Waste Characterisation Study in 5 African Countries

P.A. Smuts. Pasco Waste & Environmental Consulting, Pretoria, South Africa. smutswp@icon.co.za

ABSTRACT

A solid waste characterization study analysing the composition of waste streams from 5 cities in Africa was initiated by the Bill and Melinda Gates Foundation in 2011. The objective was to determine how waste streams differ so that grantee partners (both NGOs and municipalities) can use the data as input for valorisation schemes. Generator-based sampling was undertaken. Variables such as seasonal effects, terminology, waste densities, sampling approaches and socio-economic conditions were considered. Packaging within the waste stream, general density of the waste, moisture content of the waste, waste generation rates were assessed. The organic, garden refuse and "other" fractions defined as organic or compostable material from the various regions, cities or towns represent approximately 66%. The remainder 34% is typically considered dry recyclable waste materials. Waste from all regions were fairly contaminated which amplifies the need for separation at source to ensure efficient recycling of waste materials.

1. INTRODUCTION

Based on historical waste characterization studies (Pasco 2011), (Onibokun et al. 1999) the Bill and Melinda Gates Foundation (The Foundation) required that waste be sampled in five African countries. The objective was to keep up with changing environments while building on past work done in this field. This paper covers the outcome of the sampling and characterisation exercises.

The project is defined as a municipal solid waste characterization study analysing the composition of waste streams from 5 cities in Africa as shown in Table 1.

Table 1: Cities sampled

Country	City
Egypt	Cairo
Ghana	Sekondi
Ivory Coast	Abidjan
Liberia	Monrovia
Zimbabwe	Harare

This study relied on generator-based sampling to obtain information on the waste composition, waste generation rates and existing recycling patterns of the waste. Due to recycling initiatives in some cities, albeit informal, landfill based sampling was not considered as it would only provide information of waste finally disposed in the landfill and would vary depending on the extent of the recycling or waste minimization initiatives at the landfill and prior to disposal. To take cognizance of the seasonal effects on the composition of generated waste the study was conducted twice during the year in the various cities except for Abidjan where, due to administrative issues, a second round of sampling could not be performed.

1.1 Objective of the Project

The objective of the project was to determine how waste streams differ among and within five African cities so that grantee partners (both NGOs and municipalities) could use the data as input for valorisation schemes:

- As a result of an examination of the activities in their grant-making portfolio, The Foundation team attempted to work with partner organizations to produce sustainable models which achieve two goals: promoting the opportunity for more and better resource allocation for the poor in developing world cities, and reversing market failures in developing world cities.
- One potentially lucrative sector in which the urban poor may work is the management of municipal solid waste; but because the value of bulk waste and the technical issues surrounding its management depend on its composition; and the composition depends on seasonal changes, residential income, and location of interest; The Foundation desired to know more about how the variability of waste composition in the developing world depends upon various factors.

- The Foundation was interested in testing new technologies that could be harnessed to produce more and better access to resources for the urban poor. But in order to introduce or test them, The Foundation team needed a better understanding of what they were working with in terms of the waste – some fractions of the waste stream they could compost or recycle, but other innovations that could be relevant in other cases.

1.2 Project Scope

The project scope was defined as the following:

- To conduct a desktop study on available historical data based on earlier studies conducted and published. Identify potential historical significance for this project to which new information could be added and in so doing establish potential future trends.
- Based on the outcome of the background study (Pasco 2011) five cities as the focus point of this waste characterization study were identified by The Foundation Team.
- Sampling protocols to obtain waste composition information from the 5 cities to meet the project objective were designed. Seasonal differences in the choice of cities and the need to repeat sampling in the alternative seasons were also considered.
- A report covering the cities to compare the information thus obtained was compiled and covered:
  - § Demographics covering socio-economic breakdown
  - § Mean waste generation rate (kg/cap/d)
  - § Mean bulk mass
  - § Waste composition in terms of percentage (by weight) of the various waste streams:

2. BACKGROUND

Information on the composition of waste is of specific significance in the design of waste recycling systems with specific focus on the recovery potential of different materials.

Waste materials also known as trash, refuse, garbage has its origins in manufactured packaging or container materials and organic or vegetable material. Not only will information regarding the composition of the waste stream be important but also the origins and thus the manufacturers of the various packaging materials who are indirectly responsible for the bulk of the waste/trash production. With information available on the supplies of aluminium cans, plastic sheeting and bags, paper wrapping, cardboard and glass bottles, the relative quantities could be useful to enable negotiations on a direct buy back with the manufacturers. It is thought that the manufacturers may also have an incentive to negotiate once they are aware of the magnitude of the waste stream thus created through the utilization of their products.

2.1 Earlier studies

Noted during the background study were a number of cases where comparison of information was not possible due to different terminologies used in earlier waste characterization studies. Generic terms used, such as organics, and what fractions were included under this term, also led to confusion.

Densities of waste as a management tool are generally (and often short-sightedly) not determined. Waste densities would also vary depending at which stage in the management process the waste stream is assessed.

Little to no mention was made of waste comparisons done in areas with different socio-economic standing in earlier studies. No reporting on recycling or composting of the materials and the impacts thereof on the composition were found in the cases listed above.

2.2 Summary findings of earlier studies

Non-standard methodologies and references to waste types have led to confusion when comparing data of earlier studies.

Earlier studies in Namibia, Sudan, Egypt (Zaki et al. 2010), Tanzania, Zambia, Morocco, Liberia, Tunisia, Nigeria and Cote d'Ivoire (Terrabo 2010) revealed the average results as shown in Figure 1. From all the samples taken from various regions, cities or towns assessed, garden refuse and "other" fractions totalled between 50% and 66% (1/2 to 2/3) organic materials which are typically compostable. The remainder (33%)

could have been defined as pure recyclables (dry waste) to be separated through appropriate recycling programmes.

