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Household Solid Waste Generation and Composition in Njoro Division, Nakuru County, Kenya

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Authors' contributions

This work was carried out in collaboration between both authors. The first author carried out the study while the second writer was involved in the writing of the paper. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The objective of the study was to establish the waste per capita per day and the composition of solid waste generated in the study area.
Study Design: The study was a descriptive, cross sectional survey.
Place and Duration: The study was carried out within Egerton University and the neighbouring community located in Njoro and Mukungugu sub-location, in Njoro Division, Nakuru County, Kenya. The study was carried out in the middle of January – May 2009 semester within a period of seven day as recommended by Pfammatter and Schertenleib (1996).
Methodology: The sample size was 103 households and household equivalent units, drawn from students within the Egerton University halls of residence, tenants within and outside the University and farmers outside the University.
Results: Waste per day per capita generated was generally low being 105.87±15.54 g which was lower than the average generated in low income areas of urban centres of developing countries. Food waste was the largest fraction of total waste at 55%, followed by fines (22%) and plastics 11%.

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Conclusion: In conclusion, the study findings established that the waste composition was largely in agreement with what is expected in developing countries whereby the largest fraction was food waste however, the waste amounts were lower than the average expected for developing countries.

Keywords: Solid waste; waste composition; waste generation; per capita waste; Egerton University.

1. INTRODUCTION

Zurbrugg [1] defines solid waste management (SWM) as all activities that seek to minimise the environmental and aesthetic impacts of solid waste. Further, SWM has also been defined as a process that comprise the collection, transportation, processing, recycling or disposal of waste materials, usually ones produced by human activity in an effort to reduce their effect on human health, local aesthetics or amenity (Pitchel, [2]; Fraser & Gelanis, [3]; Stokoe, [4]). SWM in developing countries is a big challenge in all aspects; from low waste separation and recycling rates, lack of efficient waste collection services in terms of coverage of targeted population and waste amounts collected, and improper disposal exposing local residents to related health hazards (Wilson, Costa and Cheeseman, [5]).

There are diverse factors that influence the amounts and composition of waste in urban areas. Sha'Ato [6] infers that the population size of an urban area, population growth rates and per capita waste generation influence the volumes of solid wastes generated. Cointreau-Levine [7], holds that higher incomes are related to higher waste per capita and higher proportions of packaging materials and recyclable wastes whereas lower incomes are related to lower waste generation rates. In 1992, Cointreau-Levine reported that the income elasticity of waste generation is 0.1 meaning that a 10% growth in income leads to a rise of 1% in the quantity of waste (Pearce and Turner, [8]). Cointreau-Levine [9] further reported that the larger the urban centre and the higher the income level, the higher the per capita solid waste produced. Chandrappa and Das [10] reports that solid waste is generated at the rate of 0.4–0.6, 0.52 - 1.0 and 1.1–5.0 kg/person/day in large urban areas of low, middle and high income countries respectively whereas in smaller cities the generation rates are comparatively less. According to Troschinetz and Mihelcic [11], daily per capita waste amount generated in developing countries ranges 0.3–1.44 kg as compared with developed countries where the rate is 1.43– 2.08 kg. It has also been shown that waste amounts tend to increase with time with Chandrappa and Das [10] reporting that in the United States of America, per capita waste generation varied from 1.22 kg/day in 1960 to 1.66 kg/day in 1980, 4.50 kg/day in 1990 and 4.65 kg/day in 2000 where it stabilised and started decreasing slightly in 2007. In some African cities, generation rates may range from 0.3-1.4 kg/capita/day (Chandrappa and Das, [10]) or even lower for instance, Amiga [12] reported that in Addis Ababa, people living in unplanned and poor housing conditions generate 0.15 kg per capital per day of solid waste.

In terms of composition, Chandrappa and Das [10] states that waste characteristics in developing countries is marked by the following characteristics as compared to waste from developed countries: density of 2-3 times, moisture content of 2-3 times, larger fraction of organic waste and a large fraction of smaller components. According to Palczynski [13], municipal solid waste from Accra, Ibadan, Dakar, Abidjan, and Lusaka has putrescible organic content ranging from 35-80% with general trend leaning toward the higher end of this range; plastic, glass, and metals at less than 10%; and paper with a percentage in the low 10s. Furedy [14], states that the organic fraction of waste streams typically comprises 35-70% of total municipal waste generated in large cities of developing countries. Xiao et al. [15] reported that in Beijing, the proportion of organic substances (food waste, paper, plastic, wood and fibre) accounted for 86% of total waste generated. Dhokhikah, Trihadiningruma and Sunaryo [16] found that the composition of the household waste in eastern Surabaya, Indonesia, was as follows: food waste (64.18%), plastics (10.79%), paper (9.24%) and used diapers (6.97%). In Kenya, the composition of solid waste from low income areas of urban centers was reported as comprising food (57%), paper (16%), plastics (12%), textiles (2%), grass/wood (2%), leather (1%), rubber (2%), glass (2%), cans (1%), other metals (0) others (4%) (Rotich et al. [17]).

