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Quantification of Solid Waste Destined in Kigali City Nduba Dumpsite

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Abstract

Kigali is Rwanda's capital located in geographic center of the country. Rwanda is a fastest developing country where the urbanization is extensive and accelerates the increase of waste generated from households. Biodegradable organic matter constitutes a great portion of Municipal solid waste from Kigali City. The research was focused on the composition and quantification of Solid Waste destined in Kigali City dumpsite. The survey was carried out in Nyarugenge Sector of Nyarugenge District, city of Kigali with three selected cells and in each cell, two villages were selected in each village. The survey was conducted every week for four weeks corresponding to a month, to estimate the quantity of municipal waste discharge over a day and 60 households sample were involved in the research. Moreover, this survey was conducted between 24/June and 21/July. The sorting-and-weighing methodology was used for assessing the waste composition from each of the sample households for each week. The sorting-and-weighing methodology was used in assessing the waste composition from each of the sample households for each week. In the survey, the amount of solid waste generated and disposed of in each of survey areas (villages) as quantified, was found to be 686.000 kg. The result showed variation of weight percentage of waste: plastics (4%), paper (3%), cartons (3%), glasses (2%), metal (1%), biodegradable organic wastes (75%), others (clothes, shoes, bones, hair, pampers) (14%). The organic waste was found to be more generated with 500.000 kg and 73% fractions of entire municipal solids waste in Kigali city.

Subject Areas

Sociology

Keywords

Municipal Solid Waste, Nduba Dumpsite, Waste Composition, Waste Generation

1. Introduction

Rapid upward changes in urbanization, industrialization, population growth and lifestyles in Rwanda contribute to increasing the per capita municipal waste generation. The characterization and quantification of household solid waste in Kigali would bring together data on the generation rate and the composition of waste. This will help the authority to operate an efficient waste management system. Solid waste generation is an outcome of human activities. Poor solid waste management practices have a serious threat to health and environment because it may lead to air, soil and water pollution. Quantification and characterization of solid waste components consider an important step in solid waste management procedures [1]. The objectives of solid waste management in an area are to advance the environmental quality, safeguard its health, and strengthen its technical and economic efficiency [2].

Data on waste composition, production, and recycling are essential for designing routes of collection systems, determining placements for bins, and selecting appropriate solid waste disposal options, and it's crucial if alternative waste management schemes should be developed. A reliable estimate of the quantity of solid waste generation in the city is very important for proper solid waste planning and management [3].

In Rwanda since 2005, improvements have been made in the management of solid waste, and municipal regulations have been implemented to prohibit the dumping of domestic waste outside of private property. Although solid waste collection has improved significantly, there is a health risk for garbage collectors (mainly women). Poor handling of solid waste poses serious safety and health risks, especially groundwater contamination [4].

The collected waste is transported directly to the vehicle's landfill. In some areas, waste is transferred to the transfer area, where organic waste is sorted and recycled into compost and briquettes. In other areas, most of the organic waste is removed from the collection point and used to generate biogas, greatly reducing the amount of waste. Despite efforts to recycle, Rwanda's waste recovery rate remains relatively low. In addition, the city of Kigali produces approximately 450 tons of solid waste, of which the proportion of organic waste comes from households, restaurants, hotels and markets [4].

2. Problem Statement: Collection of Solids Waste in Kigali City

Solid waste management is an important problem throughout the world. It is estimated that in 2006, the total amount of municipal solid waste generated glo-

bally reached 2.02 billion tonnes, representing a 7% annual increase since 2003 [5]. Between 2007 and 2011, the global generation of municipal solid waste was estimated to rise by 37.3%, an equivalent to roughly 8% increase per year.

The Republic of Rwanda has environmental challenges that have been faced by the population for decades. The waste management is a big challenge in Rwanda, especially within the urban areas. The solids waste generated from Kigali city are around 450 tons per day of which between 300 and 350 tons/day is contrary collected, only about 24% of those solids waste generated were disposed legally at Nyanza landfill but nowadays that landfill was full and replaced by the newest called Nduba dumpsite.

It is foreseen that in the incoming days it will be a challenge of waste disposal due to the rapid increase of waste which will be affected by the development and increase of population.

This paper consist of quantification of solid waste destined in Kigali city dumpsite by identifying the quantity and characteristics of municipal solids waste generated in Nyarugenge Sub-Urban part of Kigali and suggesting the means of their management.

The waste materials are not good as for cause a significant effect on the aesthetics, health, and environment. The collection of solids waste is still a problem in Rwanda as a developing country; various effects like less knowledge, ignorance, poverty, etc. cause this.

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At the moment, there are some companies that are using to collect the waste for composition to another composite and disposing then to the dumps site. However, this is not on the required scale and cannot handle all solids waste generated in the city of Kigali as the waste found in some place in Kigali.

