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Factors influencing solid waste generation and composition in urban areas of Tanzania: The case of Dar-es -Salaam

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Abstract: Solid waste characterisation study was carried in Dar-es-Salaam to quantify the waste generation rates and composition. By studying solid waste generation trends for three socioeconomic statuses, it was found that the solid per capita generation rate decreases with decreasing socioeconomic status. Solid waste compositions also exhibited variations due to socioeconomic status. It was also found that solid waste generation and population and GDP growth are positively correlated. Furthermore, a comparison of the results with data from previous studies and data from other urban centres in East Africa indicated that solid waste composition in Dar-es-Salaam has been changing over time. This article presents the findings and elucidates factors influencing solid waste generation and composition.

Keywords: Population Growth, GDP Growth, Solid Waste Generation and Composition, Socioeconomic Status, Dar-es-Salaam

1. Introduction

Organised solid waste management practices were first implemented in the ancient city of Mahenjo-Daro in the Indus Valley by 2000 BC [1]. According to [2], by 500 BC, the Greeks had both issued a decree banning waste disposal in the streets and setup the first Western-type ‘municipal dumps’ while the Chinese had ‘disposal police’ to enforce disposal laws by 200 BC. The primary purpose for solid waste management strategies is to address the health, environmental aesthetic, land use, resource, and economic concerns associated with improper solid waste management [3-5]. In the modern world, quantification and characterisation are the most important ingredients of any sound solid waste management system. Thorough knowledge of the characteristics of the solid waste is as important as knowing the quantities generated. Solid waste management systems usually handle large quantities of solid waste and it is therefore important to have detailed information on

quantification and characterisation for proper handling at different stages of the system [6]. In their review paper, [6] contend that “... there should be reliable information on solid waste quantification and characterisation, which is the prime requirement of the system”. It is after having a clear picture on the anticipated amount and nature of solid waste to be generated, marshalling of the resources (financial, human, equipment and technologies) in managing the waste can be done. Characterisation provides data on the type of waste generated and thus determines the methods and techniques for disposing them. Furthermore, with data on the type of solid waste, various management options can be explored. For example, investment in recycling, reuse, composting, and energy generation could reduce the amount of waste that the authorities have to dispose off and at the same time creating employment.

A number of researches on characterisation and

quantification have been done worldwide for the purpose of understanding composition of solid waste. Examples include the works of [6-18]. Specific studies on Dar-es-Salaam solid waste management system and characterisation have been carried out by [19- 22].

Furthermore, [6] point out that it is necessary to have detailed information on quantification and characterisation of solid waste for proper handling of solid waste at different levels of the solid waste management system. Thus any proper solid waste management system should inevitably take into consideration the type of waste generated. It is the type and not the quantity that determines the methods and techniques of disposing solid waste. This view is shared by [23] who contend that the type of decision making that leads to adequate solid waste management should be based on sound understanding of composition. Furthermore, [13] noted that characterisation of solid waste generation is fundamental for adequate decision making for a solid waste strategy in a city. It thus clear that without thorough knowledge of the composition, the solid waste is bound to be improperly disposed. In regard to this [8] noted that "... characterisation of solid waste streams and the estimation of solid waste generation rates are critical data required to propose any sustainable and viable alternative solutions to municipal solid waste management".

Although solid waste management is an important environmental challenge the world over, the problem is bigger in the developing world [24-29] where the waste produced by burgeoning cities is overwhelming local authorities and national governments alike [30-31]. Institutional weaknesses, lack of financial resources, improper choice of technology and public apathy [19, 28, 31-32] are normally cited as major setbacks to proper solid waste management. Rapid urbanisation [6, 21 and 33] is also said to compound the problem. In developed countries there exist data from long term characterisation studies and monitoring solid waste streams both at the local and national level [15]. However, such data are virtually inexistent in developing world. An example is the African Development Bank report [25]. Governments on the national and local level in countries with less developed economies generally do not have funding for performing such expensive studies like the monitoring of the solid waste stream [15]. If any, the funds are usually from foreign donors or nongovernmental organisations and are usually scarce and limited in scope. However, [15] suggest that periodic short-term (1-2 weeks) studies could be a possible solution in the absence of comprehensive scientifically valid data needed to develop an efficient solid waste management system. Such studies do not require significant resources or funding. Implicitly, it means developing countries can carry out such studies within the confines of their budgets and available resources. In this paper, we identify and elucidate the factors influencing solid waste generation and composition in the three municipalities (Kinondoni, Ilala and Temeke) of Dar es Salam and compare the results with previous researches and data from other East African countries.

