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Appropriate approach in measuring waste generation, composition and density in developing areas

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The purpose of this paper is to

- ***critically review current waste generation, composition and density measurement methods***
- ***develop an appropriate measuring approach(es), and***
- ***determine the factors that affect waste generation, composition and density in developing areas***

The aim of developing an appropriate approach is to assist local authorities, waste managers and related interest groups towards accurate assessments and measurement of waste generated in developing areas in order to get the most appropriate and cost-effective waste management system.

This paper covers the importance of waste generation quantification and the shortcomings of current waste generation measuring techniques. Factors that affect waste generation, composition and density are assessed.

In this study, an innovative technique of measuring waste generation, composition and density, for denser and less dense waste was developed. Two hundred and eighty four samples from formal and informal households were subjected to detailed manual waste analysis and classification. Interviews were conducted from the sampled areas to get accurate demographic and related information.

It is concluded that current waste generation measurement techniques should be evaluated. A calibrated plastic bag for less dense waste and a bucket for measuring dense waste directly from sampled households are recommended. It is further concluded that waste generation, composition and density are not affected by income, occupation of the household's income earners, duration of stay and origin of migration. Furthermore, seasonal variations have no effect on waste generation, composition and density of solid waste in the study areas.

INTRODUCTION

Background

Rapid population growth in developing areas has resulted in informal settlements forming on the fringes of cities and a considerable increase in backyard shacks in formal areas. This growth has caused an increase in the amount of waste generated, littering and illegal dumping. Koushki and Al-Kaleeji (1998) noted that urban waste continues to accumulate, often at a rate faster than population growth, and attempts to dispose of this waste continue to ravage the environment.

Managing and rendering waste management services in developing countries is one of the most costly services as it takes up to 1 % of GNP and typically absorbs between 20 % and 40 % of municipal revenues (Habitat 1988; Schertenleib & Meyer 1992). This cost is despite the fact that in a 'typical' urban area of a developing country, the municipality collects only between 13 % and 70 % of waste generated and serves less than 50 % of the population (Meyer & Schertenleib 1992; WRC 1995).

While the problems of solid waste management in developing areas are well documented (Mbande 1998; Schertenleib & Meyer 1992; WRC 1995), information on waste generation, composition and density and how this can be acquired is sketchy. Yet, the operational framework of waste management stages, which encompasses generation, composition, storage, collection, transportation, recycling and disposal, revolves around the knowledge of waste generation and composition rates. With the exception of recycling, a failure of one stage results in the collapse or inadequate provision of the total waste management process.

This paper reports on the results of a research study on waste generation, composition and density measurement undertaken in developing urban areas of East London in the Eastern Cape Province of South Africa.

Research objectives

The specific objectives of this paper are to

- review current waste generation measurement methods and their shortcomings in developing areas
- develop appropriate waste generation, composition and density measurement methodology in developing areas
- explore the difference between waste generation and composition in formal and informal areas in developing areas
- measure how much solid waste is generated by an average household per week and average person per day
- establish the effect of income, occupation of income earners, urbanisation and interurban movement, the seasonal variations and the type of energy used by different households on waste generation, composition and density in developing areas

Importance of measuring waste generation quantities

Knowledge of the quantities and composition of waste generated is critical in the planning, design and implementation of waste management because it enables the local authority, waste contractor, or waste practitioner to determine the following:

- *The size and physical characteristics of primary and secondary storage requirements of waste from households, businesses and institutions:* For effective waste management, storage requirements have to conform to the requirements of both the municipality and the users. The municipality requires that its workers should be able to lift the container and load it onto the collection vehicle and that the waste conforms to the collection vehicle requirements. The user expects a container that meets aesthetic, handling and storage requirements. The physical characteristics refer to the ability of the container to withstand the weight and the volume characteristics of waste without tearing or reaching its strength capacity.
- *The capacity, size, number, speed limits, and the options to use compaction and/or non-compaction collection vehicles:* The acquisition, maintenance and operation of waste collection vehicles are the most expensive items within the municipal solid waste budget. It is critical that their acquisition be based on the most up-to-date and accurate information on waste generation and composition.
- *The required physical fitness of employed personnel:* According to Van Rensburg *et al* (1981) the physical demands of refuse collection are sufficiently high to generally exceed local and international restrictions prescribed to prevent the onset of fatigue over extended periods of work. Knowing the average weight of the bag or container would help in designing the physical employment selection criteria.
- *Costing policy:* The costing policy of waste according to the average weight and volume per socio-economic household grouping, institution, type and size of business or factory which could be measured as a unit could be determined.
- *The size and life span of transfer stations and disposal sites:* Accurate knowledge of quantities will reduce the risk of under/over design of transfer stations and disposal sites, resulting in cost savings.
- *The potential and level of recycling within the waste stream:* Recycling is a business venture that provides employment to many people. According to the Central Statistical Services (Living on junk 1993) South Africa's dumps provided an industry that contributed about R204,5 million to the GDP in 1990 and employed 163 700 people, enough to provide a monthly income of R104 to each waste picker (normally known as a scavenger).
- *Waste policy:* The database on waste generation, recycling and disposal provides valuable information in environmental and waste policy formulation for local, provincial and national government and for comparison with other nations.