3. Materials and Method: Municipal Waste Generation Survey

3.1. Study Area

A solid waste generation survey was carried out in 6 selected villages of Nyaru-

genge sector, in Nyarugenge district of Kigali city municipality. These were Ganza, Muhabura, Biryogo, Umurimo, Umucyo, Umurava.

3.2. Survey Areas and Sample Sizes

The selected areas where the survey was carried out and the number of the areas under each class organization, the size of the samples that were considered are listed in Table 1.

3.3. The Geographical Location of Survey Areas

Rwanda is located in central Africa, to the east of the Democratic Republic of the Congo, at the co-ordinates 2˚00'S 30˚0'E. At 26,338 square kilometers (10,169 sq mi), Rwanda is the world's 149th-largest country.

As shown in Figure 1, Nyarugenge is a district of Kigali City 1˚59'0"S, 30˚1'0"E, Rwanda at 134 km^2. Its heart is the city center of Kigali (which is towards the west of the urban area and the province), and it holds most of the city's businesses. Among 4 districts, is divided into 10 sectors (Imirenge): Gitega, Kanyinya, Kigali, Kimisagara, Mageragere, Muhima, Nyakabanda, Nyamirambo, Nyarugenge and Rwezamenyo.

3.4. Survey Methodology

The surveyed area is classified according to their classes, the reason of categorizing the residential area is that garbage quantity and composition is related to socioeconomic factors. The survey was carried out in Nyarugenge Sector of Nyarugenge District with three selected cells and in each cell, two villages were selected and in each village, 10 houses were surveyed.

In each of the survey villages, the sample size that was surveyed comprises 5% - 10% of the families within the designated villages. According to [6], when the sample size is as large as 5 - 10 times the size of the population, chi-square (X2) which is the measure of randomness holds true and hence reflecting the pattern consistent with the population being examined. However, low sample sizes (e.g less than 5 times the size of the population) cause deviations in the observation due to temporal and or spatial variations that can result in the exaggerated pattern being the output.

Table 1. The selected areas where the survey was carried out.

Upper class	KIYOVU	GANZA	10 houses
		MUHABURA	10 houses
Middle class	BIRYOGO	BIRYOGO	10 houses
		UMURIMO	10 houses
Lower class	AGATARE	UMUCYO	10 houses
		UMURAVA	10 houses

