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Solid waste in Kitwe

Solid waste characterisation study for the city of Kitwe, Zambia : Phase 1

By Barbara Kazimbaya-Senkwe
Alex H. Mwale

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SUPPORT FOR IMPLEMENTATION OF NATIONAL PLANS OF ACTION

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<u>For the</u>

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ACRONYMS

KCC	Kitwe City Council
SMW	Solid Waster Management
CBU	Copperbelt University
PSO	Provincial Statistical Office
MSW	Municipal Solid Waste
EPPCA	Environmental Protection and Pollution Control Act
SLP	Sustainable Lusaka Programme
NGOs	Non Governmental Organisations
KCCI	Kitwe Chamber of Commerce and Industry
DEO	District Education Officer
CDB	Central Business District
ECZ	Environmental Council of Zambia
JCTR	Jesuit Centre for Theological Reflection
LCC	Lusaka City Council

EXECUTIVE SUMMARY

1. INTRODUCTION

This study is the second one done under the SINPA Zambia project in Solid Waste Management. SINPA Zambia is a capacity building project on Local Government in Zambia and has been working with the Kitwe City Council (KCC) as a pilot. The project identified solid waste management as one of the 5 key areas where the KCC needed help in terms of capacity building. The first report was meant to establish the current situation in SWM in the City of Kitwe. It established that there was no information on the quantities and types of solid waste that was being generated in the city. Without information like that it would be difficult for the KCC to be able to plan properly and also to work out strategies of dealing with the problem of SWM. This was even more important given the fact that the KCC was going through a very difficult period financially. As a result one of the key recommendations from that report was the need for a follow up study which was going to establish not only the amount of SWM generated but also what types are generated and the sources where they are coming from.

The current study therefore sets out to achieve what follow up on the findings of the first report. The specific objectives of this study were to:

1. Establish the quantities and composition of waste for the different land use sectors within the city of Kitwe over different seasons,
2. Project future quantities of waste generation in the city,
3. Review the available technical options to ensure sustainable SWM in the city;
4. Investigate the potential for recycling, and
5. Estimate the cost and revenue of managing generated waste in Kitwe.

The study used four different methodologies. These were:

1. **Quantitative Survey:** This was used to identify the main types and sources of waste. It included the development of 4 types of questionnaires for the 3 land uses selected for the study i.e. Residential, Commercial and Industrial;
2. **and 3. Physical Observation and measurement of generated waste:** This involved the use of bin liners which were given to the respondents. Specific individuals were engaged from each property involved n the survey to increase compliance. Measurements were done for waster collected over a six day period;
4. **Chemical analysis:** To determine the chemical composition of waste.

The study was undertaken by a team of 38 comprising 2 consultants and 36 researchers who were students from the Copperbelt University. They were given training to prepare them for the task of administering the questionnaires and doing the measurement of the waste. The period of the study was from 12th March to 2nd April 2001 which is the rainy season. Two series of measurements were done over this period: one in the middle of the month and the other at the end of the month when most people get paid to gauge whether there were any significant differences. It is necessary that another study be done in the dry season to get the complete picture. The ideal month would be October.

2. RESULTS

The main results from the study have been presented according to the land uses selected i.e. Residential, Commercial and Industrial. Chisokone market has been discussed separately because of its unique position in the sense that it produces a huge amount of waste.

(I). QUANTITIES AND COMPOSITION OF WASTE

(a). Residential areas

This land use was divided into 4 main categories which are: Low cost; Medium cost, High Cost and Peri-urban areas. In total there were 172 respondents from the residential areas. The household size was highest in the high cost as well as peri urban areas which was 9 whereas for medium and low cost houses it was 7. The head of households were mostly employed in the formal sector with the high cost areas having the highest at 65.9% and the peri urban areas lowest at 20%. Unemployment was highest in low cost areas at 30% and lowest in medium cost 10%.

Physical measurements showed that garden waste accounted for the largest percentage of the waste from all the categories representing a per capita generation of 0.32kg for low cost, 0.4 kg for medium cost, 0.31kg for high cost and 0.21kg for the peri urban areas. The figure was lowest for the peri urban areas because they do not normally have big yards. Food waste accounted for the second highest waste in all categories

The overall per capita waste generation per day by household category was highest for the peri urban areas at 0.75, followed by high cost areas at 0.62, medium cost was 0.60 and low cost had the lowest at 0.45. These figures compared well with those for the City of Lusaka. The fact that the peri urban areas had the highest rate of generation can be explained by looking at the socio economic results. The results show that 63% of household head were involved in the informal sector of which 75% actually worked from home. This means that the waste being generated from the Peri-urban areas consists of domestic and industrial/commercial waste. The generation figures were similar to estimates by researchers for low-income countries like Zambia.

In terms of components of the solid waste results showed that for moisture the lowest was 29% and the highest 79% which were outside the optimal values of 50-60% required for metabolic activity to occurs. The results for density ranged from 116 to 260kg/m^3 which were well within the optimum. Density is an important characteristic as it enables municipal managers to plan and identify capacity of waste haulage vehicles to be used.

The waste also had carbon to nitrogen mass ratio which was within the optimum range for waste to undergo biodegradation indicating its suitability for composting to be used as a fertiliser. Furthermore, the results indicated that much of the waste comprised cellulose with good heating value characterised by low ash and high volatile matter.

About 70% of the respondents indicated that they disposed of their waste by throwing it in rubbish pits dug within their yard. This was followed by disposal by using a communal heap which accounted for about 20% of the respondents in the peri urban and medium cost categories. Private collectors were only engaged in very few household in the high cost areas.

(b). Commercial Areas

The companies who took part in the survey had been operating in Kitwe for an average period of 11 years. 75% of the firms indicated that they obtained their merchandise locally which increased the possibility of some waste being "taken back" for reuse. The main types of waste generated were sweepings, paper, food and cardboard. Not many firms cooperated so results of the measurements were collected from very few firms which showed a mean weight of waste generated per day of 4.75kg. In terms disposal 44% indicated that they used private firms to collect their waste. Only about 15% indicated that their waste was collected by the KCC. Most (66%) of the firms not using private companies to collect their waste indicated that they would not be willing to pay for their waste to be collected. It is clear that most of them intent on disposing of their waste a situation that should make the KCC more vigilant to inspect premises to make sure that waste disposal is being properly done.

(c). Chisokone Market

A total of 38 marketeers took to the survey of whom 58% of the respondents were male and the average period of trading was 6 years. The types of waste varied widely and included clothes, vegetables and fruit, fish, dry foods such as beans, jewerelly, flowers, groceries, cosmetics, wood products, electrical hardware and audio tapes. Only about 17% of the respondents indicated that they obtained their merchandise from outside the country.

Food remains accounted for 32% of the waste, with paper being 26% and sweepings 24%. Plastics made up 13% while cardboard and pieces of cloth accounted for 3% each.

(d). Industrial Areas

A total of 60 firms took part in the survey with an average period of operating in Kitwe of 18 years. 48% indicated that they obtained their raw materials locally indicating that the possibility for "take back" of packaging also exists in the industrial sector. 93% indicated that their main clients were local businesses which means that there is great potential for the cooperation on matters of cleaner production.

The main types of waste generated were metal followed by paper. These accounted for 25.6% and 20.9% of the respondents respectively. In terms of disposal of waste 35% of the respondents indicated that they take their waste to the dumpsite while 21% use pits, 19% incinerate and 17% give their waste to other industries for reuse and recycling. Only 2% have engaged a private contractor to collect their waste. There is need for the KCC to take an active interest in what is going in this sector as a lot for waste is not being properly disposed off. Only 3% of the respondents indicated that they were registered with the ECZ for purposes of waste disposal. The level of willingness to pay for private waste collection was quite low at 21%.

(II). PROJECTION FOR FUTURE WASTE GENERATION
This was done by using population projections for the 2005 and 2010 years. The projection showed that the waste generated would rise from 71 807 tonnes in 2000 to 74 725 in 2005 and 77 781 in 2010 an overall rise of 8.1%. These however, are rates for the rainy season and are likely to be higher than those of the dry season. However they give a general indication of the amount of the increase of waste generation in the city.

(III). COST AND REVENUE OF MANAGING WASTE COLLECTION BUSINESS
Although this was one of the main objectives of the study it proved to be extremely difficult to calculate with any measure of accuracy the cost of providing a solid waste collection service. This is mainly because the companies involved in this business were doing it as one part of a package of services they offer. Thus the costs incurred were not exclusively for the solid waste management collection service. However, the study was able to identify the main costs that go into the collection and disposal of waste: (i). Capital costs (vehicle purchase, interest on commercial bank loans and depreciation of equipment); (ii). Transport and Vehicle operation cost i.e. repairs, fuel and oils; (iii) Health and Safety clothing (overalls, safety shoes, rubber gloves and respirators); (iv). Labour costs for driver and waste collectors; (v). Fees to ECZ, Dump site and the KCC; (vi) Establishment expenses such as travel and subsistence, insurance, office equipment, rent for offices including utility bills. The revenue normally would be the cost plus a mark up of between 20 – 50% which companies usually use

(IV). POTENTIAL FOR RECYCLING
The results showed that in the residential areas a significant amount of waste is already being re used with the highest being in the peri-urban areas where this was 90% followed by medium cost with 85% and the lowers was the high cost area with 57%. The waste mostly being re sued was the plastic followed by garden waste. There is need to encourage the people in the high cost areas to reuse their plastics as they generate a lot of plastic waste. This can be done through encouraging them to reuse their old carrier bags and payment for brining back disposable bottles.

The commercial sector had the second highest level of waste with 34% indicating that they re use their waste, of which 36% indicated paper as their main re used waste. In the industrial sector only 25% indicated that they re-sue their waste while at chisokone market this was 21%.

There is also another form of re-sue where the informal collectors pick some of the waste for their own use mostly in small businesses. This is most prevalent in residential areas where the highest was reported in the medium cost area at 45%. The high cost area reported 44% while the peri-urban areas reported the lowest at 10%. These were mostly plastics and bottles.

The pattern was very similar in the residential and commercial sectors as well as at Chisokone market where 38%, 41% and 50% respectively, of the respondents reported dealing with informal collectors.

This means that the informal collectors have potential to contribute to waste management in the city and solutions to the problem of SWM must include them.

(V). RECYCLABLE WASTE

In residential areas composting was a very widely reported option for recycling waste. This is mostly the garden waste and some foodstuffs. It is a viable option for recycling as it does not need high technical and financial input. The re-use of plastic was high as well especially in the peri-urban area. However, it was not common in the high cost areas where the generation of plastic waste is very high. Overall potential for recycling was found to be low as the amounts of waste being generated at the moment would not sustain large-scale intensive recycling options.

Separation of waste for purposes of recycling is not being widely used at the moment. For example in the residential sector only 29% reported doing it in the high cost areas and much lower for the other three areas. This figure was 15% for the commercial areas and 13% for the industrial area. This means that there is need for people not only to be educated on the need to separate waste but also to recycle and reuse some of their waste. The results also showed that there are very few people who understand the concept of recycling and let alone cleaner production in the residential areas. In the commercial areas about 60% reported knowing about it and only 14% at chisokone Market. As expected 83% in the industrial sector knew about cleaner production with only 28% involved in some form of cleaner production. In the commercial sector 26% of the respondents knew about cleaner production and 21% reported being involved in it.

3. RECOMMENDATIONS

(a). Residential

The high numbers of people in the informal sector in the low cost and peri urban areas means that there is a high potential for using SWM for employment creation in these areas. It is recommended that the KCC working with the Small and Medium Business Association and some NGOs look at the possibility helping residents of these areas to set up micro enterprises for collection of SWM. This has been done in Lusaka by the Sustainable Lusaka Programme (SLP).

The residents should also be encouraged to composite their waste. Some of which cane been be sold as garden manure. Due to the high level of unemployment and falling purchasing power of the kwacha an increasing number of people are turning to agriculture as a source of food security so their would be a market for this manure.

(b). Commercial

Most merchandise is locally procured an indication of a high potential for take back of waste for re-use. Since the bulk of the waste is foodstuff it can also be used for composting which can be sold to individuals for use as garden manure. Small enterprises can be encouraged to collect this waste and composite it for resale using a similar arrangement as recommended above.

The KCC should be vigilant enough to policy the disposal of waste from this sector There is a lot of potential to get the private sector involved in the disposal of the waste in this sector. In this sector unlike the residential the businesses do have money which they can use to pay for the service but the main problem is that the KCC is not talking to them to make them see the benefits of proper disposal of their waste. The KCC also needs to pass the by laws that were started by the Solid Waste Management Task force which are meant to help enforce compliance.

(e). Chisokone Market

There is great potential for recycling and composting of waste at chisokone because a considerable amount of waste is generated within a small geographical area which is centrally located. There is an existing market committee which is in charge of the SWM in the market. The committee can employ people to separate the waste and their payment could be the waste they separate which they can re use or recycle. These people can also be helped as already shown above to start small businesses in composting as 54% of the waste can be composted. A market for this definitely exists.