Earlier studies by the author in other regions, especially in the tropical and wet climate areas, have highlighted differences in waste composition between the seasons. Seasonal effects have therefore been considered as part of the Foundation characterization study.

To date poor communities have been found to produce more organic material or more fines such as sand in their waste fractions. The latter is often due to yard sweepings that are disposed with the general waste stream. Affluent communities have been found to produce large volumes of pure recyclables and potentially less organic materials due to food being obtained through packaged or canned products and thus not as agricultural products directly from the markets.

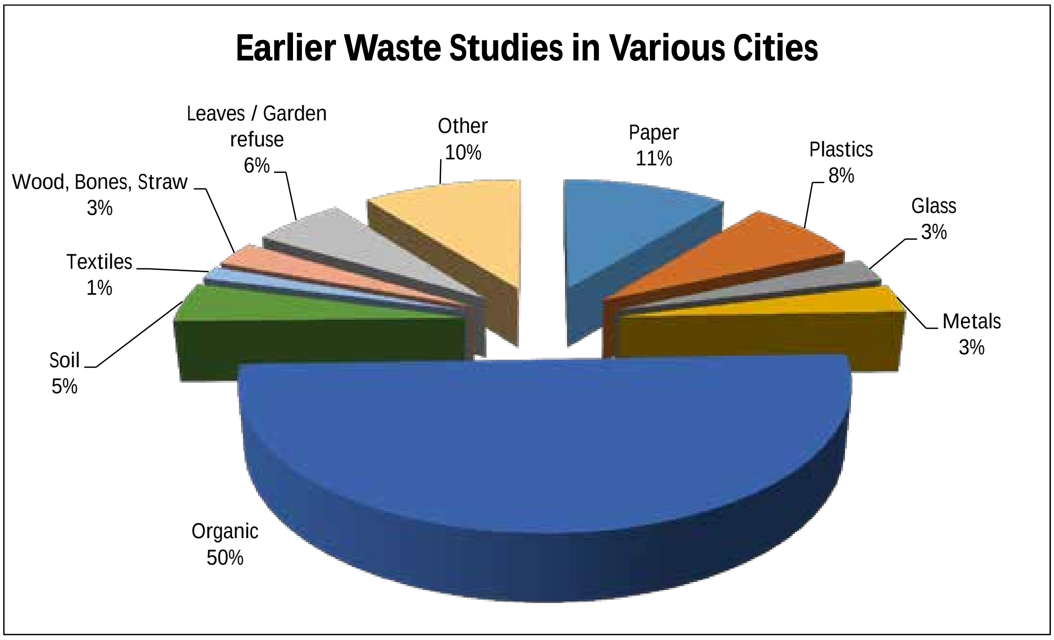


Figure 1: Summary of waste composition – Earlier studies

3. MUNICIPAL WASTE SAMPLING

3.1 Objective

Waste sampling is done in order to form an idea of the types of waste being disposed of and to ascertain whether better alternatives such as reuse or recycling or waste to energy programmes instead of current waste disposal methods (typically landfilling) could be implemented.

Additional demographic information was obtained and added to Table 2 showing the cities where sampling took place. The sample sizes were based as close as possible to the recommended statistical sample sizing graphs as suggested by the Irish Environmental Protection Agency (EPA) (Crowe et al. 1996). An extrapolation (straight line) of the graphs was carried out where a city consisted of more dwellings than allowed for in the graphs i.e. working outside the limits of the graphs. This approach was considered conservative as statistically the number would decrease following an exponential downward trending curve.

Table 2: Cities sampled

Country	City	Est. Pop.*		Proposed Sample size
		City	Metro	Households
Egypt	Cairo	6.7 mil	19.4 mil (2006)	8 375
Ghana	Sekondi	445 205	No Metro (2005)	1 160
Ivory Coast	Abidjan	3.66 mil	6.2 mil (2007)	4 500
Liberia	Monrovia	680 000	1.01 mil (2008)	1 500
Zimbabwe	Harare	1.6 mil	2.8 mil (2008)	2 500

Source: www.indexmundi.com

3.2 Methodology

The Irish EPA has development a standard methodology (Crowe et al. 1996) for conducting a waste characterization analysis and this approach was adopted and adjusted where necessary for the Foundation study. To ensure uniformity in the approach the same sampling methodology was used in all cities. Results could then be compared between the cities and possible other areas.

The process required the following equipment, tools and vehicles:

- A covered 150m² hard stand area,
- Minimum 5 ton tipper truck,
- Mechanical shovel (small front end loader - for mixing the sample),
- A 60kg precision scale (10g increments - for weighing the separated fractions), sieve with 20mm round mesh openings, a tray for fines recovery, containers for storing and weighing separated fractions,
- A magnet (to separate the metals from the remainder of the waste),
- A fire heated container (for moisture content) and
- A plastic graduated container (200-300 litre) to determine bulk density analyses were used during the exercise.
- As a minimum the workers were issued with masks and heavy duty gloves.

Occupants of households chosen for the survey were not be informed of the survey thus avoiding any bias that may be created by a temporary change in the process. Samples were collected on the same day waste would normally be collected from the households. Vehicles were thus dedicated to collect the waste from the identified areas. With no weighbridge available in any city samples were weighed manually (bag by bag or per container depending on the circumstances).

To determine the weight of waste generated per household separate bags were distributed to a number of houses in various socio-economic groupings and collected after 24 hours.

