid waste collection and disposal to be among the five (5) most severe problems in cities worldwide (UNSD, 1999). This number shows the importance of well-functioning waste management systems, and the necessity of making improvements in this field. If waste is unmanaged, it becomes a source of contamination and disease (UNCHS, 1989). Proper waste management is needed to reduce health problems, water pollution risks and other environmental hazards, besides the negative aesthetic impacts. Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal program (Figure 3). ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions.

The approaches in the area of solid waste management are not only very capital intensive, but also difficult from the environmental and social points of view therefore, there is a need to develop, master and implement a simple, but reliable tool that will help the decision makers in the analysis process. Integrated Municipal Waste (IMW) model (Figure 4) is a tool which seems to meet all the requirements (White, 1997; Bjorklund, 1998; Eriksson, 2002; McDougall, 2001). The results of the analysis from the IMW (Figure 4) model give vast amount of information, but it is rather fragmented. Waste management is in itself a large and complex system that is difficult to survey. The system grows even more complex as one considers its links to other sectors such as manufacture, energy production, and agriculture. Based on this reviewed model and other models, the author proposes a model that is easy to understand and that will also be easy to convert into a

Figure 3. Integrated Solid Waste Management System (www.epa.gov/globalwarming).

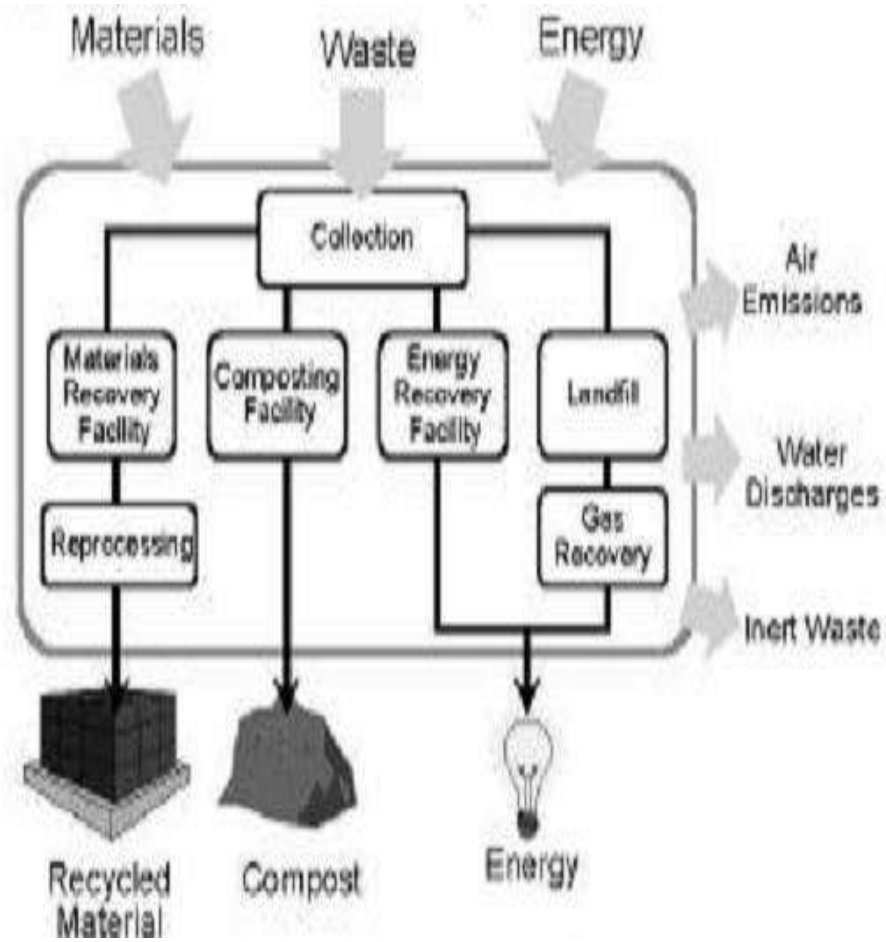

Figure 4. IWM Waste Management Model (www.plastics.ca/epic).

database that can be used by the waste management agents considering the level of technology. The mode designed in this paper gives a broad presentation of the important elements necessary in the management of waste. The major findings of this paper are that the model will enable monitoring of waste types from each location

and help set targets for waste minimization.

MATERIALS AND METHODS

Quantitative analysis

An analysis of the amount and types of waste generated was conducted at Ross camp. This analysis was conducted to determine the amount of waste generated per week by a population of 483 people. Ross camp is a community that consists of 77 households and each house was given a task of accumulating their daily domestic waste for a week.