(f). Industrial Area

The potential for "take back" is very high in this sector which should be encouraged. There is need for the KCC to police what is going on in this sector together with the ECZ and the KCCI (who are very cooperative). The number of companies using the private contractors is very small and it is not clear as to how many of those doing their own disposal are doing it properly. Therefore the companies should be encouraged to register with private contractors. This can be done by passing by laws which should be enforced but also through the provision of incentives such conducting competitions and giving prizes to winners.

There will be need for the KCC together with the KCCI to embark on a programme of environmental education. This can be done in collaboration with the Copperbelt University Institute of Environmental Management. These firms should also be given incentives to start using cleaner production techniques. Incentive could include competitions to award some prizes to those who are doing well or possibly to waive their license fee by the KCC for a year.

(g). Cost and Revenue

There is need for a dedicated study to find out the actual cost of SWM by the private sector and determine its viability. However, since all those involved did not indicate that they would stop it must be profitable. More importantly however there is need to investigate the viability of small-scale enterprises in SWM in residential areas. There are lessons that can be drawn from the projects done under the Sustainable Lusaka Programme (SLP).

(h). Potential for recycling

As already shown above there is great potential that exists for recycling and it is worth reiterating that incentives have to be given to various potential actors in the process of recycling to make it happen.

Potential for recycling on a large scale however, does not exist since technology for that is lacking and also it is would be uneconomic to do that as the amount of waste being generated is not large enough.

(i). Environmental Education
This is a very important activity that the KCC should take seriously. It can be done with the CBU, KCCI and the District Education Officer (DEO) and should target various institutions and should accompany the implementation of the various proposals discussed under recommendations.

(j). Review of technical options
On the basis of the findings firm thus study it has been recommended that the KCC adopts the recommendations from the report by Senkwe et al (1999) where the high cost areas are served by door to door collection by the private sector and a communal system for the low cost and peri-urban areas.

1.0 BACKGROUND TO THE STUDY

Since the SINPA Zambia project was launched in 1999 to build capacity for service delivery in the Kitwe City Council, effort has been made to improve the situation of solid waste management. Senkwe et al (1999) highlight the solid waste problem in Kitwe and the participatory framework adopted by the KCC to deal with the same. Senkwe and Huysman (2000) highlight the achievements so far and point out important issues that still need to be tackled. Key amongst these is the need for a solid waste characterisation study which amongst other things is intended to provide information on the quantity and general composition of the waste material that is generated in Kitwe. This information is of critical importance in the design and operation of solid waste management systems.

With the decision taken by KCC to privatise solid waste management, the study is even more important as the information gathered will inform decisions on safe handling of various wastes including storage and final disposal; determining which wastes can be recycled or re-used; developing appropriate financial models (i.e. potential costs and revenue) and will thus help in enabling the two camps (i.e. the private collectors and KCC) to play their new roles adequately. Future projections of waste generation linked with other population characteristics to be identified e.g. economic growth in the city, will make it possible for all players to anticipate future trends for waste management.

The output of this study will be two-fold:
(i). First it will provide information on the actual types of waste generated, quantities, physical composition (e.g. moisture content, density, particle size etc.) and to some extent chemical composition (e.g. volatile matter, ash, ultimate analysis, heating value etc.). These will be linked to relevant population characteristics e.g. income levels, type of neighbourhood etc, and

(ii). Provide information for training of various stakeholders including KCC workers and the community on concepts of solid waste management (e.g. re-use, recycling), safety and health of informal waste pickers sometime referred to as scavengers etc.

2.0 LITERATURE REVIEW

Solid wastes can be defined as all wastes in solid form which are discarded as useless or unwanted and in general arise from human activities (Peavy et.al. 1985). According to Kiely (1997), solid waste is defined as those wastes from human and animal activities. Wastes accepted by public authorities for ultimate disposal, including hazardous waste, liquid-solid sludge from industry and water/waste water plants are within this definition. Solid waste can be classified as municipal waste (e.g. paper, plastics, food wastes, ashes, and special wastes such as street sweepings, dead animals etc), industrial waste (e.g. timber, demolition and construction waste, treatment plant waste, hazardous waste, etc) and hazardous waste (e.g. radioactive substances, chemicals, biological waste, flammable waste, explosives etc.).

2.1 Solid Waste Characterization

To assess the management possibilities of solid waste it is important to conduct a waste characterization analysis (Otten 1997). For the analysis to be properly conducted, Peavy et al 1985 and Otten (1996) recommended that it is imperative to:

- identify waste generation sources,
- identify waste characteristics,
- develop waste categories
- develop sampling methodology
- conduct field studies
- conduct market surveys for special waste for recycling and materials and energy recovery and
- assess factors affecting waste generation rates.

They further recommended that field waste characterization studies are preferred because the relative quantities of materials are influenced by several local factors (Otten1997, Peavy et al 1985). These factors include community demographics (e.g. urban, rural, suburban, income level), seasonal variations (e.g. resort areas), collection frequency (affects amount collected), extent of salvaging and recycling, public attitudes and legislation.

Kiely (1997) proposes the relevant physical properties of waste to include; density (kg/m^3) and moisture content %, particle size and distribution (range in mm), field capacity (%), hydraulic conductivity (m/day) and shear strength (kN/m^2). Of significance to this study is density and moisture content which are important for estimating the calorific value of waste and land fill sizing. Thus information on moisture content in Kitwe will be useful for the future development of Uchi. This information is also useful for determining health risks associated with wet wastes and also for purposes of determining waste handling procedures and techniques. Field capacity, hydraulic conductivity and shear strength, are matters related directly to management of the dumpsite. Management of Uchi dumpsite is however outside the scope of this study and hence these characteristics will not be dealt with here.

Chemical Composition of Waste is important for landfill management in so far as it relates to sites for disposal, site protection and the safety of the waste pickers (scavengers). It is also important to provide information on potential for recycling of particular wastes. It is also important for evaluating energy recovery options (see Peavy 1997), for example if waste is to be used as a source fuel or energy

2.2 Solid Waste Generators

Table 1 below shows the main waste generators in a city and the types of waste that they generate.

Table 1: Key Waste Generators in a City and Classes of Wastes Generated

Classification/ Type of waste	Waste Generator
Food wastes, garden waste, paper, plastic, glass, tin cans, other wastes	Residential
Food wastes, demolition and construction, paper, plastic, glass, tin cans, other wastes.	Commercial
Food wastes, demolition and construction, paper, plastic, glass, tin cans, other wastes.	Institutional
Surgical, biological, pharmaceutical, Food wastes, garden waste, paper, plastic, glass, tin cans, ash, other wastes	Hospital
Special, hazardous, demolition and construction, paper, plastic, glass, tin cans, metals, rubber, ash, other wastes.	Industrial
Street sweeping, roadside litter, dead animals	Streets in CBD

The common waste generators are the key land use sectors and include mining, manufacturing, transport industries, residential areas, supermarkets, car breakers, traders, street vendors, residential open markets, hospitals/clinics, schools/colleges/universities, government offices, hotels/restaurants etc. The increased unemployment levels due to the liberalisation and privatisation of the major industries in the country, has led to an increase in the number of street vendors who contribute significantly to street sweepings at the close of each business day.

2.3 Solid Waste Recycling

Previous studies of urban waste streams have indicated that much can be recovered, reused or recycled from the waste. For instance, the city of Fullerton, California identified that its MSW can be classified as:

- 40% recyclable
- 29% compostable
- 12% potentially compostable
- 19% Other (see Hey et al; 1993).
-

Items commonly found in wastes stream that are recyclable or potentially recyclable range from paper and cardboard, aluminum/tin cans, glass, plastics, yard/garden waste, organic food fraction and other miscellaneous items.

3.0 OBJECTIVES OF THE STUDY

The main objectives of the study were to:
1. Establish quantities and composition of waste for the different land use sectors within the city of Kitwe over different seasons.
2. Project future quantities of waste generation in Kitwe.
3. Review available technical options to ensure sustainable SWM in the city
4. Investigate the potential for recycling
5. Estimate cost and revenue of managing generated waste in Kitwe

4.0 METHODOLOGIES AND ORGANISATION OF FIELD WORK

The study made use of four different methodologies namely: a quantitative survey, physical observation, physical measurements and chemical analysis through laboratory tests.

4.1 Quantitative Survey

Due to limitations of time and finances, the study adopted a rapid appraisal method using quantitative surveys to identify the main types and sources of waste. These surveys formed the basis of the second research protocol which involved actual measurement of quantities and establishment of the physical and chemical characteristics of the different categories of waste.

The surveys involved administering 4 different questionnaires to 3 land use sectors under study. As was noted in section 2.2 above, there are 6 main land use activities generating different types of waste. Due to both financial and logistical constraints, this study however only dealt with 3 land use sectors in the city which included residential, commercial, and industrial. The residential and commercial were chosen because these are the areas where the KCC has already taken a decision to privatise waste, hence the information from the study will be directly beneficial in speeding up the efforts of KCC to improve solid waste management in these areas. The industrial sector was included because it is an area where currently very little information is available on the situation of waste management. This sector is however one with the highest potential for contributing to environmental degradation through deposition of hazardous wastes. Hence a study such as this one must endeavor to establish the status quo in this sector.

Table 2 below shows the different types of properties surveyed in each land use sector.

Table 2: Major Land Use Sectors Surveyed.

Land Use Category	Type of Properties
Domestic	Low , medium and high cost residential neighbourhoods and Peri-urban settlements
Commercial (Trading)	Fast foods, Supermarkets, Hotels, Guest houses, butcheries, bakeries, electrical shops, clothes shops, offices, wholesale shops, furniture shops
Commercial (offices)	Banks, clearing agents, research institutions,
Commercial (Markets)	Green Markets, Clothes markets, Curio Market
Commercial (Recreation)	Bars and night clubs
Industry	Construction, sawmills, dry cleaning, textile, glass, steel, breweries, mechanical , foundry, rubber, bottling, car repairs and panel beating, battery manufacture.

The study borrowed from the protocol used in a quantitative survey for the social assessment for the Copperbelt Water Companies in 2000 (see Malama and Senkwe 2001). Two consultants supervised all aspects of the survey. This included a training session comprising role playing, practicing live interviews and analysis of how researchers performed and how the questions were perceived. The quantitative survey covered all 3 land use sectors i.e. residential, commercial, and industrial establishments.

Draft questionnaires were field tested and revised during the initial days of training and research (two days). The field-testing involved the consultants accompanying researchers in interviews to observe their performance, and debrief them at the end of the interview on technique and completeness. After the field testing the consultants revised the questionnaires (see Appendix I) and techniques of interviews were also discussed. Once the questionnaire was finalised, the consultants spent time thinking through how data would be coded as input in order to facilitate analysis. The data from the quantitative survey was entered into an SPSS system with variables labeled so they were ready for analysis. One of the students was trained as a data entry person and was responsible for entering the data, with close supervision from the consultants who also cleaned the entered data. Data entry begun immediately after all questionnaires were returned. This was done to avoid any delays in analysis and provided an additional check on any variations or problems in how the questionnaires were being filled out.

To ensure accuracy of data collected, the consultants allocated time each day to go over each questionnaire with researchers to ensure they were completely and accurately filled in. Except in very difficult circumstances, researchers worked in pairs in order to provide a check on quality.

For domestic consumers, since collection frequency and tariffs are set according to the house category, the unit of analysis, and therefore of sampling, was according to housing category i.e. high cost, medium cost, low cost and peri-urban.

4.1.1 Characteristics of Sampled Residential Neighbourhoods:

Generally, the High cost neighbourhoods are defined by large individual plots, averaging 1500 square meters in land area. The plots are normally sparsely built with a plot coverage ranging from 25% to 40% being the permitted average. These would usually have ample room for digging of rubbish pits on a rotational basis. They generally house the affluent section of society with relatively high-income levels.

Medium cost houses average 750m^2 and are occupied predominantly by the working class. These will normally be middle-income earners. However the current SAP programme being pursued by the government of Zambia has had a major impact on this group as a result of job losses. The average house will be much smaller than the high cost house and free space for rubbish pits will not be readily available.

Low Cost Neighbourhoods have plots of average size 300m^2 which is less than half that of the medium cost category. Houses where there are gardens will be very small and free space for rubbish pits is extremely rare. People who live here are generally those from the low incomes jobs and would most likely have problems paying for a solid waste service provided by the private sector. Land areas on these premises are very low with very little room for rubbish pits. This forces many households to dump their waste on unused open spaces.

Peri-urban settlements are informal settlements generally located on the outskirts of the city. As with all informal settlements, there are no established standards on either plot or house size. However, general characteristics include fairly heavily built up plots haphazardly arranged with more than one household on every plot and normally in every housing unit. Land for pits is generally very scarce and is likely to lead to use of communal heaps.