With varying truck loads collected from city areas, the loads (not less than 5 tons) were offloaded on hardstand areas and reduced to a more manageable size. The ideal sample size for characterization was set to between 100 - 200 kg (minimum 100 kg) and the size reduction was achieved by a Coning and Quartering technique. This involved the following:

- The sample was placed on the floor of the sorting area and thoroughly mixed by mechanical shovel.
- The sample was then placed in a uniform pile of approximately 0.8 m high.
- The pile was divided into four quarters using straight lines perpendicular to each other.
- Either pair of opposite corners was removed to leave half the original sample.
- The process was repeated until the desired sample size i.e. 100-200 kg was obtained.
- The surplus ‘two-quarters’ from the last size reduction was retained for analysis of moisture content and bulk density.

Larger sized particles were contained within the quarter sampled to reduce sample bias.

Once the sample size has been determined and a reduced or workable sample obtained, the following procedure was carried out.

- Sort reduced sample and pick out larger items first e.g. glass, paper, plastics.
- Record waste category, weight (kg), % of category and % of total. An example of the waste categories can be found in the appendix A.

- Any remaining material should be passed through a 20 mm mesh sieve and classified as 'Components smaller than 20 mm round mesh'.
- Any unclassified material should be allocated as Combustible or Incombustible.

Both the moisture content and the bulk density of the sample were measured. Due to a lack of proper equipment and location rudimentary field work was carried based on the following:

The surplus 'two-quarters' from the last cone and quartering step are set aside for analysis. The two quarters are combined and a further cone and quartering performed. Each pair of opposite quarters were then combined to form two samples, A and B. Sample A is then analysed for moisture content and sample B analysed for bulk density. Moisture content of the waste was determined by subtracting the weight of the wet waste from the sun dried waste spread out on a black plastic sheeting.

To determine the densities, waste was poured into containers between 100 and 250 litres and the container dropped (3 times) to effect a degree of compaction. The bulk density as kg/litre of the partially-filled container, was calculated as the difference in full and partially full weight divided by the difference between full and partially full volumes.

This was however done in the field and thus not under laboratory conditions as no drying facilities were available resulting in qualitative information.

The above process was carried out with due regard to safety procedures. Once the waste composition survey process was complete waste was recovered and safely disposed.

3.3 Sample size and frequency of sampling

3.3.1 Selecting a representative sample

The Foundation team recognized that selecting a representative sample from the residential areas is one of the most difficult tasks associated with a waste stream analysis especially as far as socio-economic groupings are concerned.

To obtain information on the socio-economic groups in the local authority catchment area, the city (assembly or municipality) planning department/other authorities were approached. It was considered important to include as much as possible socio-economic groups in the sample size so that a representative total sample could be obtained. Where possible the socio-economic classes were divided, generally into three groups, e.g. high, middle and low income or development density. The size of the sample from each socio-economic class was thus determined based on the percentage of representation.

The number of households was determined by considering the population size and typical number of persons per household. Due to a lack of available planning and statistical information in most cities the perceived percentage of socio-economic representation was guesstimated based on local perception and knowledge of various socio-economic groupings and the estimated associated suburb size relative to the overall size of the city. A representative sample size of the area under consideration was then determined based on the statistical sampling graphs as published by the Irish EPA (Crowe et al. 1996).

3.3.2 Sample size

With the size of sample being dependent on the number of households in the sampling area, and based on an assumed waste generation rate of 0.5 kg per person per day and six people per household, sample sizes ranged from two small ($5m^3$ each) waste collection trucks per socio-economic division to four large collection containers ($15m^3$ each) in larger areas.

3.3.3 Frequency of sampling

Sampling in the various cities were carried out during different seasonal periods. The cities considered were, in the north Cairo, a dry desert area, in the south Harare with distinct winter and summer seasons and in the west Abidjan, Monrovia and Sekondi with distinct wet and dry seasons. Winter and summer seasons are associated with cold and hot climatic conditions respectively and mild low rainfall. During wet and dry seasons in the tropical areas the temperatures and humidity remain relatively constant. Extreme rainfalls are experienced during the wet season (up to 4500mm pa) leading to different social activities as well as different agricultural produce than in the dryer south and north.

Cairo has been experiencing influx of many industries such as textile, food processing and building materials with chemical, pharmaceutical, leather products, soap, fertilizer and plastics finding its way into the markets throughout the year (Zaki et al. 2010). Although they experience a dry and wet season it is understood from residents that it does not impact on the waste stream. However, the religious period of Ramadan was seen to have a significant impact on the lifestyles and thus waste stream and was thus defined as a seasonal event in terms of this waste study (GTZ et al. 2009). Ramadan was also considered representative of the other religious periods throughout the year. Two sets of sampling were thus conducted in Cairo – one during Ramadan period and one during the wetter rainy season.

Harare is located in the southern arid areas and in a typical city environment with a mix socio-economic society. The country has been experiencing economic hardship which could have impacted on the living standards of the population and thus the waste disposal patterns. Sampling was however carried out during the dry winter season and wet summer season.

The cities of Abidjan, Sekondi and Monrovia are located in West Africa along the tropical belt where extreme rainfall is experience in the wet season, predominantly during April to September. The rainfall in Monrovia is known to be double that of Sekondi and Abidjan. With two distinct waste disposal patterns experienced during the wet and dry seasons, sampling was carried out twice in this region i.e. during the dry season and again during the wet season. Sekondi (CHF et al. 2010) was sampled during the wet season and in November commonly known as the dry season. Monrovia was sampled at the end of the dry season and end of the wet season. A first round sampling was conducted in Abidjan (Terrabo 2010) in July. Due to logistical and administrative complications which made it difficult to complete the work Abidjan a second round of sampling was not possible.