In developed countries the fraction of waste food is much lower. According to NIR and CRF (Skovgaard et al. [18]) in 27 countries making up Europe, municipal waste in 2003 composed of 38.9% food waste, 0.3% garden waste, 21.2% paper waste, 1.7% wood waste, 3.0% textile wastes, 10.6% plastics and 24.2% inert waste. In the USA, waste composition data in 2007 revealed paper and paperboard at 32.7%, glass 5.3%, metals 8.2%, plastic, rubber and leather, textiles, wood and other related waste were 27% whereas food wastes was 12.5, yard timings 12.8%, and other miscellaneous waste 1.5% (Environmental Protection Agency, [19]).

It has been recognised that there is still need for more waste data in developing countries with the Intergovernmental Panel on Climate Change, [20], reporting that there is general lack of comprehensive data on waste generation in developing countries where most waste generation rate reported only account for the urban population. Guerrero, Maas and Hogland [21], after review of publication in two major waste journals reported that surprising few publications focused on quantification of factors influencing waste management. Liu, Wu, Tian and Gong [22] states that the success of waste management planning lies in the related knowledge and data on waste generation and collection profiles and further holds that sustainable recycling is based on knowledge on generation and collection, the categories, quantities, participants and channels for disposal.

High population growth and rapid urbanisation are known to lead to increasing waste amounts with management becoming a challenge if there are no clear strategies to handle the waste. The population in Kenyan Universities has been expanding rapidly since the government delinked enrolment from bed capacity such that from 2009 – 2014, the average growth in enrolment in Universities was 25%. Most of the additional students are accommodated outside the universities resulting to mushrooming of unplanned settlement around the universities which are poorly prepared to handle the rise in waste amount. In Egerton University, Njoro campus, the area around the University has become semi-urban yet no waste services are offered outside the University. The objective of this study was to determine the amount and composition of waste generated by students and tenants (resident staff in their homes) within the University and tenants and farmers in the community around the University which would provide data that can be used in planning for waste management.

2. METHODOLOGY

2.1 Description of Study Area

2.1.1 Physical location

The study was carried out in Njoro Division of Nakuru County, Kenya. It covered the community in Egerton University, Njoro campus and the area around it within Njoro and Mukungugu sub-location in Njoro division. Njoro Division lies between longitudes 35º 28´E to 36º 10´E and latitudes 0º 13´S to 1º 10´S which is to the south-west of Nakuru town. It occupies an area of 313.6 km^2 (Republic of Kenya, [23]).

2.1.2 Climate

The area is characterised by annual rainfall of between 760 – 1270 mm and experiences a bimodal pattern with long rains in April – June and short rains from July – August. The average temperature is 16.5ºC which varies with altitude (Republic of Kenya, [23]).

2.1.3 Economic activities

The principal economic activity in the study area is farming. However, due to the proximity to the University, the area has diverse business activities. There is also a large pool of employees within the community outside the University. The employee provide labour to the University, companies and other institutions like flower farms, canning factory, schools and health facilities in the study area. To accommodate this pool of employees many rental premises have been constructed in the area around the University.

2.1.4 Population

The study population comprised student population within Egerton University and the neighbouring community in the villages of Mukungugu, Beeston, Mwigito, Eriithia, Njokerio and Ng'ondu. The population at the time of study was 50,750 persons and 13,048 households (Kenya National Bureau of Statistics (KNBS), [24]). The population under study comprised farmers (all outside the University), tenants (mostly employees both within and outside the University) and students (all within the University). Since the year 2008, the government

of Kenya uplifted the restriction that tied University enrolment to bed capacity within the University. Following this move, the enrollment in universities exploded from only 122,800 in 2008 (KNBS, [25]) to 443,800 admissions in 2014 (KNBS, [26]), an average annual growth rate of about 25%. This has resulted to a very high proportion of students being occupied outside the University in the communities around Additionally, most of the staff houses within the University have been converted to hostels, forcing the staff to move to the neighbouring areas.

2.2 The Study Design and Sampling

This study design adopted was a descriptive cross section survey implying that data collection was only done once.