Current methods used to estimate waste generation and composition in developing areas and their shortcomings

- *Weighbridge records and truck loads:* A weighbridge at the waste disposal site is used to log the mass of each truckload of waste that arrives at the disposal site. For developing areas, Flintoff (1984) reported that measurement of the total mass of waste delivered to a disposal site is seldom an accurate indication of waste generated. In South African urban developing residential areas, illegal dumping of waste on street corners and in open areas is common. Local authorities either ignore such dumping or develop a systematic illegal dump removal programme involving the use of mechanical front-end loaders. Soil and grass are also picked up in the process, resulting in an artificial increase in waste tonnage.
- *Volume estimates from collection vehicle surveys:* The volume is estimated from the container measurements of a collection vehicle. For compactor vehicles, Mayet (1993) highlights that this figure is multiplied by a conversion factor which is estimated to be three. For non-compacting vehicles, the loose volume is estimated. The total volume of each collection vehicle is multiplied by the number of trips to the disposal site per week. A total volume is then estimated from the sum of the volume of all vehicles. The shortcoming is that the transported volume is considered to have reached capacity when it arrives on site, irrespective of whether it is full or not, thereby causing skewed results.
- *Average unit generation rate:* Currently, average total waste generated is calculated by multiplying average waste generation per person per day (usually based on previous estimates from typical developing areas) with population numbers. This method is used because of the lack of local records on waste generation and the absence of appropriate methods for measuring waste generated. The literature gives a rate for higher weight per capita (kg/p/d), low density and negligible ash/dust content of waste for developed countries and a low weight per capita, high density and high ash/dust content rate for developing countries (eg Habitat 1988). This generalisation does not take into account that there are high-income communities in developing areas who generate waste that may be consistent with industrialised counties. Also, the rates are not accompanied by an analysis of how they have been calculated. In the light of serious shortcomings on waste measurement techniques, the data from the literature have to be used with caution.
- *Topographic surveys of disposal sites:* This involves capturing the contoured survey of the disposal site before disposal and after certain periods to check on the accumulated waste using contour levels. The disadvantage of this method is that the accumulated waste is never a reflection of the total amount of waste disposed due to systematic decomposition activities in the landfill. Furthermore, different types of waste decompose at different rates. Certain items, such as ash, hardly decompose making it difficult to monitor the decomposition progress.
- *Portable vehicle road monitor:* This is connected to a vehicle and measures the waste as it is loaded and transported. Gibbons *et al* (1994) noted that this needs specialised equipment, which would not be available in developing areas.
- *Counting refuse bags on site:* The waste generated could be estimated if every bag that arrives at the disposal site is counted. The flaws in this process are the same as those in weighbridge and volumetric measurements.

Lombard (1994) suggested that measuring waste generated through the current conventional means should be corroborated using different methods. Flintoff (1984) recommended that waste generated in developing areas should be measured at source.

DEFINING URBAN DEVELOPING AREAS IN SOUTH AFRICA

Formal housing and backyard shacks

Formal housing in South Africa's developing areas consists typically of two- or four-roomed houses associated with low- to middle-income groups. Some of these housing developments have grown from their original intention to encompass backyard dwellings either in the form of outbuildings or shacks. Frescura (1991) observed that owner-built shack backyard dwellings occur in high-, middle- and low-income areas in KwaNobuhle, Uitenhage, Eastern Cape. Sapire and Schlemmer (1990) in a Gauteng survey found that 86 % of all informal dwellings are situated in yards of formal houses in proclaimed black areas.

The existence of backyard shacks has a direct effect on waste generation by a community as more people per site generate more waste.

Informal housing areas

Hart (1992) categorised informal settlements in South Africa into site and service and free-standing or open field informal settlements. Hart defines informal settlement as housing that is established unconventionally.

- *Site and service:* The site and service concept was developed by Haarhof and Maasdorp in the 1970s as a measure to accommodate informal housing rather than try to prohibit people from settling (Haarhof 1991). Sites are designed according to the minimal standard of national building and health regulations. Basic services such as water, roads, sewage and waste management are provided. Hart (1992) notes that apart from delivering access to tenure, a number of site and service sites have remained indistinguishable from typical shack sites.
- *Free-standing or open field settlement:* The other type of informal settlement is known as the free-standing or open field settlement, which Hart (1992) defined as informal housing that is often produced outside the normal process of township establishment and constructed using a variety of unconventional shack materials. Sapire and Schlemmer (1990) noted that these settlements have regional variations and composition.

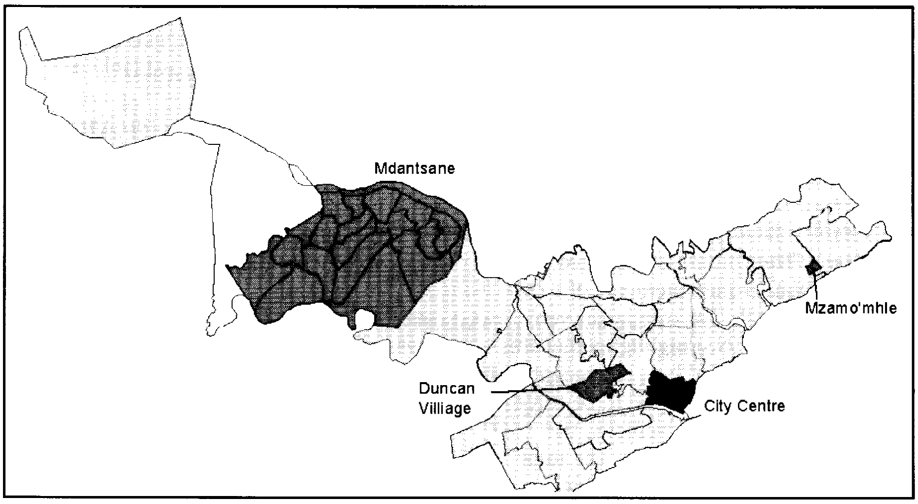
While there has been limited work done on waste generated in formal and informal areas (Blight & Mbande 1994), little is known of waste from each category and the methodology employed in gathering the current limited data.