Table 3: Sampling periods for the cities covering the different seasons and events

Country	City	Sampling seasons	
		First sample	Second sample
Egypt	Cairo	August (Ramadan)	November (Wet Season)
Ghana	Sekondi	May (Wet Season)	November (Dry Season)
Ivory Coast	Abidjan	July (Wet Season)	
Liberia	Monrovia	April (End Dry Season)	October (Wet Season)
Zimbabwe	Harare	June (Winter Dry)	November (Summer Wet)

One survey per socio-economic grouping per season was carried out in all the regions except in Monrovia where this was not possible due to no town planning structure plan.

3.4 Definition of waste fractions

3.4.1 General definitions

The study considered the main category of waste materials and sub-materials as well as the refined definition of plastic materials. Typical waste materials such as paper, cardboard, composite materials, glass, metal, plastic, textile and organic material were extracted from the waste samples. The remaining fractions defined as unclassified combustibles, classified combustibles, special municipal waste and fractions less than 20mm were also extracted. The unclassified combustibles and fractions less than 20mm were further defined as contaminated organic material and soil-like organic material (potentially compost) respectively. This was done to identify and highlight the total organic fraction in the waste stream.

The contaminated fraction consisted of small fractions of paper, plastic, wood, metal, food, faeces, seeds, stones, etc. The compost soil-like material consisted of sand, soil, decomposed fractions and small stones. This fraction also contained small fractions of metal, wood, paper, cardboard and plastic and was to some extent also contaminated. The entire sample was thus defined as shown in the figures.

3.4.2 Special categories

In all samples the organic fraction, fractions less than 20mm and the unclassified combustible and incombustible materials formed the largest volume in the overall sample. Typically waste such as paper, cardboard, composite materials, glass, metal, plastic and textile referred to as dry recyclables, formed the remaining group.

Organic waste typically identified as garden waste, food and bones would be material used in the composting process. Paper and cardboard could also be used in the composting process.

Fractions less than 20mm and 8mm could be identified as a mix between sand, excrement, and food waste already in the process of decomposition. In the larger fraction (> 20mm) gravel, smaller stones, seeds or pips with a certain amount of food and excrement already well advanced in the decomposition process were noticed. The latter formed a heavy fraction of the larger sample.

By far the largest fraction in all cases were the unclassified combustibles and incombustible material. The unclassified group would consist of a mix of bits of paper, cardboard and plastic fluff, plant fibres, leaves, sand, stone and excrement, not taken out of the stream by hand (process of direct identification) due to it being too small to sort but not passing the larger 20mm sieve. In some cases more stone and sand and thus heavy materials were present. In other cases more fibrous material was observed. The latter was then also defined as more combustible than the heavy incombustible solid materials. To some extent the fibrous material would also be grouped with the organic material if little paper and plastics were observed. All fractions described above were contaminated in one way or the other.

Special municipal waste was generally defined as hazardous waste from industrial outlets especially where they are found in large volumes/quantities. Typically small quantities of household hazardous waste (batteries, energy saving bulbs, etc.) which would have insignificant impacts on the environment were identified. Overall the volumes of special municipal waste category were found to be negligible.

A major concern and found in virtually all waste streams was medical waste, specifically sharps and syringes, in many cases still with the needles attached. In other cases vials containing blood were also observed. This poses a serious threat to the waste workers and is something the authorities need to address without delay.

Single large items such as tyres, suite cases, boxes, etc. were observed during the sampling process. They were however discarded scientifically as part of the sample “coning and cutting” process.

3.5 Sampling sizing methodology

Waste was collected in either containers or waste collection trucks and then dumped on a hard surface where the mixing process was carried out either by hand or heavy machinery ranging from a Bobcat to a CAT 966 loader.

After the mixing process the waste samples were quartered by splitting them and removing the opposite quarters and mixing the remaining quarters. The process was repeated until the required sample size was obtained. During the mixing process the plastic waste bags containing waste was also cut or ripped open to ensure an even spread of all waste materials during the mixing process. With the assistance of the waste pickers the waste bags were hacked open with the tools they used on a daily basis to salvage waste on the landfill.

The waste generation rate per household or person was, albeit a very rudimentary approach, determined by distributing a number of refuses bags to households on a random basis and collecting them after a day. The number of people in the households were recorded per bag and the bags weighed to provide a generation rate in kg/person/day. This method however has a number of associated problems such as the accuracy on the number of people per household, people not wanting to divulge information either on numbers or waste itself, and waste from the previous day(s) also being added to the one-day bag.

Although communicated with the waste collectors not to remove any material from the collection load a concern was noted as to how much “valuable” recyclable material was removed before the waste samples were presented for further analyses. One specific issue is the PET bottles which do not seem to be finding their way into the waste stream i.e. before final disposal. It could therefore be debated whether it has become a waste product or diverted material.

4. FINDINGS

This study has shown that approximately a quarter to 30% of the materials such as paper, cardboard, textiles, plastic, glass and metal are recyclables. Not all materials are however recyclable specifically the composites and contaminated fractions such as paper and cardboard not separated at source. Less “dry” recyclable were recorded along with much more organic including unclassified material than earlier studies.

The fractions much less than 1% of the total sample were not represented on the graphs to follow (See Figure 2). It however does not imply that such materials were not present in the waste stream. In many mixing processes all types of materials were noticed but did not represent a significant volume in the overall stream. These were typically tyres, suitcase, dead animals and dangerous elements such as a piece of wood with protruding nails or syringes with needles.

During collection and then sampling all efforts were made to ensure that recyclable materials were not extracted from the loads earmarked for the characterisation study. The practise of pre-extraction could lead to inaccuracies in future as only waste arriving at landfills, transfer stations or centres earmarked for disposal may be available for envisaged waste projects where waste is not obtained at the source through waste separation initiatives.