Selection of houses involved firstly a stratification of neighbourhoods into distinct zones defined mostly by physical features such as major roads, streams etc. The selection of individual houses from these zones was done randomly although an attempt was made to pick every fourth, fifth or sixth house depending on whether it was in the high, medium or low cost category. This was done to provide for variety and peculiarities within the neighbourhoods. Within the high cost areas an attempt was made to identify households that were already registered with a private contractor. However this proved to be fairly difficult and was eventually abandoned. A total of 172 houses were selected, 82 in high cost, 20 in medium cost, 50 in low cost, and 20 in peri-urban. Table 3 below shows the distribution of each category across the different categories.

Table 3: Households Sampled in each House Category

House Category	**Number of Households Sampled**
High Cost	82
Medium Cost	20
Low Cost	50
Peri-Urban	20
Total	**172**

4.1.2 The commercial Sector
Commercial activities in Kitwe are undertaken from the Central Business District (CBD), and from residential shopping centers within the different residential neighbourhoods. For the purposes of this study, the commercial sector was limited to the CBD and covered both the first and second class trading areas. The main market in the city (Chisokone) was also taken as part of the Commercial sector but treated as a separate entity due to its peculiar, physical, socio-political characteristics. 40 market traders from Chisokone market were surveyed in total.

4.1.3 The Industrial Sector
The main industrial area in Kitwe is comprised of both light and heavy industries. An attempt was made to cover all industries but only a total of 60 firms responded. The survey of the industry was limited to administering of the questionnaire and no measurements were taken there due to both financial and logistical difficulties.

4.2 Physical observation and Measurement of Generated Waste
In terms of actual measurement, a specified number of bin liners were provided to all respondents who were asked to use these for all their waste collection for the particular days of study. The respondents in the residential areas were asked to separate all waste into 7 classes namely food, glass, paper, plastic, metals /tin, garden waste, and others. For the commercial sector, sweepings were also included as the eighth class. For the market sector, only 1 bag was provided for all wastes, which were referred to as combined waste.

Wherever possible, the research team identified areas on all sampled premises where the bin liners were to be stored. These places had to be protected from the elements (i.e. rain, direct sunlight etc) and where they could not easily be tampered with especially in the residential areas. In order to ensure the highest levels of compliance and cooperation from respondents, the research team engaged the services of identified individuals who were either resident at or worked at the premises depending on the type of land use activity. These individuals were the key contact persons between the respondents and the research team and were identified before administering of the questionnaires. A similar approach was used by Malama and Senkwe, (2001) and proved an extremely useful and effective way of collecting data about household activities. It must be noted that the possibility for error is fairly high with this approach since it relies on using people who may not necessarily fully understand the significance of scientific thoroughness. Thus to take care of such likelihood, the study also engaged the use of monitoring through visitations by research assistants. In addition, attempts were made to ensure that all family members were present when the bags were delivered and the study introduced. Within the residential areas for instance, the questionnaire was administered on Monday 12th February which was a national holiday.

The time frame for observation and measurement was taken as one study week. This was used because this is the current time frame used by most waste collectors as the collection period therefore making the results more relevant. In terms of actual measurement waste was collected for a total of 6 days. It must be noted that with putrescible wastes like food waste), waste to be measured was not left to stand for 6 days but was measured and removed twice a week. This was in order to reduce possible errors in measurement due to putrefaction and to minimise the risk of unpleasant smells. At the end of each specified study period the research team visited all premises for the purpose of measuring the collected waste. In all cases, the respondents were given specified days and times when they were to commence and end the exercise.

4.2.1 Physical and Chemical Composition of Waste

Components of solid waste that were analyzed in this study included; weight, moisture, density, volatile matter and energy content. The energy values were evaluated on both "dry basis and on ash-free dry basis. The type of solid waste that was dealt with is the Municipal waste, which was collected from various locations of the Residential Sector.

4.2.1.1. Composition of Waste: Determination of waste composition was by way of physical separation and observation of collected wastes. Each bag of waste was weighed first and then its contents emptied and separated, and a note made of all the different types of waste that constituted each class of waste. E.g. Food waste may be composed of potato peelings, vegetables, bones etc whilst paper waste may be made up of newspapers, magazines old books etc.

4.2.1.2. Quantity of Waste These were measured by weight using calibrated scales. Both the dry and wet weight (as discarded basis) of the solid waste were measured in order to establish the reuse value of the wastes for such purposes as energy generation, composting etc. Information on wet and dry weight of waste also assists in determining the handling procedures for collectors since waste is easier to handle when it is dry than when it is wet. To some extent this information is also important for establishing the recyclable materials.

4.2.1.3. Moisture, Density, Volatile Matter and Energy Content. Analysis to establish the above was based on a 100-kg sample of waste. The solid waste samples were initially collected as separate components in labeled polythene refuse bags. Each bag contained a separate type of waste ranging from food, paper, plastic, garden trimmings, glass, metal and others. From each bag a representative sample was as follows:

(i) The waste was spread on the polythene bag to expose all the elements (type of waste) present.

(ii) The elements were sorted out and picked to make a representative sample (e.g. garden waste comprised of grass, leaves, branches, soil etc) which was taken to the laboratory for analysis.

Each classified and representative sample was weighed in a crucible, on an analytical balance, correct to four (4) decimal places.

The crucibles were dried in an oven at 105^{o}C for 24 hours to attain a constant weight prior to weighing and using them in analytical measurements.

Moisture Determination: Each separate component of waste was weighed and placed in an oven for drying. After 24 hours of drying of the samples at 105^{o}C, the samples were cooled in desiccators and then re-weighed. The moisture content as a percentage was determined from the following formula:

$$\text{Moisture content (\%)} = \frac{(a-b)}{a} * 100$$

where a = initial weight of sample as delivered
b = weight of sample after drying.

Determination of Density: Estimation of the density of waste sample was computed using the formula:

$$\text{Density} = \frac{\text{mass (kg)}}{\text{Volume (m}^3\text{)}} = \text{kg/m}^3$$

The volume of the waste (as discarded) was determined by using the data on typical densities for solid wastes components and mixtures (refer Table 10-5, Peavy et al. 1985).

Determination of Volatile Matter and Ash: The dried sample, and crucible was placed into the muffle furnace and ignited at 950^{o}C for 30 minutes, till the ash was charred to a clear white colour. The crucible plus ash was removed from the muffle furnace cooled for at least 30 minutes and carefully weighed on an analytical balance.

The weight of volatile matter (on a dry basis) was computed as the difference between the dry weight of solid waste and the weight of the residue after ignition.

Therefore:

$$\text{\% volatile matter (on dry basis)} = \frac{\text{weight of dry solid waste – weight of residue after ignition x 100}}{\text{weight of dry solid waste.}}$$

Ash content is the amount of residue obtained after ignition of solid waste

Therefore

$$\text{\% ash (dry basis)} = \frac{\text{weight of residue after ignition x 100}}{\text{weight of dry solid waste}}$$

Determination of Energy Content: The energy content of the solid waste sample on both dry basis and ash-free dry basis was estimated by using the data on typical energy values of various components (refer Table 10-7, Peavy et al. 1985).

Energy values converted to dry basis:

$$\text{kJ/kg (dry basis)} = \text{kJ/kg (as discarded)} * \frac{100}{100 - \%\ \text{ash} - \%\ \text{moisture}}$$

Energy values on an ash-free dry basis:

$$\text{KT/kg (ash-free dry basis)} = \text{kJ/kg (as discarded)} * \frac{100}{100 - \%\ \text{ash} - \%\ \text{moisture}}$$

4.2.2 Possible Sources of Error

Sources of error might have arisen from the transfer of samples from the oven into the balance room due to possible contamination. The warm crucibles may not have been handled properly and spilling lighter and smaller pieces of waste was a possibility.

4.2.3 Chemical composition of Waste

This was done in reference to work by Peavy et al (1985) who uses what is referred to as proximate analysis which involves looking at moisture, volatile matter, ash, carbon. This is followed by, ultimate analysis (percent of carbon, hydrogen, oxygen, nitrogen, sulphur and ash), heating value (energy value). Volatile matter is measured by igniting waste at 950°C. Moisture content can be determined from 105°C for an hour. For the ash, it can be weighed or simply observed physically. Ultimate analysis was done using the modified Dulong formula or typical data on ultimate analysis (see Peavy et al. 1985:585). The heating value can be calculated from the Dulong formula or from the typical energy values.

4.3. Establishing Recyclable Materials

The distinction between recycling and re-use is not always easy to make. Recycling and reuse can mean the use or re-use of a waste as an effective substitute for a commercial product or as an ingredient or feed stock in an industrial process. It includes:-

- Reclamation of useful constituent fractions within a waste material
- Removal of contaminants from waste to allow re-use

In this study, recyclable or reusable materials are also taken to mean those waste materials that occur most commonly in those situations where a product can be used in more than one application. Currently in Zambia the only evident existing demand for formal waste re-cycling has been in the paper and scrap metal industries with Zambezi Paper Mills and Scaw Limited being the key industries involved in this activity. At an informal scale, a few scavengers are involved in collecting plastic bags, which are used for production of floor polish.

On the other hand, there is evidence of a relatively high level of reuse of wastes, in particular plastic bags for repackaging, bin lining, and roofing; bottles (both plastic and glass) for repackaging, water and food storage; paper for packaging and as a fuel; garden waste for composting; and saw dust for use as a floor bed in chicken runs.

What this suggests is that there is a potential for reducing waste production in most land use operations and thus a need for this study to identify all wastes that are potentially recyclable and or reusable and to identify ways in which these practices can be enhanced. Methodologically, this was done through identifying all materials being collected or reused from the surveyed from premises.

4.4. Projecting Future waste generation
This was done using projections of population and key assumptions about the likely trend of the population given the prevailing economic scenario.

4.5. Projecting Cost and Revenue Management for Waste Management
The study attempted to develop financial models were to measure the cost of handling and disposing of waste from the residential sector. Estimate of cost and revenue of managing generated solid waste was dependent on various factors including collection and transportation of waste from household to final disposal site. The major cost elements included size of trucks being used, tonnage of waste, number of workers, tools and equipment, fuel costs, and other overheads such as frequency of collection, replacement of protective clothing, Population being served etc. Data collected on quantities, types and composition of waste was used in arriving at the costs and revenues.

4.6. Review of technical options for SWM in Kitwe
This was conducted through the identification of available options (in use and not in use) from a review of literature and linking this to the results on quantities and composition of waste generated in the city. .

4.7. Repeat Studies
Data for solid waste characterization studies is generally collected from physical observation and measurement of generated waste over a specified period of time. These observations have to be repeated over a number of days, weeks and preferably months, in order to get a clear picture of the trends of waste generation.

In order to get conclusive results about trends of waste generation over different seasons, data will be collected for the rainy season which runs from November to April, and for the dry season which runs from May to October. The dry season will be distinguished into the cold dry season from May to July and the hot dry season from August to October. For the wet season, data will be collected for March, whilst that for the cold dry season will be collected in June and October for the hot dry season. This report is a presentation of the results for the rainy season i.e. March.

Given that a considerable number of residents in Kitwe (i.e.43% in low cost, 48% in medium cost and 82% in high cost (see Malama and Senkwe 2001:22) are employed in the formal sector, the study assumed that household expenditures are highest at the month end when most people get paid and lowest in the middle of the month. Thus to take care of these fluctuations, data was collected in the middle of the month and at the end of the month. The selected respondents comprised the study sample for all stages of the research (i.e. for the rainy and dry seasons as well as for the different months). In this regard the study will follow the same respondents over different periods and situations in order to make conclusive results about solid waste characteristics in Kitwe.

The study was undertaken by a team of 38 composed of 2 consultants and 36 Copperbelt University students from 12th March to 2nd April 2001.

5.0 RESEARCH RESULTS

5.1 Residential Sector

5.1.1 Social –Economic Characteristics of Households

Of the 172 respondents, the majority (61%) were female and the remaining 39% male. 33% of all respondents were heads of households, 28% were spouses and the remaining 39% were neither spouse nor head but were above 18 years of age.

The mean number of households per plot was 1 in all house categories except in peri-urban areas with 2. The study found that respondents in low cost houses have lived at their current home for more than 15 years, those in peri-urban and high cost for over 7 years and those in medium cost for over 6 and half years. As was expected, household size was highest in peri-urban and high cost areas with a mean household size of 9, followed by low cost and medium cost with 7.

5.1.1.1 Employment Status of Households

Figure 1 on the next page shows the employment status of the heads of households in each house category.