RESEARCH METHODOLOGY

Background

The tabulations and analysis in this paper are based on a study conducted in three areas – the middle- and low-income formal settlements of Mdantsane, the site and service areas of Mzamomhle, and the informal free-standing areas of Duncan Village and Mdantsane in East London, Eastern Cape. The study involved a total sample of 284 households of which 184 were interviewed. The limitation of the research is the fact that 184 households instead of a recommended minimum of 200 (Lake 1987) were interviewed. However, the 8 % difference is neutralised by the following:

- The waste generation per stand is based on 284 samples; only the waste per person per day is based on 184.
- The survey was systematically spread over different households and subgroups, thus the heterogeneity of the population was captured.
- The study required only demographic information, thus avoiding asking opinions. Straightforward and understandable questions were asked, such as 'how many families stay in this stand'.
- The interviews were conducted on weekends and in the early evenings so that the head of the family could be interviewed in order to optimise accuracy.



Selection of sampling areas

A descriptive sample survey was conducted in Mdantsane zonal areas of 13, 16 and 17 formal areas representing very-low- to middle-income areas. The free-standing informal settlement areas were represented by Mahlangu in Zone 13, Zone 16 informal areas in Mdantsane and Duncan Village while Mzamomhle represented the site and service informal areas. In Duncan Village, the same households were assessed in summer and winter to determine seasonal variations. The areas were chosen because they had a monitored solid waste management system which ensured that households were using plastic bags and were not dumping waste illegally. The areas sampled as part of the study are shown in the map.

Community consultation

Various community structures were consulted about the waste generation and composition study and their support obtained. This support proved helpful during the survey as residents kept on referring back to the community structures.

Timing of sampling

The samples were collected over a period of one year, in October 1995, November 1995, March–April 1996 and July 1996.

Collection of samples and surveys

Fieldworkers especially trained for the study and who had done an exploratory study visited the targeted areas ahead of the collection truck on normal collection days. The fieldworkers would mark all the plastic bags from a given home, with area, street and house number immediately after the households had put out the bag(s).

To ensure the maximum distribution of samples, waste from every 25th formal stand and every 10th informal stand (shack) was marked. All the bags from given households were then loaded on a transporter for analysis.

All this happened without the knowledge of the households, as knowledge of waste generation measurement might result in household interference to ensure a 'cleaner' waste (Mbande 1998). The samples were taken to the disposal site, weighed, measured and analysed.

Finally, a field survey was conducted on households whose bags had been measured. The field survey involved collecting and recording demographic information on a questionnaire by means of house-to-house interviews.

The demographic information on the

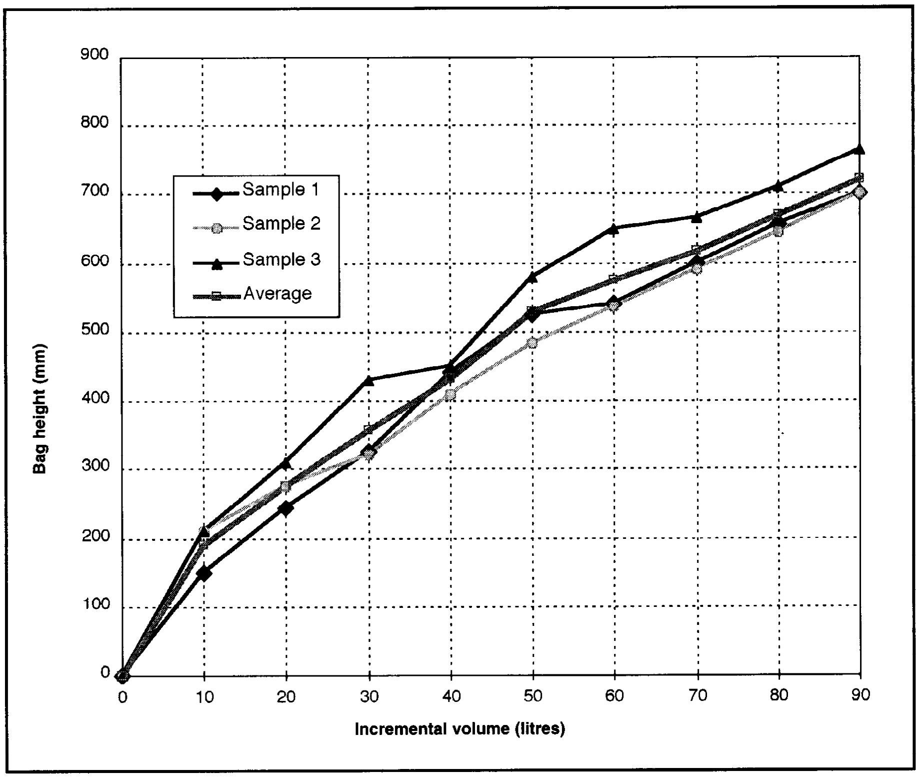


Figure 1 Domestic waste bag calibration (C Mbande)

questionnaire included finding out the overall income of the household, occupation of the major income earners, rural to urban and interurban movements, seasonal variations and the type of stove or energy the household used.