The population was stratified into three: tenants, students and farmers. Within the University, the sample included students and tenants (staff) residing within the University and outside the University were tenants and farmers. The sampling unit for tenants and farmers was households and rooms for students. The sampling design was stratified systematic and the sampling interval was obtained by dividing the population with the sample size which was done for farmers and tenants. When sampling University students, six halls of residence were selected through randomly sampling.

According to Pfammatter and Schertenleib [27], waste quantity and composition of a representative number of households could be determined in a period of one week with a reliable estimate requiring a minimum of 20 households or 1% of the households in the selected area. Mbiba [28] carried out a waste amount determination survey over period of seven days.

Taking the student rooms as a sampling unit, the sample size for the study was 103 which is above the minimum recommended by Pfammatter and Schertenleib [27]. The student sample comprised two hundred 237 students in six student halls, each hall with 82 rooms and each room occupied by an average of three students. Two of the students' halls were of post graduate students and four had undergraduate students. Half the halls were occupied by female students and the other half by male students. The total number of farmers' households were eight and the tenants households were thirteen.

2.3 Methods of Data Collection and Analysis

A questionnaire was used to collect data from the study population to provide information that could enable an understanding of the important factors that could explain waste generation patterns. The questionnaire sought information on: waste separation practices, waste types generated and disposal, demographic information like age, gender and household size, education level and income.

Each household was provided with plastic waste containers together with a plastic liner. The waste was collected from the waste generators every second day. Before storage, the source of each bag of waste was labelled and then stored in a secured room within the University where the determination of amounts and composition would be done.

After seven days, the waste bags were separated by their sources and placed on a bench that had been covered with a thick plastic liner. The label on the bag was noted down, the waste emptied on the bench and then carefully segregated into the various streams. Each stream was placed in a standard plastic bag whose weight was known and then weighed. A recording sheet was used which comprised the following information: code of the waste generator, type of waste generator, total waste amount from each waste generator, type of waste (waste stream) and amount of each waste stream in grams.

During data collection, ashes were not included since for those using wood fuel, ashes were removed very occasionally and actual rates for ashes would have been difficult to determine within the seven day period. Further, the waste determination survey only collected that waste which was to be disposed and hence the respondents were informed that they should only put in the bin what they had no use for.

Data collection was carried out at the middle of the semester to avoid extreme condition of waste generation at the beginning of the semester and towards the end of the semester with high and low generation rates respectively. This is because at the beginning of the semester the student were bound to produce a lot of waste because of possession of more money for subsistence whereas towards the end of the semester the amount of subsistence money with

the students would have dwindled hence less waste generation. It was assumed that the middle of the semester, the average conditions of the students in regard to waste generation would be captured. This was done in the month of March during the January-May semester, 2009.

After the waste amounts were recorded, the data was coded and entered into the Statistical Package for Social Sciences (SPSS) statistical software for analysis. Descriptive statistics were used to present of waste amounts and composition results as means, percentages, measures of central tendency and frequencies.

3. RESULTS AND DISCUSSION

3.1 Socio-economics Description of Respondents

The majority of respondent farmers were females whereas for students and tenants, the majority were males (Table 1). Males, on the other hand, were more than 60% for tenants and students.

The farmers had the highest percentage of respondents with up to primary level of education whereas the tenants had a comparatively high percentage with greater than secondary education (Table 2). All the students were either undergraduate or postgraduate students.

Table 1. Sex of respondents

Respondent	Sex	Frequency	Percent
Farmers	Male	3	37.5
	Female	5	62.5
Tenants	Male	8	61.5
	Female	5	38.5
Students	Male	151	63.7
	Female	86	36.3

The farmers were relatively older (48.2±8.4 years) as compared to tenants (29.9±2.5 years) but had relatively lower incomes (9,500±4,252.45) compared to tenants (91,428.57± 33,318.0) (Table 3). On the other hand, the household size of the farmers was relatively smaller (4.00±0.655) than that of the tenants (6.15±1.043).