Great concern is expressed over health of the waste pickers and collectors where medical waste, in many case open and loaded syringes were found in the waste stream. This requires specific attention from the authorities.

Historical analyses have highlighted variations in the composition of waste linked to the socio-economic status of communities. It has however not been confirmed decisively through this study as the town planning boundaries within cities seem to disappear due to limited availability of land in all countries. In the case of Sekondi vs Harare representative of poorer communities quite the opposite than expected had been noticed where materials such as organics and plastics have increased instead of decreasing.

Although not straight forward due to different descriptions used historically to describe the waste components (terminology), comparison of information between this study with previous studies showed a great deal of similarity. The exception is however Monrovia where it is expected as living conditions and the economy after the war are only now starting to stabilise with more and more products becoming available in the markets. However, typically it is not clear what it meant by the “other” component as mentioned in earlier reports or even whether the use of organic material is understood by all in the same way especially where garden waste (“greens”), straw and soil weren’t grouped with organics . Furthermore, it is also not clear from earlier studies whether organic waste consisted of only food waste.

This study attempted to separate the organic waste stream as far as possible for a number of reasons relating to potential end users. Clean organic waste such as garden and vegetable or food waste where clearly definable was considered “clean” organics. Organic not clearly definable was considered contaminated (with typically pieces of paper, plastic, cardboard, tin, glass, etc.). The last organic fraction was the fermented small fractions i.e. virtually composted or in the process of fermentation and is often mixed with sand and soil.

Very obvious in this study were the differences in waste samples in bins that were heavier than others containing higher volumes of smaller fragments, unclassified components and organic waste with high moisture content compared to those containing more light weight recyclables.

In all cases organic waste or food waste were found to be dominant and thus the largest component within the waste streams.

Densities of the waste samples varied quite considerably and ranged from 223 and 618 kg/m^3 as extremes. Generally the densities ranged between 300 and 500kg/m^3 with an average of 372kg/m^3.

Although attempts were made to determine the waste generation rate per socio-economic grouping, no plausible and arguable figures could be determined due to a number of factors. These were:

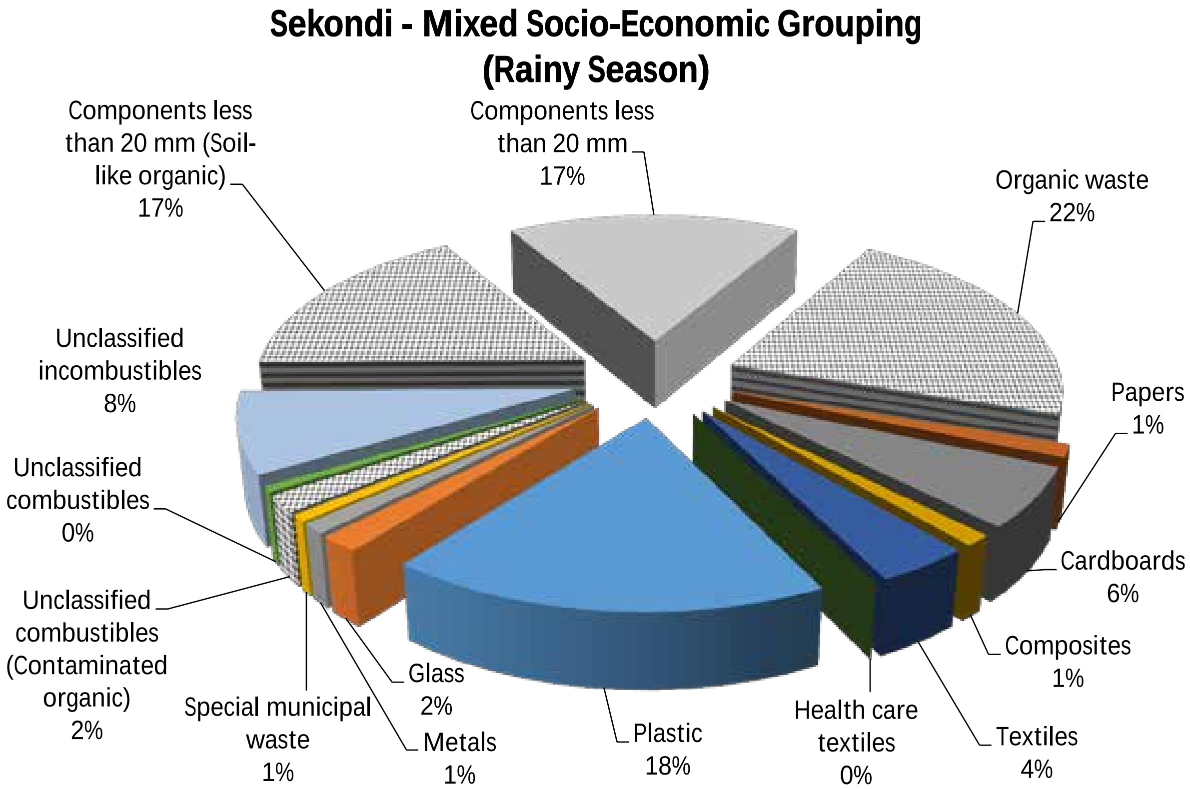
- i) lack of accurate statistical information of the communities being studied,
- ii) available and secured space for the communities partaking in the exercise to stored their waste samples,
- iii) absolute understanding of the goal and “buying into the process” by the communities,
- iv) limited time during which such exercise could be executed.