In commercial areas, such as township shops and in the central business districts, a number of plastic bags were given and collected and measured weekly for a period of three months. Volumes of on-site storage facilities were measured and frequency of collections monitored in certain businesses in central business districts.

Sorting and measurement

Volume measurements using a 10 ℓ bucket

A 10 ℓ bucket, 85 ℓ plastic bag, 3 m tape calibrated in mm, 10 hand gloves and a battery-operated electronic scale calibrated in divisions of 50 g were provided. A crew of trained fieldworkers undertook sorting and measurement as follows:

After samples of waste from selected areas were delivered to the sorting area in marked plastic bags, the volumes of the bags were measured using the 10 ℓ bucket. Waste was then hand-sorted according to local market experience on recyclables and literature.

After repeated measurements, the process of measuring volume using the 10 ℓ bucket became cumbersome and a volume measurement using the calibrated plastic bag method was developed in its place.

Volume measurements using the calibrated plastic bag method

A method of measuring the volume of each bag faster and with better accuracy was developed by calibrating the plastic bag with waste as follows:

- Two workers held an unused 85 ℓ plastic bag vertically with mouth opened facing upwards from which the length was measured.
- The 10 ℓ bucket was filled with the mixed waste and tipped into the plastic bag with the two workers shaking and rocking the bag to allow the waste to settle, after which a 3 m tape was used to measure the level of waste from the average tip of the waste to the average tip of the lip of the plastic bag.
- The average of the four corners was taken for each successive reading.
- Each reading was then subtracted from the height of the plastic bag to get the average waste level.
- This procedure was repeated until the bag was full.

The graph of incremental volume (litres) vs averaged height from the base of the 85 ℓ domestic waste bag used is shown in figure 1.

As the domestic waste was tipped into the plastic bag from the 10 ℓ bucket, the following happened in the bag (figure 1):

- *0 to 10 ℓ:* The first 10 ℓ of waste occupies mainly the pleated bottom areas of the plastic bag. The waste at this level does not visibly affect the elasticity of the domestic waste bag because of the low density and weight.
- *10 to 20 ℓ:* At this range the weight of the waste starts to have a visible effect on the elasticity of the bag. This is shown by the curve that defines the response of the bag in adjusting to the pressure of the waste.
- *20 to 85 ℓ:* The curved shape indicates that as the waste is loaded beyond the 10 ℓ volume, waste starts to settle due to gravity. The rocking of the bags on site reciprocated the action of the householder, who pushes waste into bags exerting limited pressure to ensure that the bag does not tear in the process.

Loading the plastic bag was stopped at 85 ℓ corresponding to an average reduced height of 722 mm out of the total bag height of 900 mm. The bag height had reduced due to lateral expansion. This is because loading the plastic bag to this level was considered not necessary as the baseline data had been established. Secondly, the average household would not load the bag to this level, as it would be difficult to close.

This calibration was used to get the total volume of refuse in bags that were analysed by measuring the height from the tip of the waste to the tip of the bag and subtracting from 900 mm to get the total waste height. From each bag measured it was then easy to measure the height above the domestic waste. Figure 1 was then used to get the average volume of each bag from the household.

The study showed that the volume of household waste in a primary storage bag can be measured using either the bucket system or the calibrated plastic bag graph as in figure 1. The results from both methods are almost the same with a statistical correlation factor of 0,95. Measuring waste using the calibration method is faster and more accurate but limited to waste that can be stored using a plastic bag. A similar curve could be defined for any standard bin or bag. The bucket system use is slower, but could be used for both dense and less dense waste. Dense waste is defined as waste that would tear a plastic bag before it reaches its full capacity.

SURVEY RESULTS

Household waste generation and composition

Effect of household waste generation and composition on different settlements

The study showed that there is no difference in waste generation, composition and density between the formal and the open settlement. The site and service house-

Table 1 Comparative analysis of waste generation, composition and density

Category	RSA low income (formal areas) East London, 1997	RSA low income (open field shacks) East London, 1997	RSA low income (site and service) East London, 1997	RSA high income East Rand, Gibbons *et al*,* 1992	RSA low income East Rand, Gibbons *et al*,* 1992	Low-income countries Cointreau,* 1982	Medium-income countries Cointreau,* 1982	High-income countries Cointreau,* 1982
Sample size	152	83	28	N/A	N/A	N/A	N/A	N/A
Organic	38	38	45	32	4.6	40 to 90	20 to 65	20 to 50
Paper	32	32	27	37	3,4	1 to 10	15 to 40	15 to 40
Glass	6	1	2	4	2	1 to 10	1 to 10	4 to 10
Plastics	13	15	17	17	2,4	1 to 5	2 to 6	2 to 10
Metals	5	4	1	6	1,6	1 to 5	1 to 5	3 to 13
Textiles	5	3	6	in other	in other	in other	in other	in other
Ash / dust	1	2	1	0	82	N/A	N/A	N/A
Other	0	0	0	6	2,4	3 to 50	3 to 40	3 to 40
Average people/household	5,2	3,6	4,12	N/A	N/A	N/A	N/A	N/A
Waste/household/week (kg/week)	4,18	3,3	8,62+	N/A	N/A	N/A	N/A	N/A
Waste/person/day (kg/person/day)	0,12	0,19	0,39+	1,24	0,33	0,4 to 0,6	0,5 to 0,9	0,7 to 1,8
Bulk density (kg/cu m)	105	94	195+	N/A	268	250 to 500	170 to 330	100 to 170
Conditions during analysis	Dry	Dry	Wet+	N/A	N/A	N/A	N/A	N/A