Table 2. Education level of respondents

Respondent	Education level	Frequency	Percent
Farmer (N= 8)	Primary dropout	3	37.5
	Primary	3	37.5
	Secondary	1	12.5
	Secondary dropout	1	12.5
	Total	8	100.0
Tenant (N=13)	Primary dropout	3	23.1
	Primary	4	23.1
	Secondary	2	15.4
	College	2	15.4
	University	3	23.1
	Total	13	100.0
Students (N=237)	Undergraduate	225	94.9
	Post graduate	12	5.1
	Total	237	100.0

Table 3. Age, income and household size of respondents

	Variable	N	Minimum	Maximum	Mean	Std. error	Std. dev.
Farmer	Age	6	19	69	48.17	8.440	20.67
	Income	4	1000	21000	9500.0	4252.45	8504.90
	Household size	7	2	6	4.00	.655	1.73
Tenant	Age	12	16	45	29.92	2.51	8.68
	Income	7	2000	240000	91428.57	33318.0	88151.12
	Household size	13	2	17	6.15	1.043	3.760

Table 4. Waste generated in the study area (g)

	Households/ halls	Min.	Max.	Mean	Std. error	Std. dev.
Farmer						
Total weight	7	114.20	8408.07	3161.64	1219.99	3227.81
Weight per capita	7	19.03	1770.48	759.74	262.15	693.59
Daily weight per capita	7	2.72	252.93	108.53	37.45	99.08
Tenant						
Total weight	13	728.85	25463.08	5354.59	1599.12	6396.48
Weight per capita	13	182.21	2239.42	810.92	158.16	612.54
Daily weight per capita	13	26.03	319.92	115.85	22.59	87.51
Students						
Total weight	6	2315.38	58730.80	19367.89	8713.06	21342.56
Weight per capita	6	240.03	1048.16	544.92	129.613	317.49
Daily weight per capita	6	34.29	149.74	77.85	18.52	45.36

Mean daily waste amount per capita = 105.87±15.54 g

3.2 Per Capita Generation

Waste generation for the study population was generally low for all respondents at 105.87±15.54 g. Daily per capita waste generated was highest for tenants (115.85±22.59 g), followed by farmers (108.53±37.45g) and the least by students (77.85±18.52 g).

3.3 Waste Composition

Composition of all the waste generated by farmers, tenants and students as shown in Fig. 1 indicate that, food waste was the largest fraction at 55% followed by fines at 22%. Among the tenants food waste was the largest component at 57% of total waste although the percentage was higher for tenants within the University (72%) as compared to tenants outside the University (56%). For students, food wastes made up 70% of the waste generated and for farmers the percentage was 18. Some waste streams were unique to some generators e.g. fines (dust and soil particles) which comprised the waste generated by farmers and tenants outside the University only. The reason for this observation was because some of the tenants outside the University and most of the farmers lived in semi-permanent houses with earthen floors whereby daily sweeping of the floors produced the fines. This waste stream was 17% of the waste generated by tenants outside the University and 72% of that generated by farmers.

3.4 Discussion

The amount of waste generated in the study area was lower than the established amounts for low income areas of urban centres of 0.25-0.45 kg waste per day by Cointreau -Levine (1997) and the waste per day per capita for developing countries of 0.5 kg by United Nations Environment Program [29]. Further, the amount was less than what was reported by Amiga [12] of 0.15kg per day per person in low income areas of urban centres. Sha'Ato [6] found an average waste generation rate of 170 kg/per day/per capita in Makurdi urban area in central Nigeria in a ten day survey period and further reported waste per day per capita of 15 g in institutions. Mbiba [28] reported a waste per day per capita of 0.55 kg, 0.4 kg, and 0.4 kg in low income areas of Mombasa, Lusaka and Bulawayo respectively and 1.33 kg, 0.6 kg, 0.8 kg in high income areas of Mombasa, Lusaka and Bulawayo respectively. Ogwuelek [30] reported wastes generation rates in Abuja of 0.595, 0.626 and 0.717 kg/capita/day for low, medium and high-income groups, respectively. In Surabaya, Indonesia the average household waste generation rate was 0.33 kg each day per capita (Dhokhikah et al. [16]).

One reason that could account for the low amounts of waste was that the survey only collected waste that was to be discarded by the respondent and not all that is generated which may for example, explain the low percent of food waste for farmers which they use in feeding farm animals. On the other hand, yard waste was also not collected for all participants either because it was not considered as waste (by farmers) or was not available for collection since the respondents were not responsible for its management (like tenants and students). Some other waste types like ashes were not collected, which were