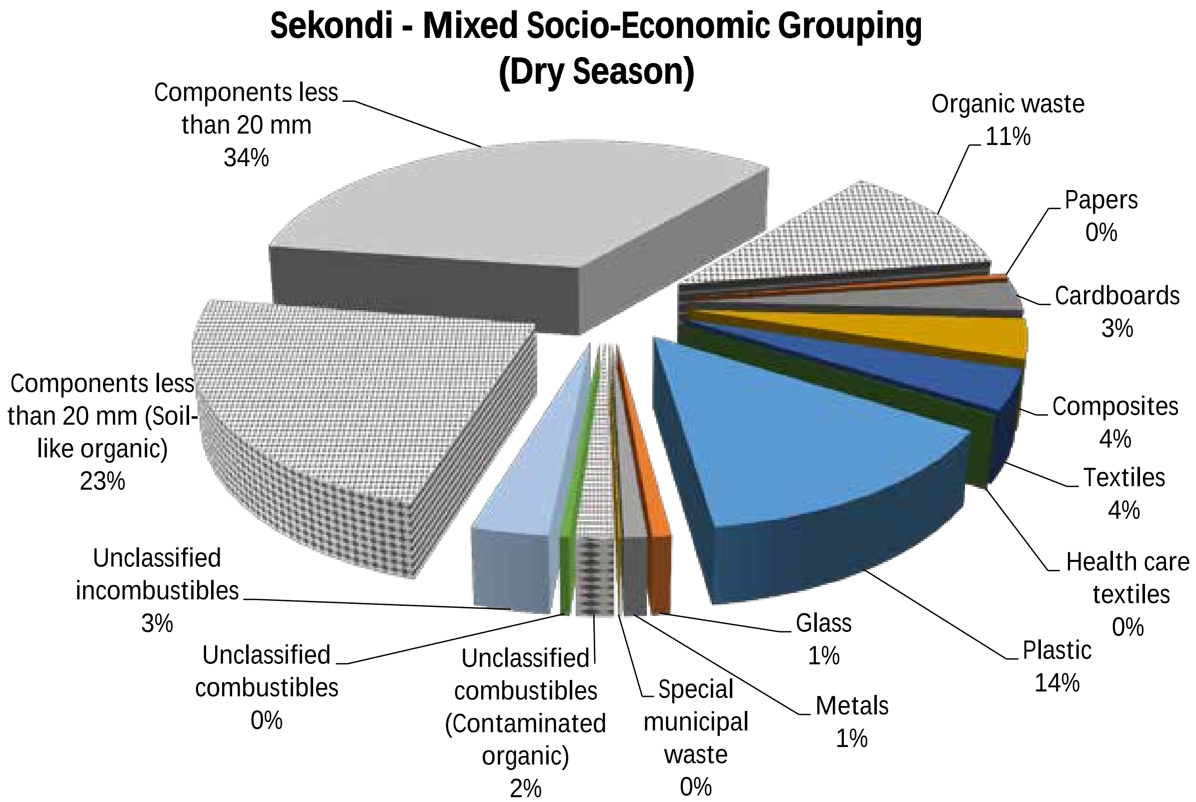
The alternative would be to determine the generation rate by considering the bulk waste collected from a community where:

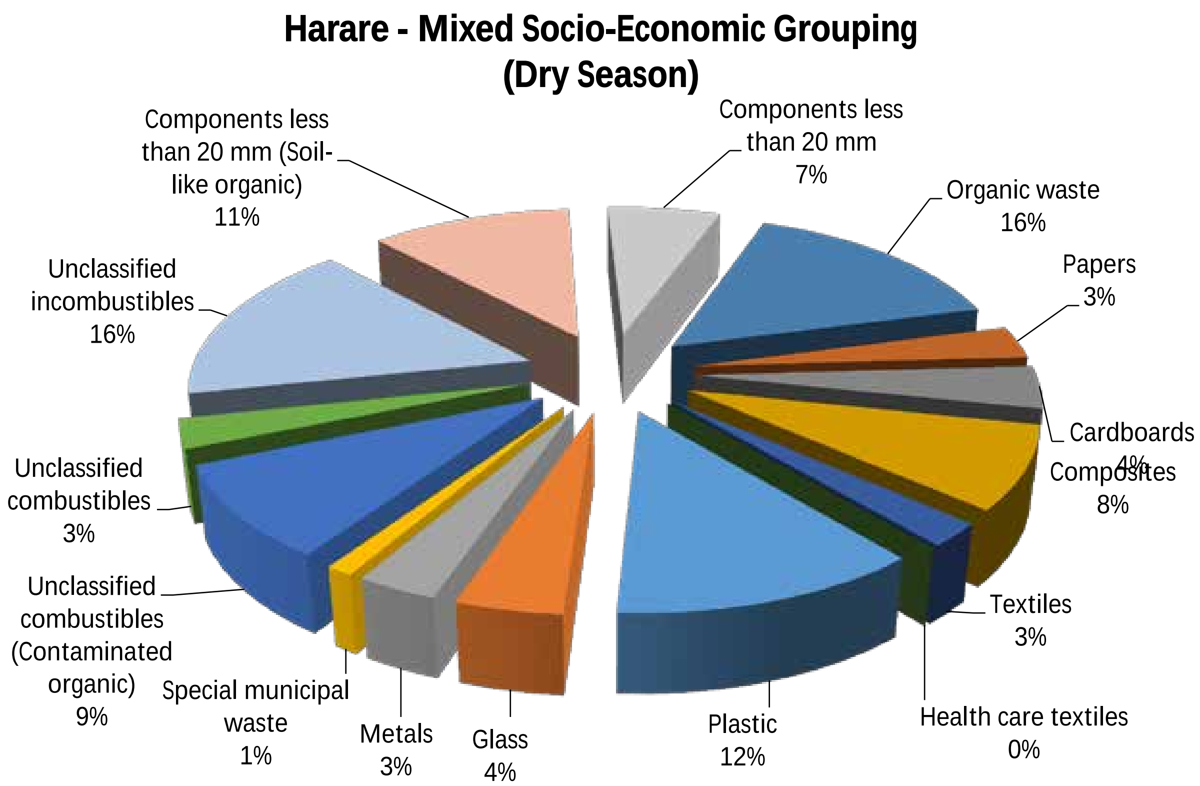
- i) exact population figures are available,
- ii) the waste collector or team accompanying the collector gathers exact information regarding the households serviced, and
- iii) a weighbridge is in place to provide accurate weights/mass of waste collected from the communities being studied.