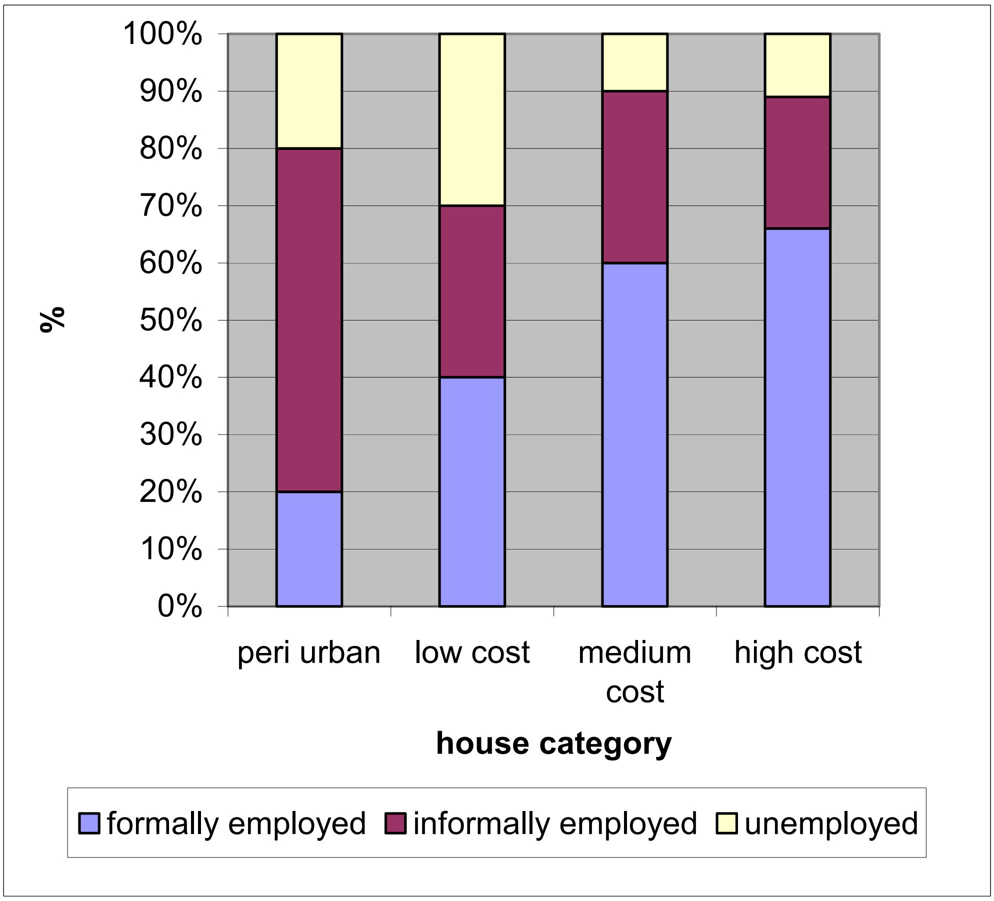

Figure 1: Employment Status of Head of Household in various household categories

As the figure indicates and as was expected, there were more people working in the formal sector in high cost areas (i.e. 65.9%) as compared to the other areas (i.e. 60% in medium cost, 40% in low cost and 20% in peri-urban). In all cases, there was a significant number of respondents working in the informal sector starting with a high of 60% in peri-urban to a low of 23.3 % in high cost. Unemployment was highest in the low cost areas with 30% and lowest in medium cost areas with 10%.

The study also found that other than the head of household there were more people formally employed in the high and medium cost areas (i.e. 45% and 40% respectively) as opposed to low and peri-urban areas where the majority i.e. 48% and 75% were informally employed.

From these results it is anticipated that households in the high-income areas have more reliable sources of income and are therefore more likely to generate more waste than in the other neighbourhoods.

5.1.1.2 Home Based Enterprises

Amongst those engaged in informal activities, a significant number conduct these activities from their homes. The study for instance revealed that economic activities were taking place from home in all house categories representing 55% in Peri-Urban, 50% in low cost, 34% in high cost and 30% in medium cost. As was expected, the figures were higher in the peri-urban and low-income category where more household members engage in informal activities.

The study revealed a fairly high variety of activities taking place from the home. However in all cases except high cost, trading was the most prevalent of all activities, representing 75%, 60% and 67% in peri-urban, low cost, and medium cost respectively. The figure for high cost was only 18%.

It must be noted however, that the sample for high cost was far much bigger than elsewhere and may therefore account for this variety. This result should not therefore be taken to mean that there is little variety in the other areas. For instance, in studies undertaken by Kellett et al (1999) and Senkwe (2000), it was found that a wide variety of economic activities take place in all housing categories within the city of Kitwe.

5.2 Physical And Chemical Composition Of Residential Waste

5.2.1 Main Types of Wastes Generated

Even though 172 households were interviewed most of them failed to conduct the waste separation exercise for the 6 days. Only 83 households managed and the results presented below are from these 83 households.

When asked to indicate what they considered as their main type of waste, the majority of respondents in low cost i.e. 51% and 45% in medium cost cited garden waste. 45% in peri-urban cited metals while 49% in high cost cited food. From the physical measurement however and as was expected garden waste was the highest in all four house categories representing per capita daily generation of 0.32kg for low cost, 0.4kg for medium cost, 0.31kg for high cost and 0.21kg for peri-urban (see Table 5 below). It was assumed at the start of the study that the highest figure for garden waste would be in the high cost areas. The low figure given by the survey can be explained by the fact that within the high cost neighbourhoods, garden waste generally consisted of tree branches, leaves and grass. On the other hand residents within the middle but particularly in the low cost neighbourhoods tended to have more soil in their garden waste resulting from sweeping around their yards. As noted above the figure was lowest for peri-urban as these areas do not normally have very large yards and gardens.

Food waste was the second largest in all areas representing 0.14 in peri-urban, 0.13 in low cost, 0.20 in medium cost, and 0.23 in high cost. As was expected, plastic and glass wastes were highest in the high cost areas (i.e. 0.03 and 0.04 respectively) where households are more likely to purchase glass wares and where the levels of shopping are generally higher thus contributing to plastics which are mostly resultant from packaging. Interestingly metal wastes were highest in peri-urban. This could be explained by the fact that most informal metal working activities such as manufacture of charcoal brassieres, aluminium pots etc. would normally take place in peri-urban areas. Table 4 below shows the generation rates for all the different types of waste by house category.

Table 4: Per Capita Daily Waste Generation Rates For Different Types of Waste

Type of Waste	Per Capita Waste Generation per Day (kg) by House Category			
	Peri-Urban	Low Cost	Medium Cost	High Cost
Plastic	0.02	0.02	0.01	0.03
Glass	0.02	0.002	0.002	0.04
Paper	0.01	0.02	0.01	0.01
Food	0.14	0.13	0.20	0.23
Metal	0.01	0.001	0.001	0.001
Garden	0.21	0.32	0.4	0.31
Other	0.01	0.08	0.01	0.01

NB: These are mean figures where N= 11 for peri-urban, 27 for low cost, 11 for medium cost and 34 for high cost.

Table 5 below shows the total daily per capita generation rates by house category. This pattern of generation where the peri-urban areas have a higher rate compared to the high cost areas is similar to that of Lusaka where peri urban and low cost areas had a generation rate of 0.56, medium cost with 0.54 and high cost had only 0.41(see LCC/ECZ 1997:53). Given that incomes in the peri-urban are generally lower than in the other sectors, the higher generation rate in these areas can be explained by the type of employment prevalent in these areas. As the quantitative survey showed, over 63% of household heads and 75% of other household members in peri-urban worked in the informal sector. 75% worked from home. This means that wastes generated from these activities constitute part of the total household waste hence giving the higher generation rate (i.e. total waste generated in peri-urban is a function of domestic waste plus commercial/industrial waste).

Table 5: Per Capita Waste Generation per Day by House Category

Per Capita Waste Generation per Day by House Category (kg/ca/day)			
Peri-Urban	Low Cost	Medium Cost	High Cost
0.75	**0.45**	**0.60**	**0.62**

The generation rates for domestic waste in most cities in the developing world range from 0.3 to 0.6 kg/day. Whilst the rates for individual house categories are rather high, the generation rate for the city of Kitwe as a whole was 0.58 and therefore compares fairly well with these figures. These generation rates work out to be 0.23 tons/capita per year for high cost, 0.22 for medium cost. 0.20 for low cost and 0.27 for peri-urban. The overall average for Kitwe is 0.2tons per capita per year, which is exactly the same as the figure given by Cointreau (1994: 41) as the estimate for low income countries such as Zambia.

5.2.2 Generation rates for Mid Month and Month End

As stated in section 4.7 above, the study intended to gauge whether there would be any difference in generation rates between different times of the month (i.e. mid month and month end). A second series of measurements were therefore taken at the end of March. From the experience of the mid-march exercise, the time frame was reduced to two days and only 50 of the 83 households were targeted[1]. However, probably due to fatigue on the part of the respondents, the research team only managed to conduct measurements in 21 households. Of these 7 were not properly done thus limiting the comparison of results to only 14 households. This sample was too small (in some cases such as peri-urban only 1 household) and hence the study could not use the results with any reasonable confidence. An important finding from these results was however the fact that the pattern of generation was the same as that of the first exercise i.e. garden waste was the most prevalent followed by food wastes.

5.2.3 Composition of Residential Solid Waste

Table 6 below shows the average results for various components from selected households in the high cost, medium cost and low cost areas. Details on calculations of the various components are found in Appendix.

Table 6: Composition of residential solid waste.

Res.area / Component	**Congo way (High Cost area)**	**Town Centre (High cost area)**	**Ndeke township (Low cost)**	**Mulenga compound (Peri urban area)**	**East of Kwacha (Medium Cost)**
Density (kg/m^3)	116.3	260.0	188.6	118.9	219.8
% Moisture	51.23	79.03	29.03	61.54	60.46
% Volatile matter	92.4	80.4	45.4	77.4	87.0
% Ash	5.84	19.56	2.56	11.23	9.76
Energy on dry basis (kJ/kg)	15021	25956	15578	18804	15300
Energy on ash-free dry basis (kJ/kg)	17064	49617	16161	25411	20313

5.2.3.1 Moisture

In this survey, moisture ranged from 29% to 79%. The optimum moisture content ranges 50 to 60% for metabolic activity to occur (see Kiely, 1997). In this respect three residential areas exhibited such results i.e. Riverside (51.23%), East of Kwacha (60.5%) and Mulenga compound (61.5%). Below the above range, metabolic activity slows down and is the case with Ndeke township with moisture content of 29%. Above the optimum range in the case of Town centre waste (79%) indicates that water

[1] In the initial study, many bags were wasted due to numerous problems such as food waste being eaten by dogs, bags being stolen, household members forgetting to throw waste in the bags on some days and households simply refusing to cooperate. It must be remembered that most households are currently not in the habit of separating waste. Hence the exercise was fairly demanding for many households.

must have filled the voids between the waste particles. This condition inhibits the presence of oxygen, reduces temperature and causes anaerobic conditions and bad odours to occur.

5.2.3.2 Density

The density results obtained in this study fall within the range of typical values of the municipal solid waste. The density of the sampled waste ranged from 116 to 260 kg/m^3. This is in agreement with values documented by Kiely 1997 (Table 14.14) and Peavy et al. 1985 (Table 10.5) which shows that none compacted MSW densities range from 100 to $180kg/m^3$. Food wastes range from 100 to $500kg/m^{3.}$ Densities for Lusaka range from $280kg/m^3$ to $447kg/m^3$, while those for Lagos, Jakarta, Karachi and Dar es Salaam ranged between 250 to $500kg/m^3$. The significance of density in MSW is that it enables the managers to plan and identify the capacity of waste haulage vehicles to be used.

5.3 Chemical Composition of Waste

Table 7 below shows the chemical composition for solid waste from two study locations. The chemical composition above show that the waste can be composted and used as a fertilizer due to the fact that the carbon to nitrogen(C/N) mass ratio occurs within the optimum range for waste to undergo biodegradation. The carbon/nitrogen ratio is a measure of the optimum biochemical conditions and occurs at a C.N ratio of 30. In this study, the C/N mass ratio ranged from 15/2 to 26/2 for Congo way and East of Kwacha wastes respectively. Previous work by Kiely (1997) shows that at the optimum C/N ratio of 30, there is adequate nitrogen for cell synthesis and carbon for energy source. At C.N ratio of about 20, the waste is biodegradable and ideal for composting.

Table 7: Chemical composition of solid waste from Riverside and East of Kwacha

SAMPLE	FORMULAR WITH SULPHUR	FORMULAR WITHOUT SULPHUR
Riverside (Congo Way)	C_{480} H_{2175} O_{1005} N_{28} S	C_{17} H_{79} O_{37} N
East of Kwacha	C_{429} H_{2817} O_{1371} N_{14} S	C_{31} H_{201} O_{98} N

5.3.1 Energy content, Volatile Matter and Ash

The results obtained in this study indicate that much of the waste comprised of cellulose `, material with good heating value, which is characterised with low ash content and high volatile matter.