* Cointreau and Gibbons quoted by Water Research Commission (WRC) (1994).
+ The higher amount of waste is due to the ingress of water during the analysis.
Other – includes textiles, leather, rubber and miscellaneous inserts

Table 2 Effect of income on household waste generation

Income	Formal areas				Open-standing areas				Site and service areas**			
	S	*kg/s/w*	*kg/p/d*	*kg/m³*	*S*	*kg/s/w*	*kg/p/d*	*kg/m³*	*S*	*kg/s/w*	*kg/p/d*	*kg/m³*
R0–R99	3	3,12	0,11	95	21	4,29	0,24	94	5	7,46	0,51	225
R100–R199	5	3,56	0,11	111	12	4,07	0,24	111	5	7,91	0,34	194
R200–R299	2	6,50	0,13	164	7	2,34	0,14	54	5	5,96	0,27	175
R300–R399	8	4.37	0,13	125	16	2,46	0,18	143	5	10,73	0,42	204
R400–R499	3	5,38	0,05	111	13	2,64	0,10	52	2	6,90	0,13	180
R500–R599	5	3,42	0,11	76	1	5,60	0,40	119	1	13,65	0,49	152
R600–R999	27	4,17	0,11	108	5	3,09	0,24	74	3	10,88	0,57	185
R1 000–R2 000	21	4,33	0,15	108	3	2,58	0,10	56	1	8,60	0,30	191
R2 000–R4 000	4	3,56	0,17	99	0				0			
R4 000 PLUS	0				0				1	12,50*	0,36	208
Sample size	78				78				28			

S – Sample size; kg/s/w – mass in kg per stand per week; kg/p/day – mass in kg per person per day; kg/m³ – density
Income – combined income per stand per month; * spaza shop; ** wet waste

holds could not be compared as the waste was wet. Results are shown in table 1.

The waste categories from table 1 are discussed as follows:

- *Organic matter or food waste (38–45 %):* Consisted largely of cuttings resulting from the handling, preparation, cooking and residue of foods. No garden refuse was found, although the local authority did not render a garden service at the time. The high percentage value can be attributed to the absence of the heavier ash.
- *Paper (27–32 %):* Consisted of a larger amount of packaging material and a lesser amount of newspapers and magazines. The high percentage of paper is also due the absence of ash. In informal areas, it was discovered during the analysis that some paper contains human waste. This can be explained as follows:
  - There is no sanitation within the immediate vicinity. With some relieving areas (dongas/bushes) dirty with human waste and /or residents afraid of venturing out at night due to crime, residents use plastic bags and newspapers as temporary relieving containers (especially for children) and dispose of this as solid waste.
  - Even if there are communal toilets, for high-density informal areas, such toilets become full/dirty/unusable and water-borne sewerage toilets are usually blocked.
- *Glass (1–6 %):* Consisted of empty bottles from food beverages, empty beer bottles and broken household cups. The low percentage is consistent with estimates from developing areas.
- *Metals (1–6 %):* Consisted largely of non-beverage cans. The percentage range is consistent with averages for low-income countries.
- *Textiles (3–6 %):* Consisted of old and used cloth. No comparable textile category comparison could be found.
- *Ash/dust (1–2 %):* Consisted of dust from house floor sweepings. No ash was found in the waste. The difference between East London and the East Rand is that the East Rand has access to cheap coal and East London does not. There is a correlation between the ash content and paper and, to a lesser extent, plastic. The higher the ash, the lower the paper and plastic content and vice versa. This could be attributed to the source of energy used. In areas where a fire is made for energy-related activities, paper and plastics are used to light fires. Any excess paper and plastic is also burnt in the process.
- *Plastic (13–17 %):* Consisted of food, drink and detergent cartons. The high percentage is also due to the low

Table 3 Effect of income on waste composition

Income	Category	Organics	Paper	Glass	Metals	Textiles	Ash/dust	Bones	Plastics
1 R0–R99	FA	14 %	58 %	1 %	1 %	16 %	0 %	0 %	10 %
	OA	33 %	38 %	0 %	5 %	2 %	0 %	0 %	19 %
	SS	50 %	19 %	3 %	1 %	5 %	0 %	0 %	23 %
2 R100–R199	FA	37 %	33 %	7 %	2 %	6 %	0 %	0 %	15 %
	OA	41 %	26 %	6 %	1 %	6 %	4 %	0 %	17 %
	SS	55 %	32 %	0 %	2 %	6 %	0 %	0 %	6 %
3 R200–R299	FA	47 %	31 %	4 %	4 %	6 %	0 %	0 %	7 %
	OA	23 %	28 %	1 %	4 %	1 %	5 %	0 %	9 %
	SS	29 %	24 %	4 %	1 %	3 %	0 %	0 %	38 %
4 R300–R399	FA	42 %	26 %	5 %	8 %	9 %	0 %	0 %	9 %
	OA	56 %	25 %	0 %	1 %	0 %	4 %	1 %	11 %
	SS	49 %	19 %	5 %	1 %	13 %	0 %	0 %	14 %
5 R400–R499	FA	48 %	18 %	5 %	17 %	0 %	0 %	0 %	13 %
	OA	34 %	31 %	0 %	3 %	3 %	1 %	0 %	19 %
	SS	26 %	45 %	2 %	1 %	4 %	11 %	0 %	11 %
6 R500–R599	FA	28 %	42 %	4 %	9 %	8 %	0 %	0 %	8 %
	OA	51 %	15 %	4 %	25 %	0 %	0 %	0 %	4 %
	SS	31 %	49 %	0 %	5 %	0 %	0 %	0 %	16 %
7 R600–R999	FA	36 %	32 %	6 %	5 %	4 %	2 %	0 %	16 %
	OA	28 %	44 %	3 %	9 %	9 %	0 %	0 %	7 %
	SS	44 %	37 %	0 %	1 %	8 %	0 %	0 %	11 %
8 R1 000–R2 000	FA	42 %	30 %	5 %	5 %	3 %	0 %	0 %	14 %
	OA	34 %	55 %	0 %	3 %	0 %	0 %	0 %	8 %
	SS	83 %	14 %	0 %	0 %	2 %	0 %	0 %	1 %