1.1. Description of the Research Area

The Dar-es-Salaam city (Figure 1) is located between latitudes 6.36 degrees and 7.0 degrees to the south of Equator and longitudes 39.0 and 33.33 to the east of Greenwich. It is bounded by the Indian Ocean on the east and by the Coast Region on the other sides. Administratively, the city of Dar-es-Salaam is divided into three municipalities of Kinondoni, Ilala and Temeke made up by 73 wards and inhabiting nearly ten percent of the total population of Tanzania (4,364,541 out of 44,928,923) according to the 2012 population census.

It is generally hot and humid throughout the year with an average temperature of 29°C. The hottest season is from October to March during which temperatures can rise up to 35°C. It is relatively cool between May and August, with temperature around 25°C. Humidity is around 96% in the morning and 67% in the afternoon. The climate is also influenced by the southwesterly monsoon winds from April to October and northwesterly monsoon winds between November and March.

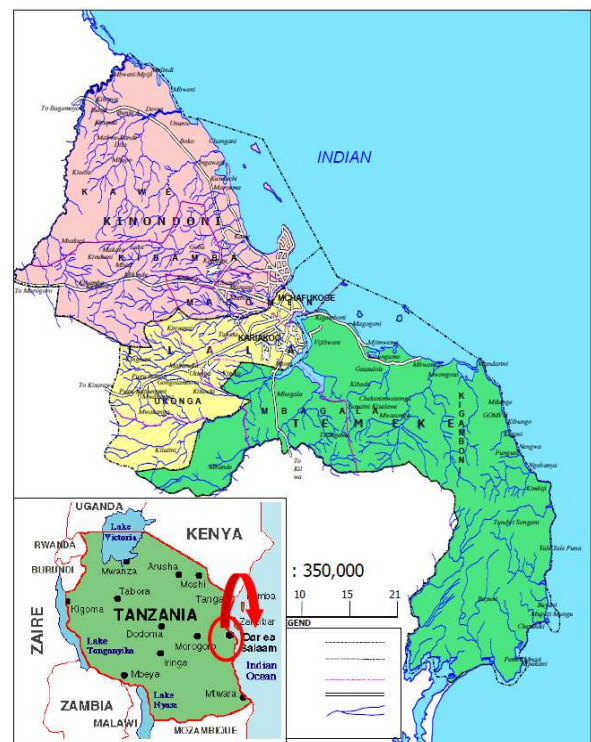


Figure 1. Map of Dar es Salaam (Dar Profile, 2004)

1.2. The Current Situation

The World Bank Report [34] estimates that Dar-es-Salaam was generating solid waste at a tune of 4200 tonnes per day in 2011 which is equivalent to 0.93kg/cap/day. Of these tonnes only 40% is collected and the remaining 60% are buried, burned, scavenged by informal recyclers or dumped by the road side or into drainage canals. In the same report, it is estimated that Dar-es-Salaam will be generating 12000 tonnes per day by 2025. Table 1 presents the current daily solid waste generation and collection by

the three municipalities. These figures show that serious planning is essential if Dar-es-Salaam will ever be clean and solid waste characterisation and quantification are important aspects of that planning process.