Proximate analysis included moisture content (29-79% by weight) volatile matter (45-90%) non-combustible fraction (ash) to 6-20% and energy content values (15,000 to 26,000 kJ.kg on dry basis and 16,000 to 50,000 kJ/kg on ash-free dry basis). These results compare fairly well with some typical values for domestic MSW as documented by Peavy et al. (1985) and Kiely (1997) in table 14.16.

The typical values are;

Moisture	15 – 40% by weight	
Volatiles	40 – 60% by weight	
Ash	10 – 30% by weight	
Energy content (dry basis)		14,500 kJ/kg
	(ash free dry basis)	20,000 kJ/kg

Some high heating values obtained in this study may be due to the presence of polythene (plastic) materials which exhibit higher volatility and higher energy content values but with low ash content.

5.4 Wastes from Home Based Enterprises

As was expected, there was a wide range of wastes generated by the economic activities undertaken from the homes. The types of wastes are related to the types of activities, i.e. where chicken rearing is high, then chicken droppings will be a major waste as in the case of medium cost areas, where tailoring is high then major wastes will be cloths as in the low cost areas, etc.

5.5 Main Methods of Waste Disposal in Residential Areas

Figure 2 below shows the main methods currently used for waste disposal. In all four categories, throwing in a pit is the most common form of waste disposal followed by dumping on communal heap. As expected private collectors are only engaged in high cost areas and of these in only 16% of cases.

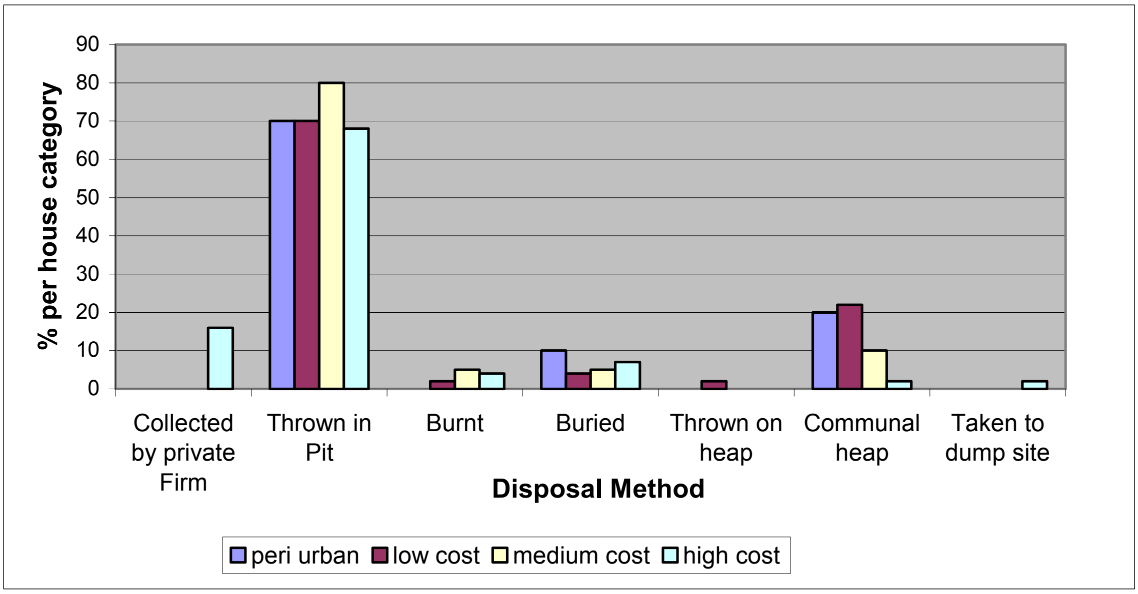

Figure 2: Main methods currently used for waste disposal

It must be noted that this result represents an improvement in the participation of the private sector when compared to 1999 where the first SINPA survey found no household using a private collector (see Senkwe et al 1999).

In low and medium cost areas, over half of the respondents (i.e. 54% in low cost and 60% in medium cost) used more than one method of waste disposal. Within the low cost areas, 63% of these buried their waste while 22% burnt it. In the medium cost the majority i.e. 67% burnt the waste while 25% took it to a communal heap. Within the high cost category only 32% of respondents used a second method of disposal with 42% burning the waste and 35% burying it. Second options of waste disposal were lowest in peri-urban areas where the figure stood at 20% with half of these taking their waste to a communal heap. In these areas there has been no improvement since the first study in 1999 (see Senkwe et al 1999).

5.5.1 Frequency of Disposal

Out of the total 14 high cost respondents who used a private waste collector, 12 had their waste collected once every week while the remaining had it collected once a month. 11 of these respondents indicated that they paid a mean monthly charge of K28000 with the minimum being K18000 and the maximum K60000.

5.6 The Commercial Sector

25% of respondents in this sector were female and the rest male. Of these 59% were in senior management, 28% in middle management and 13% were floor staff. The companies interviewed have been operating in Kitwe for an average of 11 years with a minimum of less than 1 year and a maximum of 42 years. 75% of respondents indicated that they obtained their merchandise from local sources and the remaining from outside the country. This increases the potential for development of ‘take back’ mechanisms e.g. certain packaging materials such as carton boxes, drums etc could be taken back to the suppliers as a way of reducing waste generation.

5.6.1 Main Waste Generated

The survey showed that sweepings, paper, food and cardboard were the main wastes generated in the commercial area. The study attempted to take measurements from 50 commercial entities, however only 12 cooperated. The mix of companies was however so varied that it is impossible to compare the results. On average though the mean weight of waste generated per day for the 12 was 4.75 kg. The most important information from the survey of the CBD was that related to current disposal methods which can inform the future action of KCC.

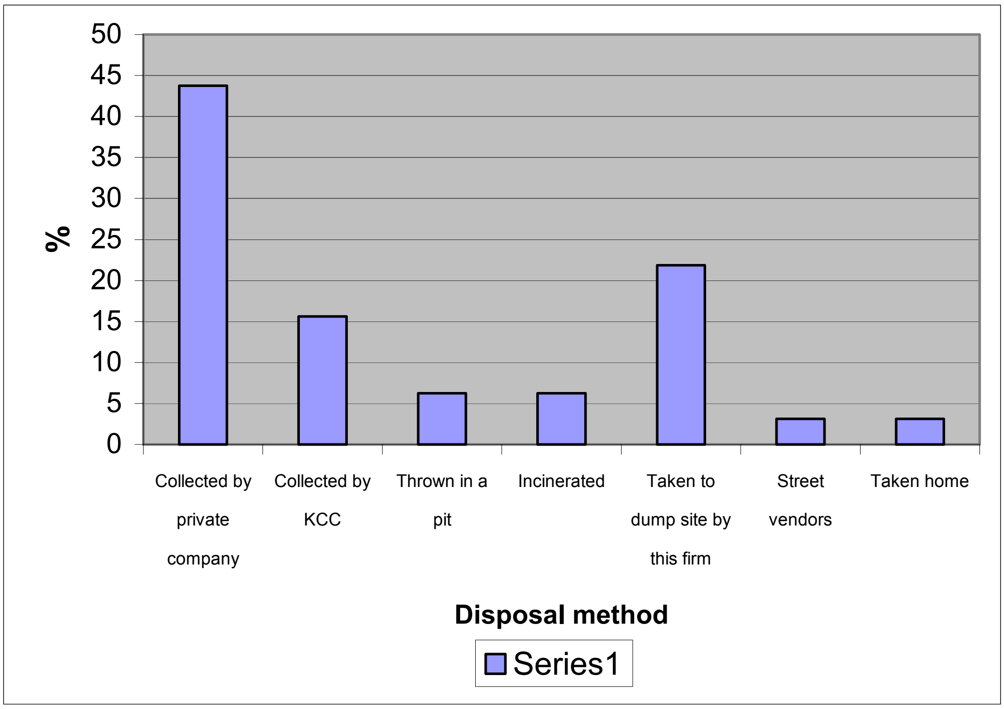

Figure 3: Method of Disposal in Commercial Sector

Figure 3 above shows the main methods of waste disposal by companies in the CBD. A total of 12 companies (i.e.44%) indicated that their waste was collected by private contractors. 7 of these indicated that their waste was collected once every week, 1 twice a week and 3 thrice a week. 10 of the 12 respondents indicated Leya Bus Services as their collector whilst Rentalque and Mpelembe had 1 client each. The mean service charge paid was K24000 per week, the minimum being K5000 per week and a maximum of K80,000 per week. Two respondents indicated that they took their waste to a dumpsite with one indicating a frequency of once weekly whilst the other was not sure of frequency.

This result does indicate some improvement in terms of getting companies to register with private contractors. However there is still a lot of room for improvement as the rest are still using methods of disposal not particularly conducive to promoting cleanliness in the CBD.

The willingness to register with private contractors is also still very low with only 34% of those not engaged with a private contractor indicating that they would be willing to pay to a private collector. They also indicated that they would be willing to pay a mean weekly charge of K10000, with a minimum of K5000 and a maximum of K19000.

23% of respondents indicated that they were registered with ECZ for waste disposal purposes. 60% indicated that they were registered with KCC but this result is doubtful as most may have been referring to their trading license and not solid waste licenses. It is important that KCC take up inspection of these premises especially given that many of them are still intent on disposing their own waste.

5.7 Chisokone Market

Out of a total of 38 respondents from the market 58% were male and the remaining 42% female. The mean length of trading at the market was 6 years with a minimum of 0 and a maximum of 37 years. All 38 respondents indicated that they trade from the market on a daily basis.

The main types of goods sold by the 38 respondents included clothes, vegetables and fruits, fish, dry food such as beans, jewelry, flowers, groceries, cosmetics, wood products, electrical hardware, and audio tapes. 17% of traders obtain their merchandise from outside the country while the rest obtain their goods from local firms both from wholesalers and other retail outlets.

As was expected, food remains (32%) and paper (26%) constitute the main types of waste followed by sweepings (24%), plastics (13%) and cardboard and pieces of cloth at 3% each. As with the CBD, the response from the measurement was very low and the results obtained cannot be used.

5.8 The Industrial Sector

A total of 60 industries were interviewed. Amongst these, 84% of respondents were male and only 14% female. Of these 62% were in senior management, 23% in middle management and the remaining 15% were floor staff.

Most organizations interviewed have been operating in Kitwe for a mean number of 18 years, with the minimum being under 1 year and a maximum of 58 years.

Most of the industries, i.e. 48% obtained their raw materials locally, 38% from abroad. And the remaining 14% did not give an answer. As with the CBD possibility for "take back" of packaging also exists in the industrial sector. Steel and metals represented the largest chunk of raw materials (i.e. 31%) followed by motor spares with 11%. Flour, timber and maize were the third largest with 9% each. 15 respondents (i.e. 25% of sample) said the question was not applicable to them because they are either just trading in goods imported from outside or offering services such as laundry etc. which do not involve any manufacturing.

93% of all respondents indicated that their main clients were local, mostly the mining companies, while only 7% sold their products to an international market. This enhances the possibility for cooperative efforts on matters to do with cleaner production and recycling.

5.8.1 Main Types of Waste Generated

As would be expected metals and paper constituted the bulk of the waste followed by oils (see Table 8 below). Very few industries (i.e.4) indicated that they generated chemical waste which included used oils, lead effluent (acidic).

Table 8: Main Types of Waste Generated in the Industrial Sector

	Frequency	Percent
Food wastes	2	4.6
Paper	9	20.9
Oils	8	18.6
Metals	11	25.6
Saw dust	3	6.97
Ashes	3	6.97
Plastics	4	9.3
Batteries	1	2.3
No answer	2	4.6
Total	**43**	**100**

5.8.2 Methods of Waste Disposal in Industrial Area

As was expected, the majority of respondents (35%) take their waste to a dumpsite themselves. 21% use a pit, 19% incinerate their waste, 17% give their wastes to other industries for reuse and recycling, 4% heap their waste outside their premises and 2% pile their waste on a heap on their premises. Only 2% have their waste collected by a private collector. The fact that over 40% of respondents use either illegal or unacceptable means of waste disposal means that there is a need for KCC to take an active interest in discussing this issue with this sector and bringing them on board the SINPA project. Whilst some of the industries must dispose of their hazardous wastes based on the provisions of the EPPCA, this result shows that there is obviously still room for the private sector to play a role in waste management particularly for the domestic waste. The fact that most wastes from the industries will contain some form of chemical components makes it even more important for the KCC to monitor this sector.

This is even more important given that of the 20 who dump their own waste, 5 dump it in illegal sites in Kalulushi, Mindolo North and Ndola road. 2 did not know where they dump it and the remaining 13 dump it at the legal site at Uchi.

8 of the 20 respondents who took their own waste to the dumpsite indicated the frequency of disposal. Of these 5 took it once every week, 2 once every month and 1 twice every week.