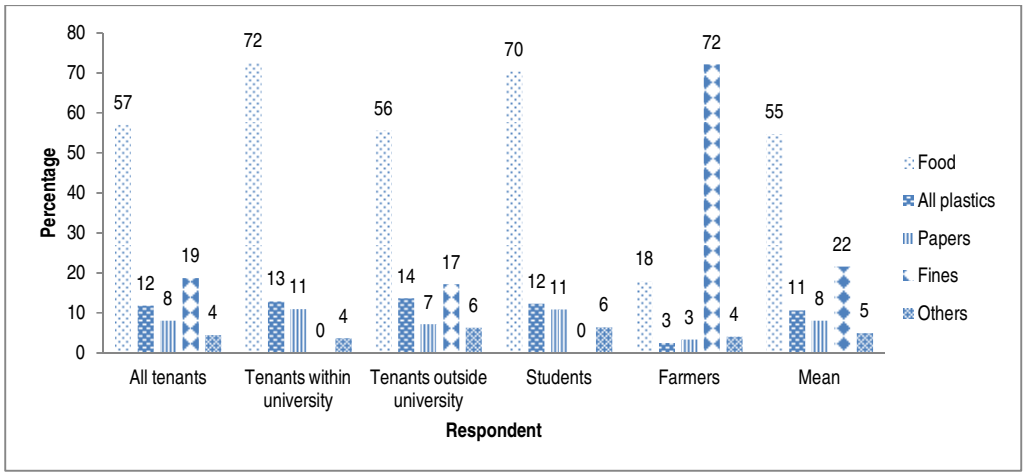

Fig. 1. Waste composition for farmers, tenants and students

Where "Others" include: Clothes, ceramics, glass, rubber, metals, dry cells

generated by use of woodfuel as an energy source, because ashes from wood stoves are infrequently emptied and hence reliable estimates could not be obtained within the duration of the survey. Organic waste is also valued by farmers for the production of manure, Eaton and Hilhorst, [31] reported that in areas around Ouagadougou, farmers were reported to make informal and illicit arrangements with drivers of the municipal waste lorries to have solid waste dumped near their fields which they would then sort out and then spread out on the farm before planting. Kim [32] observed that in Nairobi, several community based organisations engage in composting of waste and later selling the manure to farmers.

From the waste composition data, food waste was the major waste stream for all respondents except for farmers. Tenants living outside the University generated the highest amount of plastic waste which could be because of buying products in small quantities due to relatively less incomes (mean Shs. 2,500.00) hence a lot of plastic bags used in packaging. On the other hand, tenants within the University, because of their average income (mean Shs. 170,000.00) was higher would buy products in a comparatively larger quantity thus less plastic waste per product. The students on the other hand, could have generated a smaller fraction of plastic waste due to bulk purchases related to cost-sharing among students living in the same room, reducing the plastic waste generated. As for waste papers, it was observed that students and tenants within the University had the highest generation rate with each group's fraction of papers at 11% whereas in contrast, the percentage for papers for tenants outside the University was only 7% and 3% for farmers. The most likely reason for this could be because students and most tenants within the University were involved in academics hence generating higher amounts of paper.

Literature shows that food waste, in developing countries, is the largest fraction ranging between 35-80% (Palczynski, [13]; Furedy, [14]). On the other hand, Rotich et al. [17] observed that food waste make up 57% of waste generated in low income areas in Nairobi, Kenya. In Surabaya, Indonesia the percent composition for food waste was 64.2% (Dhokhikah et al. [16]). Ogwuelek [30] reported that in Abuja the percent composition for food waste was 66%, 64% and 59% for low income, middle income and high income households. Dangi, Urynowicz, Belbase [33] also reported food waste as dominant is Tulsipur, making up 46% of the waste. The percent food waste in the study area (55%) is in line with the percent given by Rotich et al. [17] for Kenya.

As for waste paper, Palczynski [13] reported that its percentage was 10-15% in several African cities while plastic were less than 10%. Dhokhikah et al. [16] stated the percentage of paper and plastics as 9.24 and 10.79 respectively in Surabaya Indonesia. In Abuja, the percent composition for papers was 8.7%, 9.41%, 12.2% and for plastics was 7.3%, 9.2% and 10.1% in low, medium and high income

households respectively (Ogwuelek, [30]). According to Rotich et al. [17], paper made up 16% of waste generated while plastics were 12% in urban areas of Kenya. Our study shows that paper and plastics are all above 10% for tenants within University and students but less than 5% for farmers. Chandrappa and Das [10] also reported that waste in developing nation is also characterised by a large amount of dust and dirt which was also observed in the study area.

4. CONCLUSION AND RECOMMENDATION

Waste composition in the study area is comparable to expectations as established in other studies whereby food waste was the largest fraction. In terms of waste amounts generated, it was on the lower scale of what is expected in developing countries, which is probably because of high rate of reuse of some categories like food waste by farmer and lack of collection of some waste categories, in particular, yard waste and ash during the study.

Due to the nature of the waste, there is potential for recovery and recycling in the study area, especially food waste that comprises 55% of the total waste which can be converted into manure for use in the farms. As recommended by Troschinetz and Mihelcic [11] composting of waste in developing countries is viable given that organic matter is usually at least 55% of the total waste.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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