Table 1. Current Solid waste generation in Dar es Salaam (WB, 2012)

Municipality	Amount Generated (Tonnes/day)	Amount Collected (Tonnes/day)	Collection Rate (%)
Ilala	1,100	430	39
Temeke	1,035	280	27
Kinondoni	2,026	823	41
Total	4,161	1,533	37

2. Methodology

In carrying out the research, the methodology used by [13] was employed. It involved sorting and weighing directly from the household where solid waste is generated. According to [35], this is an established method for characterising solid waste. The methodology involved the following steps: 1) classifying the population by socioeconomic status; 2) selecting households for the study; 3) determining the number of samples; 4) sorting and quantifying the solid waste types and 5) analysing the results

2.1. Classifying the Population by Socioeconomic Status

Classification of the population in socioeconomic status was done using socioeconomic indices for the 73 wards making the three municipalities of Dar-es-Salaam. Socioeconomic status is commonly conceptualized as the social standing or class of an individual or group. It connotes one's position in the social hierarchy, how the hierarchy is structured, and very often one's consequent life chances. In other words, socioeconomic status indicates one's access to collectively desired resources, be they material goods, money, power, friendship networks, healthcare, leisure time, or educational opportunities. Invariably, socioeconomic status is often measured as a combination of education, income, and occupation. Table 2 shows socioeconomic indices used to classify the Dar-es-Salaam wards. A total of nine wards, three from each municipality, were selected for the three municipalities.

Table 2. Socioeconomic indices used (DCC, 2012)

Socioeconomic Index	Status
<170	Low
170-180	Middle
>180	High

2.2. Selecting Households for Study

A total of 639 households were selected from three municipalities for the three socioeconomic statuses of HIGH, MIDDLE and LOW. The number of households was selected proportionally depending on the population and total number of households in each category. 229 households were selected from Kinondoni, 253 from Ilala and 157 from Temeke. Accordingly, 111 were selected from high socioeconomic status, 218 from the middle socioeconomic status and 310 from the low socioeconomic status as indicated in Table 3.

2.3. Determining the Number of Samples

The choice of number of samples was solely influenced by solid waste collection trend and the heterogeneity of the solid waste. Moreover, in the literature there is no specific method used for specifying the number of samples for solid waste characterisation [8]. Since solid waste was being collected from households once a week, we decide to sort and weigh the solid waste generated from each household once a week (a day before collection day) for seven consecutive weeks making it a total of 4,473 (777 from high socioeconomic status, 1,526 from middle and 2,170 from low socioeconomic status) samples from the 639 households. Although according to the method recommended by [36] only thirty samples are adequate, we were of the opinion that its reliability may be compromised especially when the samples are taken from various solid waste generating sources and not at dumpsites. Therefore our approach was well-suited for the purpose of this study.

2.4. Sorting and Quantifying the Solid Waste Types

The solid waste was hand sorted and classified into eight categories shown in Table 4. Sorting was based on the types found most often and those most commonly reported in previous studies [14]. The procedure adopted was the same all for waste found in the 639 households for all the seven weeks.

Table 3. Demographics of the studied areas and selected samples

Municipality	Wards	Population (selected wards)		Households		High socioeconomic status households		Middle Socioeconomic Status Households		Low Socioeconomic Status Households	
		Total	Sample	Total	Sample	Total	Sample	Total	Sample	Total	Sample
Kinondoni	3	177,599	817	46,509	229	12544	61	14907	72	19056	96
Ilala	3	192,855	888	51,365	253	2792	13	19669	95	28904	145
Temeke	3	127,656	587	31828	157	7624	37	10367	51	13828	69
Total	9	498,070	2292	129702	639	22960	111	44943	218	61788	310

Table 4. Classification of solid waste types

Type of waste	Waste Components
Organic waste	food waste, garden trimming, wood.
Plastics	any type of polymer content including materials such as PETE, HDPE, LDPE, PVC, PP, and other plastic materials such plastics bags and plastic bottles
Glass	any type of glass bottles, containers, sheets and any other type of glass including broken bottles
Paper and cardboards	any type of paper such as newspapers, wrapping materials, paper packaging materials etc.
Metals	any scrap metal and aluminum cans
eWaste	anything electronic such as mobile phones, batteries, TV, computer and computer accessories etc.
Textile	any cloth like material
Others	any other materials whose nature could not be immediately determined.