A major problem that the KCC will have to deal with is the low levels of willingness to pay to a private contractor. Only 21% of respondents indicated that they would be willing to pay to a private company for waste collection. This low willingness could be explained by the fact that industrial waste is handled by the ECZ and since the KCC at the moment does not monitor this sector, some industries are able to hide behind the provisions of the EPPCA. It must be noted though that those who were willing to pay indicated that they would only be willing to pay substantial amounts with a mean charge of K84,250 with a minimum of K5000 and a maximum of K300,000 per week. 30% of respondents indicated that they were registered with

ECZ for purposes of waste disposal. 37% of respondents indicated that they are registered with KCC.

6.0. PROJECTION OF FUTURE WASTE GENERATION

6.1. Demographic Outlook

In 1990 the population of Kitwe stood at just under 348000. The annual growth rate for the city was 2.6%. According to preliminary results of the 2000 Census of population, the population trend is on the negative with Kitwe's growth rate ranging at 0.8%. A quick count conducted by the Provincial Statistical Office (PSO) put the 2000 population estimate at 389828. Starting from a 1990 population of 348000 and a growth rate of 0.8% this study came up with a projected estimate of 376863. The average between these two figures is 383346. Given that this is not very different from the PSO quick count estimate, the study adopted the quick count figure as the population of Kitwe for the year 2000. Using the population figures dis-aggregated, into the 25 political wards in Kitwe, the study then worked out the population distribution by house category. The results are presented in table 9 below. Given the current trends where the majority of the labour force is being pushed into the informal sector (through retrenchments and public sector restructuring), it is anticipated that poverty levels will continue (at least in the near future) to be a significant factor on population growth. Hence it can be expected that the current population growth rate will prevail for some time. The study therefore used the 0.8 growth rate, to project estimates of population for the years 2005 and 2010. The results are shown in Table 10 below.

Table 9. Estimates of Population for 2000, 2005 and 2010

	Population as a % of Entire City	Population as a % of Council Townships	Estimated Population (2000)	Estimated Population 2005	Estimated Population (2010)
High cost	12	14	45397	47242	49162
Medium cost	6	8	23556	24513	25600
Low cost	21	27	81656	84975	88429
Peri-Urban	40	51	156943	163322	169960
Total		100	307552	320053	333061

Note that this population is exclusive of residents of mine townships whose population stands at 82276 for 2000, 85620 for 2002 and 89100 for 2010.

On the basis of this population and the per capita generation rates, Table 10 below shows the estimated total wastes for the city of Kitwe by house category for the years 2000, 2005 and 2010.

Table 10. Estimated Annual Waste by House Category for the years 2000, 2005 and 2010

		Domestic waste Generated (tons/year)		
House Category	**Generation rate (kg/ca/day)**	**2000**	**2005**	**2010**
High cost	0.62	10273	10691	11125
Medium cost	0.60	5159	5368	5606
Low cost	0.45	13412	13957	14524
Peri-Urban	0.75	42963	44709	46526
Total		**71807**	**74725**	**77781**

It must be remembered that these generation rates where for the rainy season and may therefore be a little high. They should therefore be compared to those for the dry season and an average of the two taken as the generation rate for the city. Nonetheless given that as yet no other study has been conducted to establish generation rates, these figures are taken as the generation rate for Kitwe. As can be noted the difference between the total waste generated in 2000 and that in 2010 is fairly small i.e. 5974 tons or 8.3%. This is because the rate of generation is related to population size. And since the population growth is very small, the growth in waste generation is also small. These figures are about a quarter of estimated waste for Lusaka (i.e. 273,280 tons for 2001), thus comparing well in the sense that the population of Kitwe is approximately a quarter that of Lusaka (i.e. 1407088 for 2000).

7.0 COST AND REVENUE OF COLLECTING WASTE IN KITWE

One of the main objectives of this study was to estimate the cost of providing a solid waste service in the city of Kitwe and linking that to possible revenue flows from the same. Unfortunately, it has not been impossible during the time available for the survey to complete this task satisfactorily. This is because collecting information on key cost components particularly transport and establishment costs, proved to be very difficult as all contractors interviewed do not have this information because their solid waste services are provided as part of other services that they are offering to the community. Hence it was not easy to separate the cost of waste management from other services.

What this study attempted to do therefore was simply to bring together all available information on other cost components as an initial step in arriving at the cost. It is anticipated that this work will be taken further when the appropriate person/s are engaged.

7.1. Calculation of Solid Waste Management Cost

In discussing costs related to waste management in Kitwe, this study is referring to refuse removal from domestic premises to the landfill site at Uchi. In working out the costs and revenue, the study assumes that the KCC will continue to use a participatory approach in which financial risks are borne by the private sector. The costs and revenues discussed here therefore refer to the operations of small-scale private collectors. The key cost components include the following:

7.1.1. Salaries and Benefits

these costs refer to the wages of general workers including the drivers and collectors. Most contractors in Kitwe employ an average of 4 collectors and 1 driver. The study therefore uses this number to work out the cost of labour per month. The figures for labour, equipment and fees are based on the prevailing market rates and can therefore be taken with a very high degree of confidence. The survey of private contractors revealed that the average monthly wage for drivers was K250000 while that for collectors was K100000. Zambia has no formally established poverty datum line. However over the past 6 years the Jesuit Centre for Theological Research (JCTR) has consistently monitored the "Food Basket" which measures the amount of money a family of 5 needs to meet very basic needs such as food, soap, etc. on a monthly basis. This food basket is generally accepted by all major stakeholders as a proxy poverty line in the country. As of June 2001, the food basket for an average Zambian family was around K330,000. In calculating the cost of labour therefore, this study ignored the current wages prevailing in the industry as they fall below the poverty line and instead adopts the food basket figure of K330000.

Given that almost all contractors engage casual labour, the salary costs given here do not include any other financial benefits such as pension, funeral grants etc. Of course it must be pointed out that in the future, the KCC must ensure that there is an improvement in the working conditions of workers in waste management.

7.1.2. Supplies and Services

This cost component is for the uniforms and protective clothing, equipment, tools and other general supplies used in the refuse removal activity. In terms of clothing, 4 main items must be provided to the workers. These include, overalls, gumboots, respirators, and protective gloves. Given the manner in which waste is currently handled (i.e. there is no separation of waste and in many circumstances, wastes at household level are not stored in proper disposal bags) the study assumes that overalls and gum boots will have to be provided once every three months, protective gloves once every month and respirators once weekly. Equipment such as shovels, brooms etc. will have to be provided once every 3 months.

7.1.3. Transport

This cost component covers operation cost for refuse collection vehicles inclusive of loan repayments, taxes depreciation and other related costs. Given that waste in Kitwe is collected in open trucks, the study proposes that the costs for waste collection must be worked out on the basis of mileage i.e. the cost of collecting 1ton of waste per kilometer. This result would be more reliable than using tonnage since an open truck may not necessarily carry its full tonnage even though its volume may be full. For instance a 12- ton truck laden with domestic waste may not necessarily be carrying 12 tons of waste because the waste is not compacted. In order to assist the calculation based on mileage, the study has worked out an estimate of road length in Kitwe.

The road length in Kitwe's formal housing areas is about 200km. Note that this does not include roads in the CBD, mine townships and the industrial area. Given that the road network of Kitwe is about 300km, this figure seems fairly realistic. With the

200km road network, what is now needed is to establish the cost per km and work out the final cost of collecting waste per ton per kilometer.

Finally the service charge required to make the system economically viable can also be established. In doing so, the willingness and ability of residents to pay for service rendered in waste collection must also be taken into account.

As noted above, the figure for the road network does not include the road network in peri-urban areas which is very difficult to determine. For purposes of costing in these areas, it is proposed that a different method based on operation of a communal transfer system (see Cointreau 1994:16, and Annex) be utilised.

It was difficult from the information given by the different contractors working in the collection of solid waste management to make any meaningful and reliable estimate of the cost of providing the service of solid waste collection. The information given above is just notes that would be helpful in the calculation of the cost and are meant to give the readers an idea of what sort of costs are incurred by the contractors.

7.1.4. Establishment Expenses

These expenses involve travel and subsistence, insurance for the permanent workers, office equipment and transport, and rental for office space including utility bills. Like transport, this cost components still needs to be worked out as it was not possible to get all necessary information.

8.0 POTENTIAL FOR RECYCLING

One of the most important results from this survey with regards to recycling is the fact that a significant volume of waste is already taken out of the waste stream through reuse. The survey showed that a lot of waste is already being reused in the different land use sectors. Reuse is highest within the residential areas where 90% of peri-urban, 76% low cost, 85% medium and 57% high cost indicated that they reuse their waste. Table 11 below shows the main types of waste reused.

Table 11: Main Wastes Re-Used in Each House Category

	Wastes Reused (% of Households)		
	Plastics	**Garden Waste**	**Glass/ Bottles**
Peri- Urban	72	6	17
Low Cost	42	26	16
Medium Cost	70	15	12
High Cost	33	50	4

As the table shows, there is a high level of reuse of plastics in all four categories followed by garden waste. The low use of garden waste in peri-urban could be explained by the fact that these areas rarely have gardens due to limited space whilst the reverse is true in high cost areas. Interestingly and perhaps not surprising, reuse of food waste was only indicated in the high cost areas by only 6% of respondents. This result could be associated with the income situation of households in the different categories. 8% of low cost and 6% of peri urban respondents indicated that they reuse paper.

The commercial sector showed the second highest level of reuse of waste with 34% of respondents indicating that they reused some of their waste. Of these 36% said they reused paper, 27% cardboard, 9% used plastics, 9% food, 9% metals, and 9% sweepings.

In the industrial sector only 25% of respondents indicated that they reused some wastes.

21% of respondents from the market indicated that they reuse their waste. Of these 25% indicated that they reuse plastics, 25% cardboard and 25% vegetables. A total of 12.5% in each case reuse food and sacks.

Apart from reuse by the waste generators, other waste is removed from the waste stream by informal collectors. For instance within the residential areas, 45% of medium cost, 44% of high cost, 28% low cost and 10% of peri-urban respondents indicated that they had people collecting special waste (i.e. informal collectors) from their houses. Of these, bottles were the most regularly special waste collected and to a lesser extent plastics (see Table 12 below).

Table 12: Wastes Collected by Informal Collectors

Special Wastes Collected	Peri-Urban	Low Cost	Medium Cost	High Cost
Plastics	0	6	10	9
Bottles	5	20	35	32

38% of respondents in the industrial sector indicated that people collected special wastes from them. Wastes collected included ash, oils, wood shavings, scrap metals, paper, cloth, motor parts, saw dust, plastics, food wastes and sacks, with none taking significant precedence over the others.

41% of commercial respondents said they had people collecting special waste from them. Of these 40% had plastics collected and 20% each for food, metals, and cardboard. At the market 50% of respondents indicated that they have people collecting special kinds of waste of which sweepings and dry foods constitute the main types (i.e. 32% each respectively). This waste is collected mostly by scavengers.

Given their level of involvement these informal collectors have a potential to contribute to waste management in the city and hence any attempt to recycle must not ignore their involvement.

8.1 Recyclable Wastes

From the survey 2 main wastes seem to offer viable recycling potential. Table 13 below shows the main purposes for which wastes are reused in the residential areas. As the table shows the bulk of waste reused is used for composting, as carrier bags or for storage purposes. This result suggests that organic waste which is mostly garden waste with some food waste has a high potential for recycling given that a significant number of households are already involved in some small scale composting. In addition there is a significant generation rate in all residential areas i.e. 0.31kg/ca/day, giving an approximate total of 121tons of garden waste per day. Composting is also viable given that it can be done using fairly low technological and capital inputs particularly if taken as a community project.

Table 13: Purposes for which wastes are Re-used in Residential Areas (%)

Purpose for Which wastes are Reused	Peri - Urban	Low Cost	Medium Cost	High Cost
Composting	6	34	18	58
Shopping or Carrier Bags	41	8	24	8
Storage	41	55	58	31
Others	12	3	0	3
Total	100	100	100	100

Whilst plastic is highly reused, it is also another waste with potential for future recycling. Inspection of contents of the bags with plastic showed that the majority of households threw away plastic carrier bags and disposable plastic bottles. Generation of plastic waste is expected to increase as the culture of shopping becomes entrenched as part of people's social activity and as free packaging of goods for consumers becomes an entrenched culture amongst traders particularly those of Zambian and Asian origin.[2]. The growth of the bottling industry and increased use of disposable bottles is highly likely to contribute to the increase in this type of waste. It must be noted, that in order to avoid environmental problems related to the non-biodegradability of plastics, efforts must be made to promote packaging in materials that are biodegradable or easier to recycle such as paper. Other measures such as promoting reuse of old carrier bags, payment for bringing back disposal bottles etc. must also be encouraged.