Proper determination of waste generation rates would require time and money. Figures were however obtained on a rudimentary basis and with a low confidence but has some significance compared to typical figures used in the industry.

Figure 2 shows the variations in waste composition between the wet and dry in Sekondi and between summer and winter seasons in Harare.







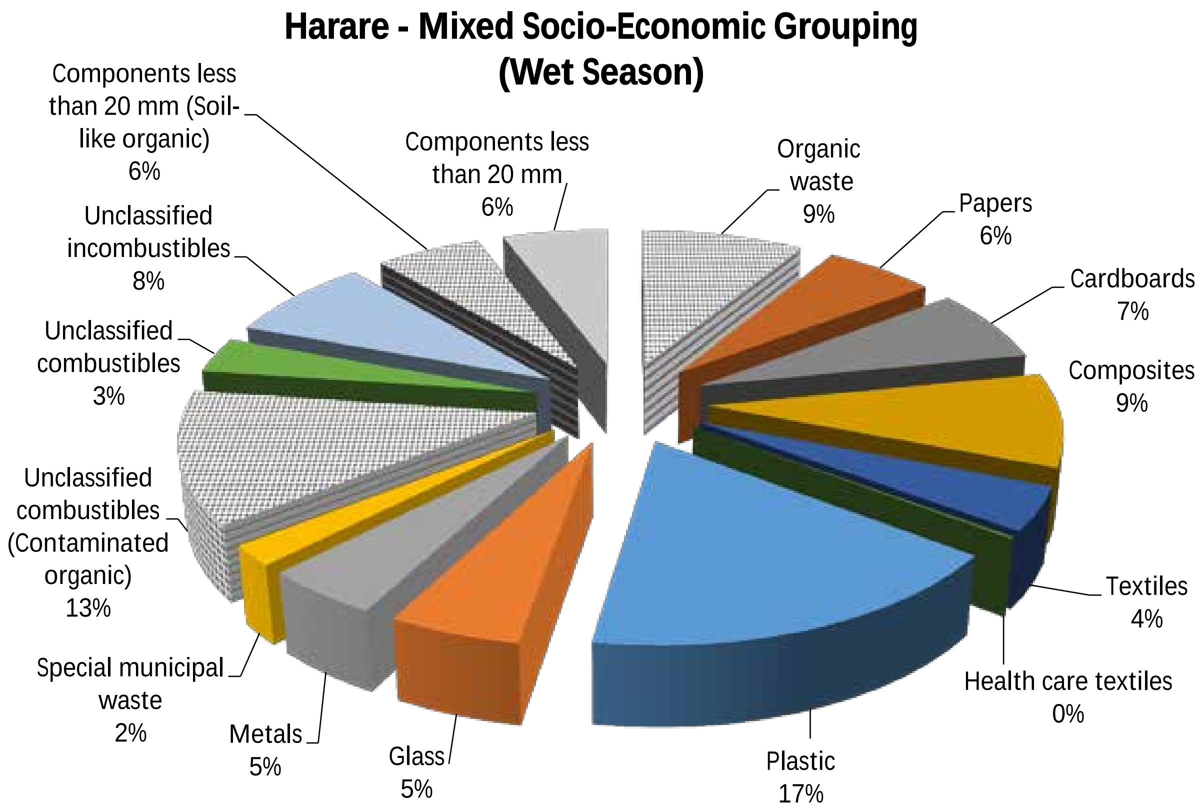


Figure 2: Seasonal variations in waste composition

Figure 3 shows the annual average waste composition of all cities studied across the wet and dry or summer and winter seasons.