3. Results and Discussion

Tables 5 and 6 present the waste generation and composition for each of the three socioeconomic statuses and the average generation and composition. Table 5 presents the results grouped according to socioeconomic status and proportional composition of the various types of waste in terms of percentages. It was found that there is a significant difference in solid waste generation among the three socioeconomic statuses. In the overall, the per capita waste generation was found to increase with improving socioeconomic status with HIGH socioeconomic status generating 1.31 kg/cap/day with the MIDDLE status and the LOW status generating 0.94 and 0.9 kg/cap/day respectively. In terms of composition there was a clear trend for organic waste, textiles and other wastes indicating increasing composition with improvement in socioeconomic status while plastics and glass showed the opposite trend.

Table 5. Solid Waste Generation by socioeconomic category

Waste Type	High socioeconomic category		Middle socioeconomic category		Low socioeconomic category	
	Kilograms	Percentage	Kilograms	Percentage	Kilograms	Percentage
Organic Waste	17,960	70.1	20,864	57.7	25,670	52.9
Paper and cardboards	2,500	9.8	4,800	13.3	4,225	8.7
Plastics	2,114	8.3	5,200	14.4	9,872	20.3
Glass	1,500	5.9	3,190	8.8	5,900	12.2
Metals	575	2.2	720	2.0	1952	4
ewaste	460	1.8	800	1.2	607	1.3
Textiles	250	1.0	300	0.8	100	0.2
Others	254	1.0	309	0.9	500	0.4
Total	25,613	100	36,183	100	48,526	100
Generation rates (kg/cap/day)	1.31		0.94		0.90	

The compositions for organics, textiles and other wastes were 70.1%, 57.7% and 52.9% for HIGH, MIDDLE and LOW socioeconomic status respectively. The possible explanation for such difference can be in terms of the differences in consumption patterns derived from the differences in income levels. In addition the high socioeconomic status can afford the luxury of having a garden, trimming of which contributes to organic waste significantly and can afford to throw away more textiles and other wastes. The opposite trend for the plastics and glass may be explained by the fact that reuse and sorting for these items is higher in the LOW category than in the HIGH category. Most of these items do not simply find their way into the waste stream as they are scavenged at the point of generation.

Paper and cardboards, metals and ewaste did not show a clear trend with socioeconomic status. It was rather strange that the percentage of metals in the waste from LOW category was the highest while metal scavenging is usually expected. The ewaste composition in the waste from HIGH category was the highest as would be expected due to more use of e-products by this category. However, for the MIDDLE and LOW categories the difference was small. Surprisingly the MIDDLE category showed the highest composition of paper and cardboards (13.3%).

Table 6. Total Solid waste generation by the three socioeconomic groups

Type of waste	Kilograms	Percentage
Organic Waste	64,494.00	58
Paper and Cardboards	11,525.00	10
Plastics	17,186.00	16
Glass	10,590.00	9
Metals	3,247.00	3
ewaste	1,867.00	2
Textiles	850.00	1
Others	1,063.00	1
Total	110,822.00	100
Generation rate (kg/cap/day)	0.99	

Table 6 presents total solid waste by type for the three socioeconomic statuses. From the results solid waste generated in Dar-es-Salaam consists mainly of four types of waste: organic waste which constitutes (58%), plastics (16%), paper and cardboards (10%) and glass (9%). The per capita solid waste generation rate was found to be 0.99kg/day, slightly higher than that reported by World Bank [34] of 0.93kg/cap/day. Solid waste composition for Dar es Salaam has been varying over the years as indicated in Table 7. Despite the fact that this variation could be due to how the researchers characterised the waste, a fact evidenced by large percentages of waste classified as "others" and lack of ewaste for the preceding years, it cannot be denied that the solid waste composition of the Dar-es-Salaam city is changing rapidly compared to the mid-1990s [18] when it was mostly organic.