Table 4 Effect of income earner occupation on waste generation

Occupation	Formal areas				Open-standing areas				Site and service areas*			
	S	*kg/s/w*	*kg/p/d*	*kg/m³*	*S*	*kg/s/w*	*kg/p/d*	*kg/m³*	*S*	*kg/s/w*	*kg/p/d*	*kg/m³*
Hawkers/informal selling	6	5,06	0,11	125	24	3,31	0,21	126	7	10,01	0,39	179
Labourers	33	4,53	0,12	114	28	3,27	0,20	84	17	8,17	0,36	190
Pensioners	11	3,79	0,12	96	11	3,33	0,16	69	2	6,70	0,18	194
Professionals	25	3,81	0,13	104	0	0,00	0,00	0	0	0,00	0,00	0
Unemployed	3	3,12	0,11	95	15	3,47	0,17	76	2	9,55	0,81	296
Total sample	78				78				28			

S – sample size; kg/s/w – kg per stand per week; kg/p/day – kg per person per day; kg/m³ – density; *wet waste

Table 5 Effect of occupation of household income earners on waste composition

Category	Hawkers			Labourer			Pensioners			Prof	Unemployed		
	FA	OA	SS	FA	OA	SS	FA	OA	SS	FA	FA	OA	SS
Organic %	26 %	43 %	53 %	33 %	37 %	42 %	33 %	41 %	37 %	52 %	14 %	30 %	53 %
Paper %	34 %	33 %	33 %	36 %	27 %	25 %	25 %	34 %	32 %	27 %	58 %	41 %	17 %
Glass %	8 %	0 %	1 %	3 %	3 %	2 %	12 %	0 %	0 %	6 %	1 %	1 %	6 %
Metals %	14 %	1 %	1 %	6 %	3 %	2 %	7 %	5 %	0 %	3 %	1 %	8 %	0 %
Textiles %	3 %	1 %	1 %	4 %	6 %	7 %	13 %	2 %	9 %	1 %	16 %	1 %	12 %
Ash/dust %	0 %	2 %	0 %	2 %	2 %	0 %	0 %	0 %	11 %	0 %	0 %	3 %	0 %
Bones %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	1 %	0 %	0 %	0 %	0 %	0 %
Plastics %	15 %	14 %	11 %	16 %	12 %	22 %	11 %	16 %	11 %	11 %	10 %	21 %	11 %

FA – formal areas; OA – open areas, SS – site and service

weight per household and the absence of ash.

The reason for waste generated per household per week being slightly more in formal areas than informal areas, while waste per person per day is less in formal areas, can be attributed to the difference in the number of people per household. The higher the number of people per household, the higher the amount of waste generated.

The waste generation rate per day and density in formal and informal areas is consistent with waste generation and density analysis conducted in KwaZulu-Natal which found a kg/family/week of 4,37 and 10,2 and a density of 143 and 160 kg/m³ for KwaDabeka and Claremont respectively (Lombard 1994). The low average waste per capita per day is consistent with developing areas.

Effect of income on waste generation and composition

The effect of the combined household income per month is shown in table 2.

Table 2 indicates that income did not have an effect on waste generation in the study areas and that there was no major differences in waste generated between formal and informal areas. This is in contrast with the fact that the higher waste generated is consistent with high income and low waste generated with low income (Blight & Mbande 1994).

The combined effect of income on waste composition is shown in table 3. As can be seen in the table, income does not have effect on waste composition in the study areas.

The household subsistence level (HSL) – which is defined by the Institute of Planning Research (IPR) (1997) as an estimate of the theoretical income needed by an individual if he or she is to maintain a defined minimum level of health and decency in the short term – was

Table 6 Effect of urbanisation and interurban movement on waste generation (kg/p/day)