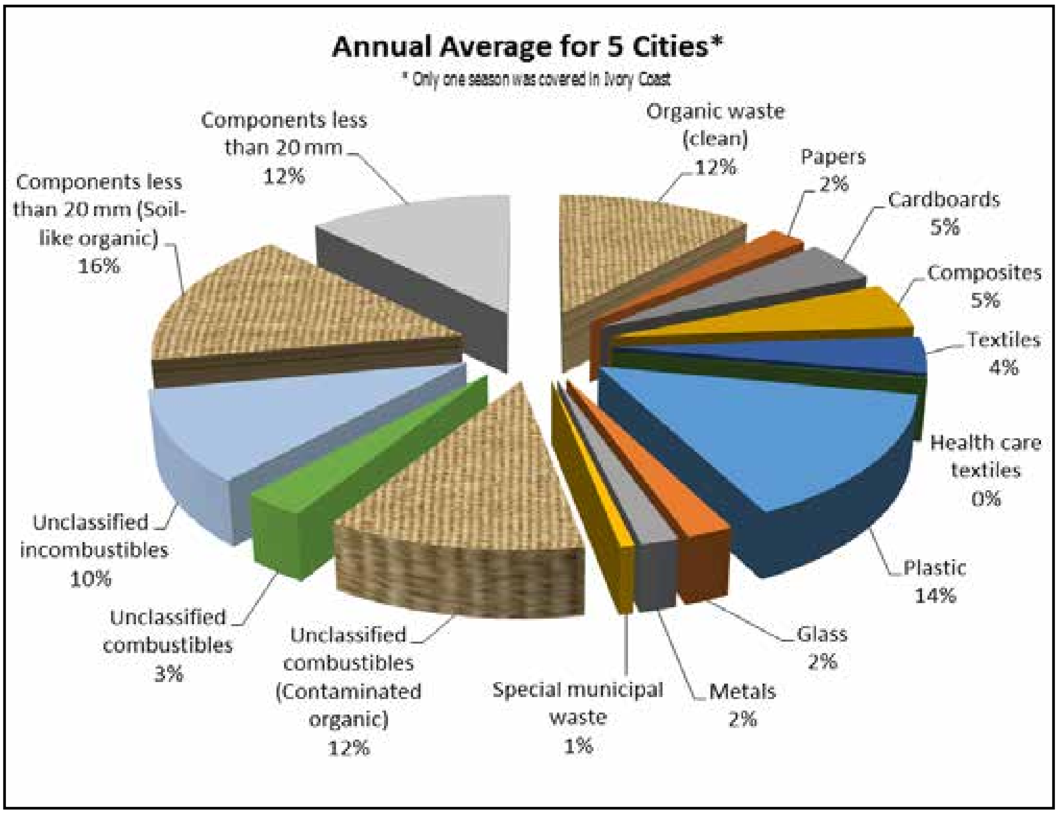


Figure 3: Waste composition breakdown for all five cities

Compared to earlier studies many of the typical “dry“-recyclables have decreased where plastics have increased, most probably because of plastic products replacing other conventional materials used as building materials or even packaging. In many cases e.g. wooden products (boards) are being replaced by plastic products. An opportunity therefore exists for the recycling of plastics which is happening in some way or the other. However mostly the “difficult” plastics remain in the waste stream to be recycled. It was quit noticeable that the PET products were not present in the waste streams – either separated at home level for reuse or exchanged for some form of deposit or trading. The thin film plastic along with HDPE products and mixed plastic made up the larger remaining plastic volumes.

The largest fraction in the waste stream was generally organic material, fractions less than 20mm (soil-like organics) and the unclassified (combustible or non-combustible). In the latter case combustibles were further broken down into contaminated organics.

Table 4: Most prominent fractions found in the waste streams.

Waste Material	Items and Sub Items	Average composition
Organic Waste (Clean)	Total Organic waste	15%
Composites	Total Composites	5%
Textiles	Total Textiles	4%
Plastic	*HDPE (2) Shopping bags, milk bottles, detergent bottles*	*2%*
	LDPE (4) Refuse Bags, Cling wrap, Squeeze Bottles	*8%*
	PP (5) Bottles, Ice cream tubs, Straws, CD cases	*2%*
	Other packaging (7) Computers, Electronics, Packaging	*1%*
	Total Plastic	15%
Unclassified Combustibles	Total Unclassified combustibles	3%
	Total Unclassified combustibles (Contaminated organic)	12%
Unclassified Incombustibles	Total Unclassified incombustibles	10%
COMPONENTS < 20 mm ROUND MESH	*Fine elements smaller than 20 mm round mesh*	*11%*
	Fine elements smaller than 8 mm	*17%*
	Total Components less than 20 mm (Soil-like organic)	16%
	Total Components less than 20 mm	12%

Table 5 shows an average summary of the parameters covering the annual seasonal cycles for the various communities.

Table 5: Average parameters inclusive of all the cities

Average Parameter	Nr
Packaging in waste stream	22%
General density of the waste (kg/m³)	372
Moisture content of the waste	18%[1]
Waste generation (kg/cap/d)	0,69
Waste generation (kg/hh/day)	4,19
People per household	5,9

[1] average qualitative figure irrespective of season and socio-economic standing

5. CONCLUSIONS AND RECOMMENDATIONS

Information obtained through this study was forwarded to the business development divisions of the Foundation. A clear understanding of the waste streams within the cities was obtained and a better appreciation of the issues relating to potential recycling projects as job opportunities especially in the poorer communities was gained.

It was clear, and follow international trends, that in order to do any meaningful recycling waste materials should be collected at the source primarily to eliminate any contamination of desired materials.

With distinct differences observed in the waste stream between seasons as well as religious events in all the cities cognisance has to be taken of this aspect when designing waste management systems. Although the city structure plans were in most cases very weak distinct difference in the waste streams were noticed between the defined low, middle and high income/density developments. Contrary to norms typically used when designing systems the middle income groupings in most cities showed the highest generations rates. This could be attributed to recyclable materials already removed from the waste stream prior to disposal. This aspect has to be borne in mind as part of waste stream assessment.

City structure planning has been neglected in most cities. It may become a serious problem for city planners as older cities appear to become intertwined due to non-availability of land resulting in dwellers ending up in any location irrespective of socio-economic status. This appears to be the case in Cairo, Abidjan, Sekondi and specifically Monrovia where no structure plan for the post-war restored city is in place. Harare however still appears to be operating on the basis of different socio-economic levels i.e. high, middle and low income areas. This aspect is important for future planning of many waste management systems based on waste volumes that are to be determined as well as the accessibility of collection vehicles within certain areas that would depend on town planning principles e.g. where narrow streets are planned for low income areas.

Assessment in various cities has also shown that it is possible to have a fully-fledged recycling industry in a city dependent on the waste stream such as in Cairo where 130 000 people are employed in a very successful plastic recycling industry.

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A copy of the full report can be obtained from the author via the above e-mail address.

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