We can see that percentages for plastics, paper and cardboards and glass increasing, implying that peoples' lifestyles are changing. On the other hand metals still account for lower percentages, not because they are not discarded but because it is a big recycling business taking away metals from waste stream. Similarly, plastics could also account for higher percentages had it not been that plastic containers are collected for recycling. For example, a single collection point in Mwenge in the Kinondoni municipality, on average, sells 541.3 kilograms of plastic containers daily. This is equivalent to nearly 200 tons a year and there are many such points that collect and sell plastic containers.

The changing characteristics of solid waste composition and increasing quantity of solid waste generated can be attributed to improving economy of the Dar-es-Salaam city. As indicated in Figure 2 the Regional Gross Domestic Product (RGDP) has been growing and thus influencing peoples' consumption behaviour. In fact, there is positive correlation between daily solid waste generation in Dar-es-Salaam and the GDP and population growth as illustrated in Figure 3. These results are in agreement with the observation by [37] that total waste generation by the urban councils is associated with national GDP per capita.

Table 7. Solid waste composition for various years (DCC, 2004, Okumu, 2012, WB, 2012, Authors, 2014)

Waste type	Percentage composition			
	Year			
	2004 ¹	2008 ²	2012 ³	2014 ⁴
Organic	65	71	49	58
Paper cardboards	7	9	8	10
Plastics	-	9	16	16
Glass	3	4	2	9
Metals	2	3	5	3
ewaste	-	-	-	2
Textiles	4	-	5	1
Others	19	4	15	1

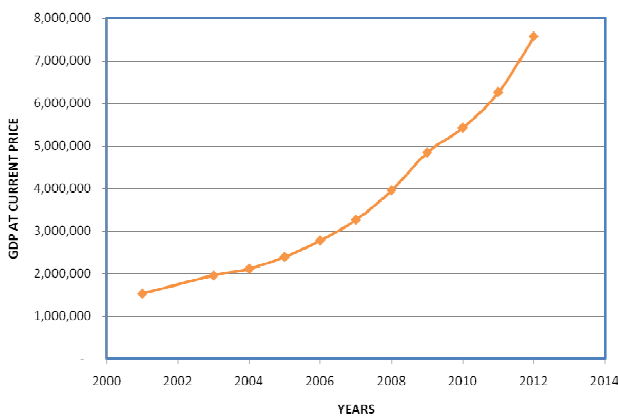


Figure 2. Annual GDP of Dar-es-Salaam from 2001 – 2012 in Tanzanian Shillings (NBS, 2013)

Table 8. Population and GDP growth and the corresponding SW generation (NBS, 2012 and Dar City profile)

Year	Population	GDP (million TSHS)	SW Generation (tons/day)
2001	2,356,263	1,530,654	2300
2002	2,487,288	1,958,790	2400
2003	2,564,394	2,114,612	2500
2004	2,642,708	2,397,247	2600
2005	2,721,926	2,780,274	2800
2006	2,801,675	3,266,242	3100
2007	2,881,548	3,959,818	3200
2008	2,961,150	4,848,914	3400
2009	3,040,118	5,428,503	3500
2010	3,118,132	6,265,440	3800
2011	3,194,903	7,571,790	4200

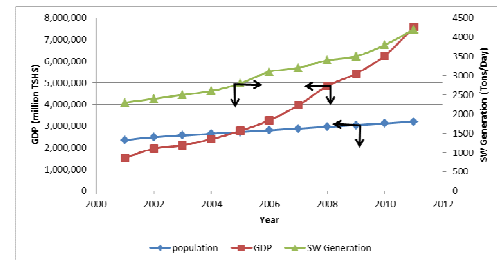


Figure 3. Daily solid waste generation versus annual GDP and population for Dar-es-Salaam (NBS, 2012; DAR CITY PROFILE)

That is solid waste generation is positively correlated to both population and GDP growth. Implicitly, knowing the population and the GDP, solid waste generation for Dar-es-Salaam can be computed at any point in time.