As stated earlier paper and scrap metals are the two wastes that are currently recycled commercially. However, the amounts generated from the residential areas are so small (i.e. 1 ton per day for paper for all neighbourhoods) that the cost of collecting them for recycling would not warrant a large-scale involvement of residents and would probably be too costly for the recycling firms. The option for recycling these two must therefore be focused on investigating the generation rates from the commercial, industrial, and educational establishments.

8.2 Recycling and Public Education

Whilst the potential for recycling does exist, it is important to note that the idea of separation of waste which is important for recycling is not yet well rooted in the city. For instance in the industrial sector only 40% of respondents separated their waste. Within the residential areas a maximum of 29% of high cost and a minimum of 5% of peri urban respondents separate their waste. The figures for low and medium cost areas where 16% and 10% respectively. Only 7 respondents in the commercial sector

[2] The culture of providing free packaging for goods has recently been brought by South African shop owners and is slowly being copied by local traders.

indicated that they separated their waste. This means that if recycling has to be promoted, there has to be a lot of public education about the importance of separation in all land use sectors.

It is important to note that in all the sectors, those who indicated that they separated their waste were not talking about separation for collection or disposal purposes but were talking about removing those waste constituents that they reuse at their premises. This is why for instance in the case of the residential areas the wastes separated included plastics, garden waste, and food as the major waste which is also the waste that is reused (see Table 14 below).

Table 14: Types of Wastes Separated in Residential Areas

	Peri Urban	Low Cost	Medium Cost	High Cost
Plastics	5	38	50	29
Garden	0	62	50	36
Food	0	0	0	21
Others	0	0	0	

As far as public education is concerned there is also need to educate the public on the meaning and importance of the concepts of recycling and cleaner production. This is because very few people know what these terms mean and very few operationalise them. For instance within the residential areas only 55% in high cost, 45 medium cost, and 42% low cost respondents indicated that they knew about recycling. The result for peri-urban was discarded as it was too high i.e. 100% exceeding even that of high cost by far. It has been assumed that too much explanation of the concept was given by the researchers in an effort to simplify or translate the concept into the vernacular. Thus the question lost its significance and the answers given cannot be taken to be true.

59% of respondents in the commercial sector said they knew about the concept of recycling. However only 5 out of the 32 respondents indicated that they recycled some waste, which included timber shavings, metals and cardboard. It must be noted that this is in reference to reuse rather than recycling.

Only 14% of respondents at the market indicated that they knew about the concept of recycling.

As was expected, the majority of respondents in the industrial areas (i.e. 83%) knew about the concept of recycling. However only 13% of respondents recycle wastes within their organizations. Wastes recycled included plastics, wood shavings, foam chips, scrap metal, oils and mealie meal.

The question on whether respondents knew about the concept of cleaner production was directed only to respondents in the commercial and industrial sectors. Within the industrial sector under half of the respondents (47%) knew about the concept of cleaner production whilst only 28% of firms were engaged in some form of cleaner production activity. In the commercial sector only 26% of respondents knew about the concept of cleaner production. And 21% indicated that they were involved in some cleaner production activity.

9.0 THE REVIEW OF TECHNICAL OPTIONS FOR SWM IN KITWE

One of the main aims of the SINPA project has been to suggest a technical option that is effective and socially, economically and environmentally efficient. On the basis of the financial analysis presented in this work, the study proposes that the KCC continues with the technical options recommended by Senkwe et al (1999) in which the high cost areas are served by a door to door collection system and a communal (transfer) system for the low income and peri-urban neighbourhoods.

10.0 RECOMMENDATIONS

The recommendations are discussed under the various headings used in discussing the results. There are however, additional headings whose recommendations are considered important enough to stand-alone.

10.1. Residential

The high numbers of people in the informal sector in the low cost and peri urban areas means that there is a high potential for using SWM for employment creation in these areas. It is recommended that the KCC working with the Small and Medium Business Association and some NGOs look at the possibility helping residents of these areas to set up micro enterprises for collection of SWM. This has been done in Lusaka by the Sustainable Lusaka Programme (SLP).

The residents should also be encouraged to composite their waste. Some of which cane been be sold as garden manure. Due to the high level of unemployment and falling purchasing power of the kwacha an increasing number of people are turning to agriculture as a source of food security so their would be a market for this manure.

The potential for composting garden waste must be fully exploited both as a means of reducing the waste stream, to provide technical support and information to those households that are already engaged in this activity and to promote small scale community based micro-enterprises that can feed into the urban agriculture sector.

10.2. Commercial

Most merchandise is locally procured an indication of a high potential for take back of waste for re-use. Since the bulk of the waste is foodstuff it can also be used for composting which can be sold to individuals for use as garden manure. Small enterprises can be encouraged to collect this waste and composite it for resale using a similar arrangement as recommended above.

The KCC should be vigilant enough to policy the disposal of waste from this sector. There is a lot of potential to get the private sector involved in the disposal of the waste in this sector. In this sector unlike the residential the businesses do have money which they can use to pay for the service but the main problem is that the KCC is not talking to them to make them see the benefits of proper disposal of their waste. The KCC also needs to pass the by laws that were started by the Solid Waste Management Task force which are meant to help enforce compliance.

10.3. Chisokone Market

There is great potential for recycling and composting of waste at chisokone because a considerable amount of waste is generated within a small geographical area which is centrally located. There is an existing market committee which is in charge of the SWM in the market. The committee can employ people to separate the waste and their payment could be the waste they separate which they can re use or recycle. These people can also be helped to start small businesses in composting as 54% of the waste can be composted. A market for this definitely exists.

10.4. Industrial Area

The potential for "take back" is very high in this sector which should be encouraged. There is need for the KCC to police what is going on in this sector together with the ECZ and the KCCI (who are very cooperative). The number of companies using the private contractors is very small and it is not clear as to how many of those doing their own disposal are doing it properly. Therefore the companies should be encouraged to register with private contractors. This can be done by passing by laws which should be enforced but also through the provision of incentives.

There will be need for the KCC together with the KCCI to embark on a programme of environmental education. This can be done in collaboration with the Copperbelt University Institute of Environmental Management. These firms should also be given incentives to start using cleaner production techniques. Incentive could include competitions to award some prizes to those who are doing well or possibly to waive their license fee by the KCC for a year.

10.5. Cost and Revenue

There is need for a dedicated study to find out the actual cost of SWM by the private sector and determine its viability. However, since all those involved did not indicate that they would stop it must be profitable. More importantly however there is need to investigate the viability of small-scale enterprises in SWM in residential areas. There are lessons that can be drawn from the projects done under the Sustainable Lusaka Programme (SLP).

10.6. Potential for recycling

As already shown above there is great potential that exists for recycling and it is worth reiterating that incentives have to be given to various potential actors in the process of recycling to make it happen.

Potential for recycling on a large scale however, does not exist since technology for that is lacking and also it is would be uneconomic to do that as the amount of waste being generated is not high enough.

10.7. Environmental Education

This is a very important activity that the KCC should take seriously. It can be done with the CBU, KCCI and the District Education Officer (DEO) and should target various institutions and should accompany the implementation of the various proposals discussed under recommendations.

10.8. Review of technical options

On the basis of the findings firm thus study it has been recommended that the KCC adopts the recommendations from the report by Senkwe et al (1999) where the high cost areas are served by door to door collection by the private sector and a communal system for the low cost and peri-urban areas.

10.9. Activities of Scavengers

The activities of informal collectors and possible scavengers at Uchi dump site must be thoroughly investigated to determine their scale of operation and possible areas where they can be formally brought onto the waste management system.

10.10. Repeat Study in Dry Season.

It will be important to conduct the repeat study in the dry season to check for any variations in per capita generation rates. This next study must include measurement of wastes generated in the CBD, market and the street sweepings.

11.0 CONCLUSION

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APPENDIX – CALCULATIONS OF PHYSICAL AND CHEMICAL CONTENT OF THE SAMPLES

(1). PHYSICAL COMPOSITION

SAMPLE 1: CONGO WAY

(a) MOISTURE CONTENT

Component	**Weight kg**	**% by Mass**	**% Moisture**	**Dry mass kg**
Food	1.5	2.68	70.44	0.79
Plastic	0.5	0.89	1.91	0.87
Garden	45	80.34	47.97	41.8
Glass	0.5	0.89	0.99	0.88
Others	9	16.07	72.41	4.43
	56kg	100.87		48.77

Basis: 100kg sample of waste.

$$\% \text{ moisture} = \frac{(100-48.77)}{100} \times 100 = 51.23\%$$

(b) DENSITY

Component	**% Weight by mass**	**Typical kg/m^3 density**	**Volume m^3**
Food	2.68	290	0.009
Plastics	0.89	65	0.014
Garden	80.34	105	0.765
Glass	0.89	195	0.005
Others	16.07	240	0.067
	100		0.86 m^3

Others = misc.organics = 240kg/m^3

$$\text{Density} = \frac{\text{mass}}{\text{Volume}} = \frac{100\text{kg}}{0.86\text{m}^3} = 116.28 \text{ kg/m}^3$$

(c) ENERGY

(i). Energy on a dry basis

Component	**% weight mass**	**Energy KJ/kg**	**Total Energy KJ**
Food	2.68	4,650	12,462
Plastic	0.84	32,600	29,014
Garden	80.34	6,500	522,210
Glass	0.89	150	133.5
Others	16.07	10,500	168,735
	100.87		732,554.5

Specific energy content $= \frac{732\ 554.5 \text{ kg}}{100\text{kg}}$

$= \underline{7\ 325.55 \text{ kJ/kg}}$

Energy on a dry basis $= 7\ 325.55\text{kJ/kg} \times \frac{100}{100 - 51.23}$

$= 15{,}020.61\text{kJ/kg}$

(ii). Energy on dry ash free basis

Component	**% weight by mass**	**Dry mass kg**	**%Ash**	**Total Ash (kg)**
Food	2.68	0.79	10.66	0.842
Plastic	0.89	0.87	3.32	0.289
Garden	80.34	41.8	5.89	2.462
Glass	0.89	0.88	0	0
Others	16.07	4.43	6.15	0.2724
	100	**48.77**	**100**	**2.8475**

% Ash (100kg sample) $= \frac{2.8475}{48.77} = 5.84\%$

Energy on ash – free basis

$= 7\ 325.55 \times \frac{100}{(100 - 51.23 - 5.84)}$

$= 17{,}063.9 \text{ kJ/kg}$

(d) % Volatile Matter $= \frac{\text{Mass of volatile matter} \times 100}{\text{Dry mass of waste}}$

% volatile matter (average) $= \frac{45.04}{48.77} = 92.4\%$

SAMPLE 2: TOWN CENTRE

(a) MOISTURE

Component	**Weight kg**	**%weight by mass**	**% moisture**	**Dry mass kg**
Plastic	0.25	1.98	1.27	1.95
Paper	0.25	1.98	4.35	1.89
food	12.1	96.04	82.16	17.13
	12.6	100	100	20.97

Basis: 100kg of waste sample

$$\%\ \text{moisture (100kg sample)} = \frac{(100 - 20.97)}{100} \times 100 = \underline{79.03\%}$$

(b) DENSITY

Component	% weight by mass	Typical density Kg/m^3	Volume m^3
Plastic Paper food	1.98 1.98 96.04	65 85 290	0.030 0.023 0.331
	100		**0.384m^3**

$$\text{Density} = \frac{\text{mass}}{\text{Volume}} = \frac{100\text{kg}}{0.384\text{m}^3} = \underline{260\text{kg/m}^3}$$

(c) ENERGY

(i). Energy on a dry basis

Component	% weight by mass	Energy kJ/kg	Total Energy
Plastic Paper food	1.98 1.98 96.04	32,600 16,750 4,650	64,548 33,165 446,586
	100		**544,299kJ**

$$\text{Specific energy content} = \frac{544{,}299\text{kJ}}{100\text{kg}} = 5{,}443\text{kJ/kg}$$

$$\text{Energy on a dry basis} = 5{,}443 \times \frac{100}{(100 - 79.03)}$$

$$= \underline{25{,}956\ \text{kJ/kg}}$$

(ii). Energy on dry ash free basis

Component	Dry mass kg	% Ash	Total Ash (kg)
Plastic Paper food	1.95 1.89 17.13	8.83 11.74 21.65	0.1722 0.2219 3.7086
	20.97		4.1027

$$\%\ \text{Ash (average) (100kg sample)} = \frac{410.27}{20.97} = 19.56\%$$

Assume upper limit value as 10

$\therefore$ Energy on dry – ash free basis

$$= 5;443\text{kJ/kg} \quad \frac{\text{x } 100}{(100 - 79.03 - 10)}$$

$$= \underline{49\ 617\ \text{kJ/kg}}$$

(d) % Volatile matter $= \dfrac{\text{mass vol.matter}}{\text{Dry mass}} \times 10^2 = \dfrac{16.87 \times 10^2}{20.97} = 80.4\%$