Duration of stay	Households coming from rural areas from						Households coming from urban areas from					
	East London		Eastern Cape		Other areas		East London		Eastern Cape		Other urban areas	
	S	*kg/p/d*	*S*	*kg/p/d*	*S*	*kg/p/d*	*S*	*kg/p/d*	*S*	*kg/p/d*	*S*	*kg/p/d*
0–6 months	0	0,00	0	0,00	1	0,08	1	0,06	0	0,00	0	0,00
6–12 months	1	0,44	0	0,00	0	0,00	2	0,14	0	0,00	0	0,00
1–2 years	0	0,00	0	0,00	0	0,00	4	0,26	0	0,00	0	0,00
2–3 years	3	0,12	4	0,13	0	0,00	10	0,21	5	0,17	2	0,17
3–4 years	1	0,20	0	0,00	0	0,00	8	0,20	9	0,37	1	0,15
4–5 years	7	0,16	4	0,11	1	0,04	8	0,14	11	0,13	0	0,00
5–10 years	9	0,13	4	0,08	0	0,00	2	0,07	14	0,09	0	0,00
10–15 years	10	0,13	2	0,20	1	0,14	5	0,10	6	0,24	1	0,04
15–20 years	5	0,09	1	0,03	2	0,05	0	0,00	3	0,35	0	0,00
>20 years	0	0,00	1	0,12	0	0,00	1	0,02	6	0,08	0	0,00
Total	**36**	**0,00**	**16**	**0,00**	**5**	**1,00**	**41**	**1,00**	**54**	**0,00**	**4**	**0,00**

NB – Only samples from formal and open areas were used as the site and service sample would taint the waste, as it was wet.
S – sample; kg/p/d – kg/person/day

Table 7 Effect of the type of energy used on waste generation and composition

Category	Electric stove		Paraffin stove		
	FA	SS	FA	OA	SS
Organic %	40 %	39 %	29 %	38 %	48 %
Paper %	32 %	25 %	34 %	32 %	27 %
Glass %	6 %	0 %	4 %	1 %	3 %
Metals %	6 %	2 %	4 %	4 %	1 %
Textiles %	3 %	11 %	12 %	3 %	4 %
Ash/dust %	0 %	0 %	2 %	2 %	1 %
Bones %	0 %	0 %	0 %	0 %	0 %
Plastics %	12 %	22 %	16 %	15 %	16 %
Kg/p/day	0,13	0,35	0,09	0,19	0,40
Kg/f/w	4,34	10,68	3,60	3,30	7,94
Kg/m^3	117	219	78	94	187
Sample	61	7	17	78	21

FA – formal areas; OA - open areas; SS - site and service areas, kg/p/d – kg/per person per day; kg/s/w – kg per family per week; kg/m^3 – density

Table 8 Effect of seasonal variation on waste generation and composition in open areas of Duncan Village

Category	Summer	Winter	Comments
Sample (no)	**25**	**18**	
Organic %	40	59	Summer consistent with the study area, winter consistent with developing areas
Paper %	34	23	Summer consistent with the study area, winter low, but still within the study area range
Glass %	5	0	Within the study range
Metal %	4	1	Within the study range
Plastic %	14	12	Within the study range
Bones %	0	1	Within the study range
Ash/dust %	0	5	Within the study range, winter due to the average low mass
Textiles %	3	0	Within the study range
Kg/p/d	0,15	0,17	Within the study range
kg/site/w	3,18	2,42	Within the study range, low mass due to less people
Kg/m^3	60	119	Low density is consistent with the study area

R1 100,82 for a family of five in East London. Only about 32 % of formal, 10 % of open standing and 14 % of site and service households are above the 1997 HSL extrapolated as R1 144,85, R795,59 and R907,08 respectively. Yet there is no difference in waste generation and composition with households that are below the HSL. The reasons for income not having an effect on waste generation and composition is that the living habits are the same throughout the income spectrum in the study area and that the different settlements and income groups use the same energy for cooking and general heating.

Effect of occupation on waste generation and composition

The study showed that the occupation of the income earners does not have an effect on waste generation and composition as shown in tables 4 and 5.

The reason for the same quantity and composition of waste is that the lifestyles are the same.

Effect of duration of stay and origin of migrant on waste generation

The objective for measuring the impact of the duration of stay and the current and the previous place of stay on waste composition is based on the assumption that, if a resident had moved from an area that utilised different cooking methods or used certain food that differed from local food, such trends would be detected. The results showed that the previous place of stay, whether rural or urban, does not have an effect on waste generation and composition, as shown in table 6.

The study showed that there is no difference in waste generated because of the period of stay in the current place. The reason for the lack of difference might be due to the following:

- People moving from other areas quickly adapt to the local way of life.
- The absence of resources they utilised in their previous place of stay force them to use local resources.
- They had the same lifestyle as their current one in the place they stayed before.

Effect of the type of energy on waste generation

The survey, which gave possible energy sources as wood, coal, electric and gas/paraffin stoves, found that only paraffin and electric stoves are used in the study areas. Such heating mechanisms do not have any effect on waste generation and composition, as shown in table 7.

A visit to some households during cold days revealed that some have paraffin heaters, while others put a piece of

Table 9 Consolidated results from the survey of institutional and commercial areas

Category per unit per week	Mass (kg)	Volume (m^3)	Density (kg/m^3)**
Schools (8 bags) – largely paper	40	0,64	63
Commercial/corner shops* (10 bags)	60	0,80	75
Community halls (2 bags)	8	0,16	50
Administrative buildings (3 bags)	15	0,24	63
Crèches (5 bags)	25	0,40	63
Parks (6 bags)	20	0,48	42

* Corner shops are typical fish and chips shops.

** This compares with the loose density of 66 kg/m3 measured from Sappi trucks that arrive at the depot, separately carrying paper and cardboard. The moisture content for both the institutional/commercial areas using visual and feeling measurement is assumed to be at an acceptable dry optimum 18 % level (Sappi 2003).

corrugated iron sheet over a flame stove to warm their houses or shacks.