The amount of waste that was generated was analyzed in terms of the type of waste, the type of waste receptacles; separation at the source was also analyzed to determine whether the residents knew about waste separation to account for waste recycling. The amount of waste that was generated in a period of 7 days was calculated and the results are shown in Table 1.

This analysis was done to determine the amount of waste and types of waste that is generated by households as the research was more to do with domestic waste.

Data collection

The purpose of this research was to design a waste management model for Bulawayo City Council and information that was necessary for the design of the model was collected. Literature from a number of waste management models was reviewed. Information pertaining to the environmental management act concerning management of domestic waste was also reviewed. This information was reviewed to assist in the design of the new model using integrated solid waste management system.

Interviews

Informal interviews were conducted at Ross camp as it was the study area. The structured questions during the interviews focused on the following:

(i) The importance of waste management
(ii) The causes of increase in waste generation.
(iii) The methods of waste collection.
(iv) The types of waste receptacles used.
(v) The frequency of waste disposal.
(vi) Their understanding of waste separation at the source and if it is being practiced.
(vii) The effectiveness of the waste management company
(viii) Waste recycling
(ix) The role of the public in terms of waste management
(x) The impact of poor waste management.

These questions were structured as an improvement process on the waste management model of Bulawayo City Council and also to find out the views of the residents on waste management.

Observations

The researcher made tours in the different locations of Bulawayo. During those tours, it was observed that the community especially in the high density suburbs, carelessly disposed wastes anywhere depicting illegal dumping. Observations made in the city center, confirmed a different perception people have towards waste. Some people would use the bins and some did not. Coming to the low density areas, provision of waste receptacles in some households is there but the concern was on the collection regularity and time management by the city councils. During these trips, besides taking notes about the physical characteristics of the neighborhoods, photographs were taken to show and record illustrative features and interesting attributes of the areas.

RESULTS

Waste management models are getting increasing attention throughout the world. It is therefore important to understand possibilities and limitations of different models. This section covered the design of the conceptual model for Bulawayo City Council Integrated Solid Waste Management Model (Figure 5) based on the reviewed models, (Figures 1 and 3) and data that was collected from the case study at Ross camp.

Case study results

Table 1 shows the results that were obtained from the study conducted at Ross camp to determine the waste generation rate. In this study, waste was collected from the 77 houses that make up Ross camp after a period of 7 days. The rate of waste generation in Ross camp in Bulawayo is 0.00024 m^3 per capita per day (Table 1). During this study, no waste receptacles were provided for the households as the study also focused on the type of receptacles the residents used. The waste components found in Ross camp included food residues, paper, plastics, metals, glass, textiles, rubber, and wood. The results obtained from Ross camp on waste composition are shown in Table 2.

From Table 2, the sampled households reflected a total weekly waste generation of 8.06 m^3 (8060 L). This gives a mean weekly waste generation of 0.010 m^3 per household. The daily per capita waste generation is estimated at 0.00024 m^3/capita/day. The value is far below; this may be due to the fact that the study at Ross camp focused on domestic waste only.

The case study (Table 3) shows the type of waste receptacles which the households use for waste storage. According to the case study, 73% of the households use makeshift (sacks, tins, buckets, plastics), 19% use proper bins provided by the city council and 8% have no receptacles.

Residents whose households do not pay for waste collection services ended up disposing their waste in open spaces, rivers, and drainage basins (Figure 1), burning or burying it. In this study, it was observed that waste collection is done once every week for those households that pay for their waste to be collected.

The factors that influence the amount of waste generated are;

(i) The time of the year: mainly holidays of the year, that is, Christmas and New Year holidays.

Table 1. Summary of the calculation of the per capita waste generation.

Variable	Sample	Total study area
Number of households	77	770
Population	483	770*6=4620
Total weekly waste generation(m^3)	0.806	0.010*770=8.06
Weekly per capita waste generation (m^3/capita/week)	0.806 m^3/483 people= 0.00167	0.00167
Daily per capita waste generation (m^3/capita/day)	0.00167/7=0.00024	0.00024