SAMPLE 3: NDEKE

(a) MOISTURE CONTENT

Components	weight kg	%weight by mass	%moisture	Dry mass (kg)
Others Food Plastic metal	2 2 0.5 1	36.36 36.36 9.09 18.18	5.50 71.81 9.97 0.02	34.360 10.250 8.184 18.176
	5.5kg	100		70.97

Basis: 100kg sample

% moisture (100kg sample) $= \dfrac{(100 - 70.97) \times 100}{100} = 29.03\%$

(b) DENSITY

Components	% weight by mass	Typical density (kg/m^3)	Volume m^3
Others Food Plastic metal	36.36 36.36 9.09 18.18	240 290 65 160	0.1515 0.1254 0.1398 0.1136
	100		0.5303

Basis: 100kg sample of waste
Assume
Metal = ferrous metal = $160kg/m^3$
Others = misc. organics = $240kg/m^3$

Density (100kg sample) $= \dfrac{\text{mass}}{\text{volume}} = \dfrac{100}{0.5303} = \underline{188.57kg/m^3}$

(c). ENERGY

(i). Energy on a dry basis

Component	**% weight by mass**	**Energy kJ/kg**	**Total Energy kJ**
Others Food Plastic Metal	36.36 36.36 9.09 18.18	18,000 4,650 32,600 700	654,480 169,074 296,334 12,726
	100		1,105,614kJ

Assume

Others = misc. organics = 18,000kJ.kg

Specific energy content $= \frac{1105{,}614\text{kJ}}{100\text{kg}} = \underline{11{,}056\text{kJ/kg}}$

Energy on a dry basis $= 11{,}056\text{kJ/kg} \times \frac{100}{100 - 29.03}$

$= \underline{15{,}578.4 \text{ kJ/kg}}$

(ii). Energy on a dry – ash free basis

Component	**% weight by mass**	**Dry mass kg**	**% Ash**	**Total ash (kg)**
Others Food Plastic Metal	36.36 36.36 9.09 18.18	34.36 10.25 8.184 18.176	0 8.9 11.05 0	0 9.1225 9.0433 0
		70.97		**18.1658**

% Ash (average)

(100kg sample) $= \frac{181.658}{70.97} = \underline{2.56\%}$

Energy on a dry-ash free basis

$= 11{,}056\text{kJ/kg} \times \frac{100}{100 - 29.03 - 25.6}$

$= 24.368\text{kJ/kg}$

(D) % Volatile matter (Average) $= \frac{\text{mass volatile matter}}{\text{Dry mass}} \times 10^2 \quad \frac{52.80 \times 1000}{70.97} = 74.4\%$

SAMPLE 4: MULENGA COMPOUND

(a) MOISTURE CONTENT

Component	**Weight 1kg**	**% weight by mass**	**% moisture**	**Dry mass (kg)**
Metal	0.5	2.17	0.012	2.17
Glass	0.5	2.17	0.006	2.17
Garden	16	69.57	67.14	
Paper	0.5	2.17		22.86
Food	4.5	19.57	4.14	2.08
Plastic	1.0	4.35	75.32	4.83
			0.004	4.35
	23	**100**		**38.48**

Basis: 100kg waste sample

% moisture $= \frac{(100 - 38.48)}{100} 100 = \underline{61.54\%}$

(b) DENSITY

Component	**% weight by mass**	**Typical density kg/m^3**	**Volume m^3**
Metal	2.17	320	0.007
Glass	2.17	195	0.011
Garden	69.57	105	0.663
Paper	2.17	85	0.026
Food	19.57	290	0.067
Plastic	4.35	65	0.067
	100kg		0.841m^3

Basis: 100kg sample of waste.
Metal = Ferrous metal

Density $= \frac{\text{mass}}{\text{Volume}} = \frac{100\text{kg}}{0.841\text{m}^3} = 118.91\text{kg/m}^3$

(c) ENERGY

(i). Energy on a dry basis

Component	% weight by mass	Energy kJ/kg	Total Energy kJ
Metal	2.17	700	1,519
Glass	2.17	150	325.5
Garden	69.57	6,500	36,347.5
Paper	2.17	16,750	91,000.5
Food	19.57	4,650	141,810
Plastic	4.35	32,600	
	100		**723,207.5**

Specific Energy content $= \frac{732{,}207.5}{100}$

$= \underline{7{,}232.0 \text{ kJ/kg}}$

Energy on a dry basis $= 7{,}232.0 \times \frac{100}{100 - 61.54}$

$= \underline{18{,}804.0 \text{ kJ/kg}}$

(ii). Energy on ash – free dry basis

Component	Dry mass	% Ash	Total Ash (kg)
Metal	2.17	0	0
Glass	2.17	0	0
Garden	22.86	14.58	3.3330
Paper	2.08	4.05	0.8424
Food	4.83	9.40	0.45402
Plastic	4.35	10.42	0.54.327
	38.48		**4.32453**

% Ash (average) $= \frac{432.453}{38.48} = 11.23$

Energy on dry – ash free basis

$7\,232 \text{kJ/kg} \times \frac{100}{(100 - 61.54 - 11.23)}$

$\underline{26{,}558 \text{kJ/kg}}$

(d) Volatile matter (average)[3]

$$\frac{\text{Mass volatile matter}}{\text{Dry mass of waste}} \times 10^2 = \frac{29.80}{38.48} \times 10^2 = 77.4\%$$

SAMPLE 5: EAST OF KWACHA

(a) MOISTURE CONTENT

Component	**Weight kg**	**% weight by mass**	**% moisture content (kg)**	**Dry mass (kg)**
Food Plastic Paper Glass	5.5 0.2 0.5 0.5	82.09 2.98 7.46 7.46	73.20 2.50 3.93 0.03	22.00 2.91 7.17 7.458
	6.7kg	100		39.538

Basis: 100 kg sample

$$\% \text{ moisture} = \frac{(100 - 39.538)100}{100} = \underline{60.46}$$

(b) DENSITY

Component	**% weight by mass**	**Typical density (kg/m^3)**	**Volume (m^3)**
Food Plastic Paper Glass	82.09 2.98 7.46 7.46	290 65 85 195	0.2831 0.0458 0.0878 0.0383
	100		**0.4550m^3**

Density (Basis 100kg sample) $= \frac{\text{mass}}{\text{volume}} = \frac{100}{0.455} = 219.78\text{kg/m3}$

[3] Metal and glass are not included on volatile matter computation

(c) ENERGY CONTENT

(i). Energy on a dry basis

Component	**% weight by mass**	**Energy (kJ/kg)**	**Total Energy (kJ/kg)**
Food Plastic Paper Glass	82.09 2.98 7.46 7.46	4650 32600 16750 150	381,718 97,148 124,955 1119
	100		**604,940**

$\therefore$ Specific energy content $= \frac{604940\text{kJ}}{100\text{kg}} = 6049.4$ kJ/kg

Energy on dry basis $= \frac{6049.4 \times 100}{100 - 60.46} = 15{,}300$ky/kg

(ii). Energy on Ash-free dry basis:

Component	**% weight by mass**	**Dry mass (kg)**	**% Ash**	**Total Ash**	**% Volatile matter (kg)**
Food Plastic Paper Glass	82.09 2.98 7.46 7.46	22.00 2.91 7.17 7.458	13.08 5.45 11.51 0.00	2.8776 0.1586 0.82.53 0	86.92 94.55 88.49 00
		39.538		**3.8615**	

% Ash (average) $= \frac{\text{Total Ash}}{\text{Dry mass}} = \frac{386.15}{39.538} = \underline{9.76}$

(Basis 100kg sample)

Energy on ash free dry basis

$$= \frac{(6049.4)10^2}{100-60.46-9.76} = 20{,}313 \text{ kJ/kg}$$

(D) VOLATILE MATTER

Component	**Dry mass (kg)**	**% volatile matter**	**Mass volatile matter (kg)**
Food Plastic Paper Glass	22.00 2.91 7.17 7.458	86.92 94.55 88.49 0.00	25.31 2.75 6.34 0.00
	39,538		34.4

% volatile matter (average) $= \frac{(34.4)100}{39.538} = 87.00\%$

(e) CHEMICAL CONTENT

The overall chemical content of solid waste is evaluated using the typical data on ultimate analysis of the combustible components in municipal solid waste. (refer to table 10-8 S.Peary 1985)

(2). CHEMICAL COMPOSITION

(a) SAMPLE 1: CONGO-WAY

Component	**Weight mass (kg)**	**Dry mass (kg)**	**Composition kg**					
			C	**H**	**O**	**N**	**S**	**Ash**
Food	2.68	0.74	0.38	0.05	0.29	0.02	0.003	0.04
Plastic	0.89	0.87	0.52	0.06	0.20	-	-	0.087
Garden	80.34	41.8	19.98	2.51	15.88	1.42	0.125	1.88
Others	16.07	4.43	2.15	0.29	1.66	-	-	-
(misc.org)						0.10	0.013	0.22
Totals	**99.98**	**47.89**	**23.03**	**2.91**	**18.03**	**1.54**	**0.141**	**2.227**

Basis: 100kg sample of waste

(ii) Summary table:

Component	**Mass, kg**
Moisture	52.09
Carbon	23.03
hydrogen	2.91
Oxygen	18.03
Nitrogen	1.54
Sulphur	0.141
Ash	2.23

(iii) Convert moisture in (ii) to hydrogen and oxygen

(a) Hydrogen $= 2/18 \times 52.09 = 5.49$kg

(b) Oxygen $= 16/18 \times 52.09 = 46.30$kg

(iv) Compute molar composition of the elements

Component	**Mass (kg)**	**% by mass**
Carbon	23.03	23.0
Hydrogen	8.70	8.7
Oxygen	64.33	64.3
Nitrogen	1.54	1.5
Sulphur	0.14	0.1
Ash	2.23	2.2
Total	**99.97**	**99.8**

Element	**Mass kg**	**Kg/volume**	
Carbon	23.03	12.00	1.919
Hydrogen	8.30	1.00	8.700
Oxygen	64.33	16.00	4.021
Nitrogen	1.54	14.00	0.110
Sulphur	0.14	32.00	0.004

(v) Determine an approximate chemical formula with and without sulphur

Element	**Sulphur = 1**	**Nitrogen = 1**
Carbon	479.8	17.4
Hydrogen	2175	79.1
Oxygen	1005	36.5
Nitrogen	27.5	1
Sulphur	1	0

∴ (a) Chemical formula with sulphur

C_{480} H_{2175} O_{1005} N_{28} S

(b) Chemical formula without sulphur

C_{17} H_{79} O_{37} N

SAMPLE 2: EAST OF KWACHA

(i) Computation of the chemical composition of a waste sample

Component	**% wet mass (kg)**	**Dry mass (kg)**	Composition, kg					
			C	H	O	N	S	Ash
Food Plastic Paper Glass	82.01 2.98 7.46 -	22.00 2.91 7.17 -	10.56 1.75 3.12 -	1.41 0.13 0.19 -	8.27 0.66 3.15 -	0.57 - 0.02 -	0.09 - 0.01 -	1.10 0.29 0.43 -
Mini glass	92.53	32.08	15.43	1.73	12.08	0.59	0.1	1.82

(ii) Summary Table

Component	**Mass kg**
Moisture* Carbon Hydrogen Oxygen Nitrogen Sulphur Ash	60.45* 15.43 1.73 12.08 0.59 0.10 1.82

*(92.53 – 32.08)

(iii) Revised Summary Table

Component	**Mass, kg**	**% kg mass**
 Carbon Hydrogen Oxygen Nitrogen Sulphur Ash	15.43 8.45 65.81 0.59 0.10 1.82 92.20	16.7 9.16 71.4 0.64 0.11 1.97 99.98

(iv) Convert the moisture content in (ii) to hydrogen and oxygen

(a) Hydrogen = 2/18 x 60.45 = 6.72kg

(b) Oxygen = 16/18 x 60.45 = 53.73kg

(v) Molor composition of the elements

Element	**Mass, kg**	**Kg/mol**	**Moles**
Carbon	15.43	12.0	1.286
Hydrogen	8.45	1.0	8.450
Oxygen	65.81	16.0	4.113
Nitrogen	0.59	14.0	0.042
Sulphur	0.10	32.0	0.003

(vi) Determination of an approximate chemical formula with and without sulphur

(a) Compute normalized mole ratios

Element	Mol ratios **Sulphur = 1**	**Nitrogen = 1**
Carbon	428.7	30.6
Hydrogen	2816.7	201.2
Oxygen	1371.0	97.9
Nitrogen	14.0	1.0
Sulphur	1.0	0

(b) chemical formula with sulphur:

C_{429} H_{2817} O_{1371} N_{14} S

(c) Chemical formula without sulphur

C_{31} H_{201} O_{98} N