Effect of seasonal variations on waste generation and composition

The study indicated that the change in season does not have any effect on waste generation and composition in the open areas, as shown in table 8.

Estimated waste generation for institutional and commercial areas

The average results from the commercial and institutional waste monitoring in the study areas per seven-day week are outlined in table 9.

The low densities in table 9 are due to the fact that the composition of waste is largely packaging material such as cardboard, paper and plastics.

The overall estimated waste generation for Mdantsane, Duncan Village informal areas and Mzamomhle site and services are estimated from table 9 data and the demographic information as derived from the Presidential Task Team (1996). The estimated total is outlined in table 10.

The combined 1996 formal and informal waste generation per week for Mdantsane is about 216 tons per week. Weighbridge waste measurements (Mbande 1998) over a five-day period conducted in 1993 showed that an average of about 20 tons per day is generated in Mdantsane. This translates to a total of 140 tons for a seven-day week, which if projected at 2,5 % annual population growth (Presidential Task Team 1996) would be 177 tons per week by 1996. This would mean an estimated overall loss of about 18 % of total waste, meaning that more than 80 % of Mdantsane waste reaches the disposal site. There were no comparative references for waste generated in Duncan Village and Mzamomhle.

CONCLUSIONS

It is concluded that:

- Current waste generation measuring techniques have to be treated with caution when used in developing areas.
- Measuring waste generated from residential areas from a landfill is unlikely to be accurate due to various losses during the waste management process. Accurate residential waste generation data can be acquired directly from the household if measures have been taken to ensure that households do not dispose of their waste illegally.
- Residential waste generated could be measured to obtain volumes from the source using the calibrated plastic bag for less dense waste and the bucket for denser waste.
- Developing areas of South Africa consist of formal and informal areas. Informal areas are divided into open standing and site and service. There was no difference in the amount of waste generated per capita per day and its composition between formal, open standing and site and service

Table 10 Estimates of current waste quantities

Category	Mdantsane		Duncan Village	Mzamomhle
	Formal	Informal	Informal	Site and service
Population (no)	**158 000**	**40 800**	**75 500**	**7500**
Mass (kg/ca/day)	0,12	0,19	0,19	0,32
Total mass (kg/week)	132 720	54 264	100 415	16 800
Total mass (kg/year)	6 901 440	2 821 728	5 221 580	873 600
Schools and crèches (no)	**152**	**0**	**6**	**2**
Mass (kg/week/unit)	40	0	40	40
Total mass (kg/year)	316 160	0	12 480	4 160
Commercial (no)	**143**	**0**	**11**	**2**
Mass (kg/week/unit)	60	0	60	60
Total mass (kg/year)	446 160	0	660	120
Office buildings and halls (no)	**31**	**0**	**3**	**2**
Mass (kg/week/unit)	15	0	15	15
Total mass (kg/year)	24 180	0	2 340	1 560
Parks and open spaces (no)	**208**	**0**	**5**	**3**
Mass (kg/week/unit)	20	0	20	20
Total mass (kg/year)	216 320	0	5 200	3 120
Central business district				
Mass (kg/week/unit)	9 570	0	1 650	1 320
Total mass (kg/year)	497 640	0	85 800	68 640
Summary (total kg/category/ year)				
Residential	6 901 440	2 821 728	5 221 580	873 600
Schools and crèches	316160	0	12 480	4 160
Commercial	446 160	0	660	120
Office buildings and halls	24 180	0	0	0
Parks and open spaces	216 320	0	5 200	3 120
Central business district	497 640	0	85 800	68 640
Total tons/year	**8 402**	**2 822**	**5 326**	**950**
Total tons/week	**162**	**54**	**102**	**18**
Average kg/ca/d	**0,15**	**0,19**	**0,19**	**0,35**

settlements in the study areas.

- Average residential waste composition for formal, open-standing areas and site and service composition is organic (39 %), paper (31 %), glass (3 %), metals (4 %), textiles (4 %), ash dust (1 %) and plastic (15 %). Organic and paper in the study area are consistent with developed areas. The low amount of ash is due to the fact that communities in the study area use non-ash generating energy such as paraffin.
- There is a correlation between the ash content and paper and, to a lesser extent, plastic. The higher the ash, the lower the paper and plastic content and vice versa.
- The study showed that the increase in the number of people per household increases the waste generated.
- The income, occupation of income-earners, urbanisation, availability or non-availability of sanitation, the use of non-residue generating energy did not affect the waste generation, composition and density in the study area.
- The residential waste per person per day (kg/ca/day) and total waste per person per day which is based and derived from individual households and from a combination of all waste such as commercial, residential, must be mentioned as such in reporting waste generation figures.
- The residential waste generated by formal households, open standing households and site and service households in the study areas was 0,12, 0,19 and 0,39 kg/person/day with corresponding bulk densities of 109, 94 and 195 kg/m^3 respectively. The low density value from the first two household types was consistent with developing areas. The third value needs to be used with caution since it was collected under wet conditions. Care should also be taken in using these values in areas where solid fuel is used as an energy source.
- The total waste generated by formal households, open-standing households and site and service households in the study area expressed as a total waste per person per day (kg/p/d) was 0,15, 0,19 and 0,39 respectively as opposed to 0,12, 0,19 and 0,35 for the residential waste per capita per day.
- In the light of the study, data that has been acquired using conventional waste generation methods needs to be reviewed. There is a need to define the methods of acquiring data when rates of waste generation, composition and density are reported.

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