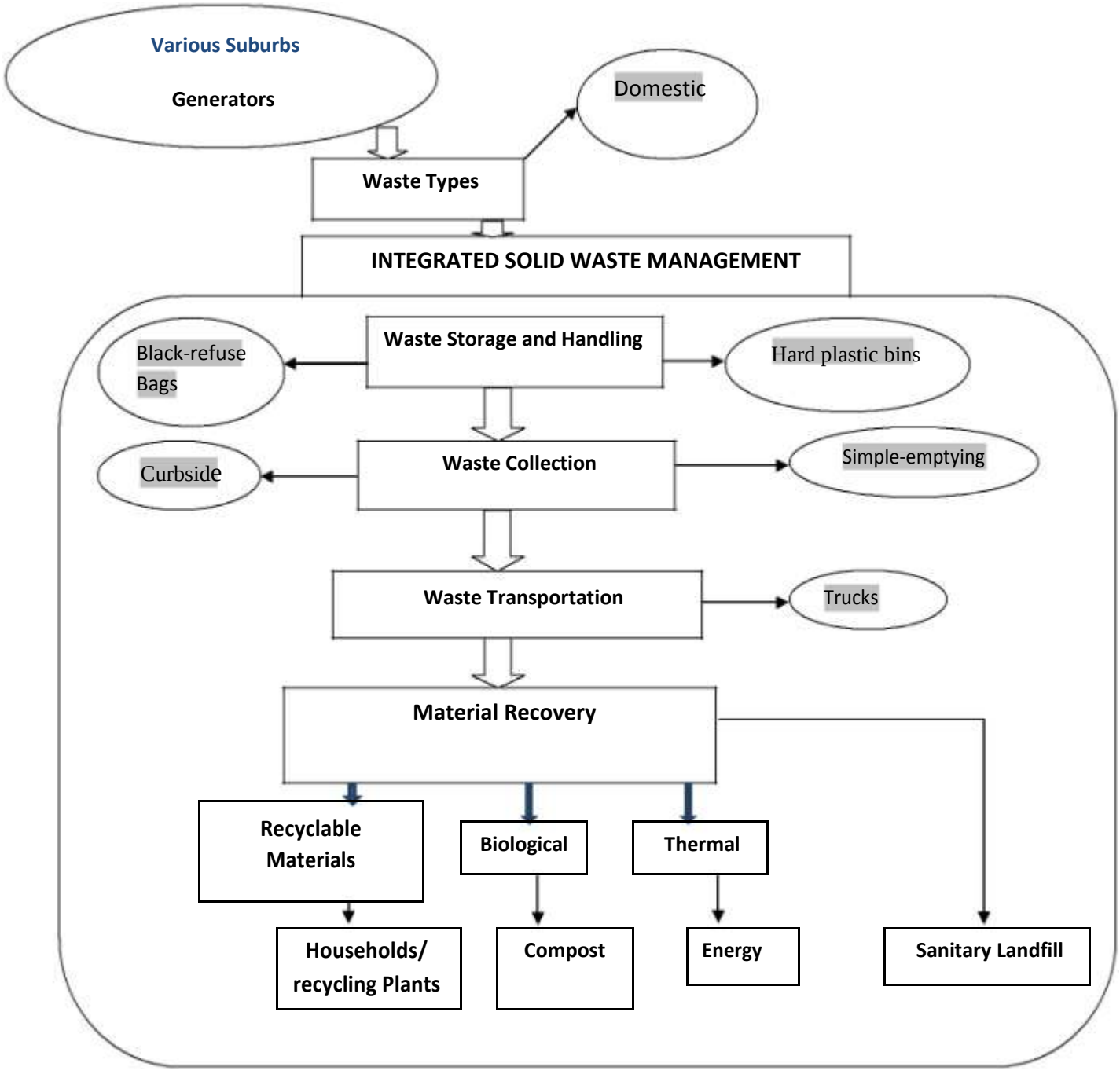

Figure 5. Conceptual Model of BCC ISWM.

Fig 4.1: Conceptual Model of BCC ISWM

Table 2. Waste Composition table.

Waste composition	%
Food remains	23
Plastic	42
Paper	30
Yard wastes	4
Glass	0.4
Metal	0.6
Total	100

Table 3. Type of Receptacles used for daily collection of waste.

Type of container	%
No bins	8
Makeshift (sacks, tins, buckets, plastics)	73
Proper bins (provided by BCC)	19

(ii) The rise in residents' earnings. (iii) Month-ends earnings.

The findings from the study also showed that waste separation at the source is not practiced by those households whose waste is collected by the waste collectors. The case is even worse for those households whose waste is not collected. From this study, waste recycling is not practiced by the residents and in any case, if waste recycling was being practiced by the waste collectors, then separation at the source would have been promoted and the residents would have full knowledge about waste recycling. Disposal of waste by residents whose waste is not collected is done on a daily basis and mostly consists of open space disposal and burning.

The information that was obtained from the case study contributed to the design of the model.