The GDP growth is reflected in reduced poverty as indicated in Table 9. The decreased poverty; resulting from increased GDP has a bearing on the consumption behaviour of the Dar-es-Salaam city's population. This, in return, affects the quantity and type of solid waste generated.

Table 9. Trend of poverty indicators for Dar es Salaam (NBS, 2012)

Year	Food Poverty	Basic Need Poverty
1991/1992	13.6	28.1
2000/01	7.5	17.6
2011/12	1.0	4.2

Table 10 presents a comparison of solid waste composition of the city of Dar-es-Salaam with other urban areas in the East African Community except Burundi whose data could not be obtained. From that Table 10, it is clear that Dar-es-Salaam has the lowest organic waste and the highest amount of plastics followed by Nairobi, while Kigali has the lowest amount of plastics; thanks to the stringent rules on plastics. Clearly, Dar-es-Salaam has a solid waste composition structure that is different from the other cities and towns in East Africa. As earlier noted, this composition may be attributed to changing consumption behaviour but also non-enforcement of the rules and regulations, especially on plastics.

Table 10. A comparison of solid waste generation in East African urban areas (KSEO, 2013; Scheinberg *et al.*, 2011; Okot-Okumu, 2012)

Type of Waste	Dar-es-Salaam	Kigali	Moshi	Kampala	Jinja	Lira	Nairobi
Organic	58	76.7	65	77.2	78.6	68.7	65
Paper and Cardboards	10	16	9	8.3	8	5.5	6
Plastics	16	1.5	9	9.5	7.9	6.8	12
Glass	9	1.4	3	1.3	0.7	1.9	2
Metals	3	2	2	0.3	0.5	2.2	1
eWaste	2	-	-	-	-	-	-
Textile	1	2	-	-	-	-	-
Others	1	0.4	12	3.4	4.3	14.9	14

4. Conclusion

Solid waste characterisation study done in the three municipalities of Dar-es-Salaam has indicated that solid waste generation and composition is highly dependent on population and socioeconomic status of the population. It is clear from this study that knowing the population and the weighted average socioeconomic status of a city can enable calculation of the solid waste generation and the composition. The per capita waste generation rates obtained are 1.31kg/cap/day for high followed by the middle and low socioeconomic statuses with 0.94kg/cap/day and 0.9kg/cap/day respectively. Moreover, the solid waste composition exhibit different characteristics for different socioeconomic statuses. That means that the peoples' socioeconomic status (usually measured by a combination of education, income and occupation) is a determining factor for solid waste generation rates and composition. It was further found, using a multiple regression technique, that there is positive correlation between solid waste generation rates and GDP and population growth. Implicitly, it means once someone knows the population and GDP, the amount of solid waste can easily be computed.

Furthermore, a comparison with data previous researches and other urban centres in East Africa revealed that solid waste composition for Dar-es-Salaam is changing very fast. This trend calls for regular short-term [15] characterisation studies to determine the solid waste composition data to aid in the planning of solid waste management strategies. That notwithstanding, organic waste and other recyclables such as plastics, metals and glass account for larger percentages of the solid waste composition. Thus, encouraging and formalising recycling and composting would greatly reduce the amount of solid waste that has to be disposed hence reducing the cost that has to be incurred. Furthermore such formalisation will attach an economic value to recyclable materials and hence encourage source separation as required by the Environmental Management Act [38] and the Public Health Act [39]. The current trend where the recyclables like plastic containers, glass bottles and metals including cans are either recovered by scavengers or by solid waste collectors along the way to dumpsites ends up littering other waste on the road which eventually find their way in trenches. Similarly, initiatives like KILIMO KWANZA could benefit from composting organic waste

which makes up 58% of the total waste generated as shown in Table 6.

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