Model design

The researcher conceptualized the system based on the fact that waste is generated from different sources and this waste is of different types depending on where it is being generated. The different sources of waste in Bulawayo town are the residential areas, industries, commercial areas, institutions, farms and construction companies etc. but the focus is on residential areas. These sources generate different types of waste which can be categorized into domestic waste, industrial waste, toxic waste, biodegradable waste etc. Waste types can be handled, stored and transferred differently. Each waste type can be separated at the source if the waste receptacle is determined. Separation at the source will bridge the gap in the current BCC model. The researcher therefore classified each waste type with a suitable waste receptacle. The different types of waste can be stored and collected differently (Table 4). Once the waste is separated at the source and stored in specific waste receptacles, it will be easy to transport waste to the designated disposal area. Other than disposal, waste can be treated by various ways to recover material. This includes energy recovery from industrial waste, compost from bio-gradable waste and recycling by both households and industries.

Bulawayo City Council as a waste management authority should comply with the regulations on waste management. The municipality has a department which manages waste and this department should comply with the acts and laws which have been put in place. The Model is designed by linking it to the environment management act and the city by-laws as compliance to the regulations. All the regulations in the environmental management act pertaining to the management of waste should be considered by Bulawayo city council otherwise it will be contravening the act.

The designer of the model included the EMA acts and the city by-laws in its waste management to show that BCC acknowledges the acts and by-laws.

This model provides a clear understanding of waste management process. The waste type characterization makes the waste recovery section easy as there will be no need for waste separation. The uniqueness of the model is that it shows;

(i) The type of waste generator.
(ii) The type of waste generated.
(iii) The type of waste receptacles.
(iv) The type of collection method.
(v) The type of transportation.
(vi) The type of disposal method pertaining to a waste type.

This model does not only reflect that the EMA is articulated, but it has included some performance measurements on the collection of waste which is part of waste management.

Strengths of the model

(i) EMA acts and the municipality by-laws are depicted in the model showing that BCC abiding by the regulations and also showing a sense of responsibility pertaining to waste management.
(ii) Performance management is very critical to waste management and for this reason the system has been designed with an aspect of performance management on waste collection.
(iii) Knowing the different types of waste is relevant in this system as the system is designed in such a way that waste type is the determinant of the waste receptacles, collection, transportation and disposal method which

Table 4. Waste Receptacle and collection method.

Source	Waste generator	Waste receptacle	Collection method
Residential	Households	Black refuse bags, Hard plastic bins	Curbside, informal, Simple-emptying
Industrial	Industries	Skips, metal bins	One-way, non-systematic
Chemical	Chemical plants	Skips, metal bins	Exchange, one way
Agricultural	Farms, Vineyards	Hard plastic bins	Simple emptying
Commercial	Restaurants, stores, hotels	Hard plastic bags, plastic bins	Simple emptying
Institutional	Schools, colleges, prisons, hospitals	Metal bins, Hard plastic bins	Simple emptying

makes it easy for learners to understand the use of the model.

(iv) Material recovery is important and this model shows the different ways in which waste can be recovered.

DISCUSSION

Waste Management acts are not fully been complied to by the city council and the community and this prompted the author to come up with a design of a model which incorporates the EMA acts as part of the driving force in waste management. The fact that waste is dumped in illegal dump sites and also the results from the interviews also contributed to the conclusion that EMA acts are not yet totally in place, and more time is needed for municipalities to be able to comply with the regulations. (EMA act is in place but no compliance)

There has been little pressure in the past for providers of solid waste management services to evaluate service quality, improve standards of performance or to justify service quality relative to its cost (Michael, 2008). This model has integrated performance measurement as an evaluation method for BCC Departments' management information systems. In practice this means establishing a reporting system on the performance of the SWM services, and routine collection of information (daily, weekly, monthly, yearly).

The results and picture (Figure 2) from the surveys show that there is no waste characterization especially in the communities and this model shows that waste characterization is the drive towards easy waste management as it draws a line between different types of waste and waste generators. This strategy of characterization of waste in terms of waste generators will help waste managers to manage the types of waste they are dealing with and how best to recover, recycle and finally dispose of it.

This model is a start to the design of a database system for the city council and other waste managers. It is a framework or skeleton for the design of a database.

RECOMMENDATIONS AND CONCLUSION

The model designed will require a design of a database for it to be fully appreciated in its capacity for managing waste. The results show that this waste management model can be useful at a number of different levels in society. For example, it can be used by companies to support strategic decisions, by municipalities for waste management planning, and for governments for policy decisions. The researcher also recommends that BCC starts waste recycling projects by incorporating residential areas as the main source of collecting recyclable waste which is separated at the source. For this to be made possible, households should be provided with waste receptacles. BCC does not have to charge waste collection charges for those residents who separate and store the agreed amount of recyclable waste on its behalf.

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