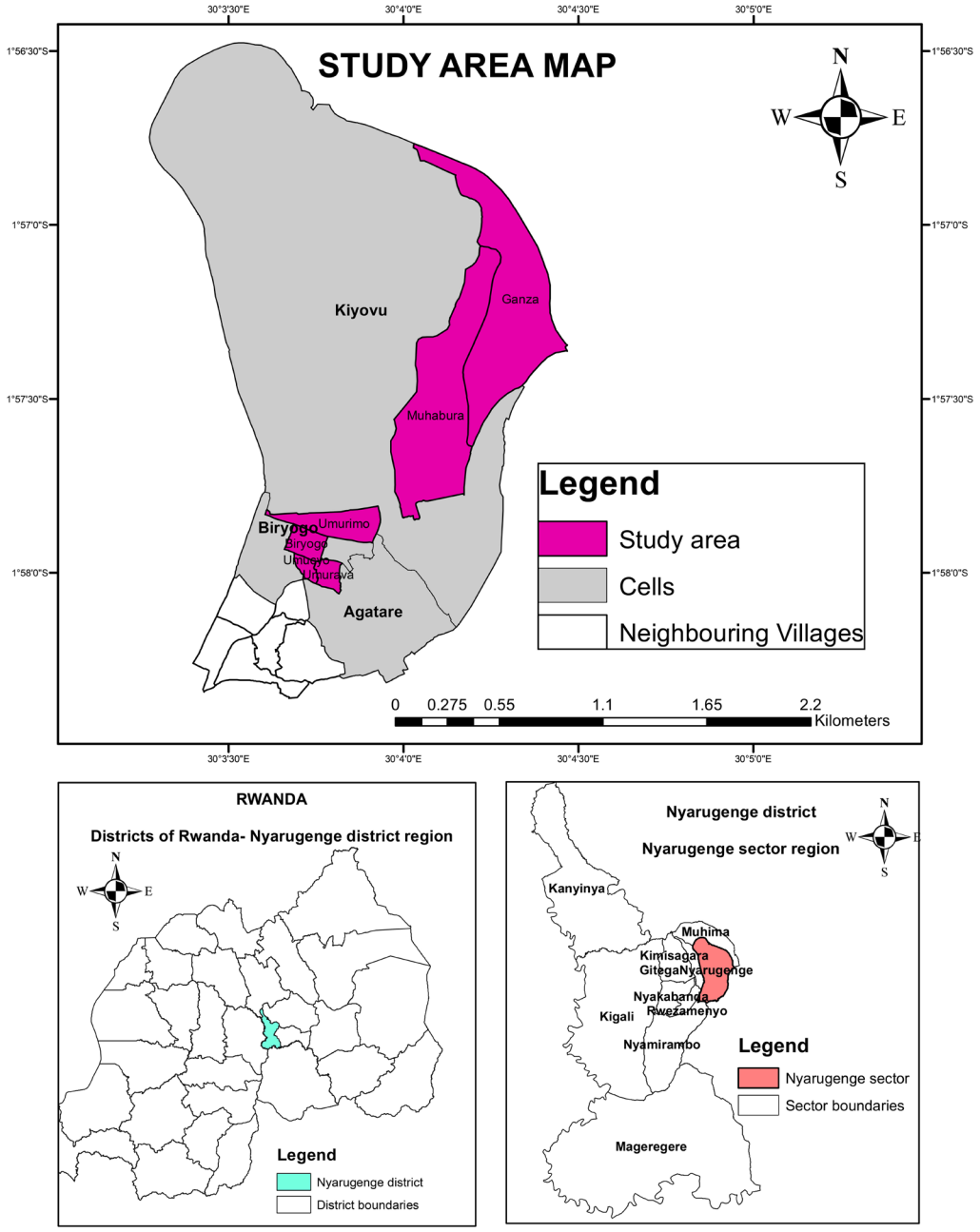

Figure 1. Case study (area of Nyarugenge district).

The survey was conducted every week for four weeks corresponding to a month, to estimate the quantity of municipal waste discharge over a day. Moreover, this survey was conducted between 24/June and 21/July. The sorting-and-weighing methodology was used for assessing the waste composition from each of the sample households for each week. In the survey, the amounts of solid waste generated and disposed of in each of the survey areas (villages) as was quantified. The methodology has the advantage of greater accuracy. (The staff helped in collection of the data). In addition, physical characterization of the solid waste streams to establish the various waste components that were

generated in each of the sample household units in the survey areas was done. The types of solid waste components and their physical state were examined in detail.

3.5. Survey Duration and Manpower Requirements

Table 2 shows the duration and manpower requirements for this survey.

3.6. Material Requirement

The weighing balance was used for weighing the garbage generated from each model houses in Kigali city. Scale having the accuracy up to 100 g was used, so that the reliable weight of the lightest refuse could be measured. The total mass of garbage from each model house was weighted prior to sorting as and the two sacks were used for sorting the organic waste to inorganic waste as organic waste in the green sac and inorganic waste in a blue sac in further the other types of municipal waste were identified. The same procedure was adopted weekly over the study period.

Rubber gloves were used for hands protection as dust masks for respiratory protection. The results were recorded in a tabular format.

4. Results and Discussion: Waste Generation Survey

The sample of MSW from each weekly collection was taken to estimate the amount of municipal solid waste generated in Kigali City. The tables below show the different data collection from three cells in Nyarugenge: sector AGATARE (lower class), BIRYOGO (middle class), KIYOVU (high class).

Table 3 shows the various fractions of the MSW and their percentage generation rate collected during 4 weeks from ten (10) houses of AGATARE cell—UMUCYO Village. Organic waste formed the highest fraction, 81% of the entire waste stream from this cell, and Glasses were not found as part of waste in this village. Higher and lower generation rate of organics waste, glasses respectively could be attributed to the socio-economic activities in the area.

Table 2. Estimate of the time period needed for carrying out all the phases of the solid waste generation survey.

Survey Area	Sample Size (5% - 10%)	No. of household surveyed	Time (h) for weekly solid waste collection and weighing	Time (h) for sorting and classification of the solid waste	Total time (h) for the survey per week
GANZA	63	10	4	48	52
MU-RA	62	10	4	48	52
BI-GO	127	10	4	48	52
U-MO	143	10	4	48	52
U-CYO	39	10	4	48	52
U-VA	81	10	4	48	52

Table 3. Agatare cell—Umucyo village.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	5.6	4.2	3.2	1.1	14.1	2%
Papers	6.2	3.1	2.9	2.2	14.4	2%
Cartons	3.9	2.2	0.7	2	8.8	1%
Glasses	2.7	0.1	0.3	0.3	3.4	0%
Metals	3.7	1.9	1.9	0.415	7.915	1%
Biodegradable Organic waste	203.5	181.8	123.4	125.2	633.9	81%
Others (clothes, shoes, bones, hairs, pampers.)	29	32.1	23	18.8	102.9	13%

Table 4 shows the various fractions of the MSW and their percentage generation rate collected during 4 weeks from ten (10) houses of AGATARE CELL—UMURAVA VILLAGE. Organic waste formed the highest fraction, 73% of the entire waste stream from this cell. Higher generation rate of organics waste could be attributed to the socio-economic activities in the area.

Table 5 shows the various fractions of the MSW and their percentage generation rate collected during 4 weeks from ten (10) houses of BIRYOGO CELL—BIRYOGO VILLAGE. Organic waste formed the highest fraction, 78% of the entire waste stream from this cell, and Glasses and metals were not found as part of waste in this village. Higher and lower generation rate of organics waste, (glasses and metals) respectively could be attributed to the socio-economic activities in the area.

Table 6 shows the various fractions of the MSW and their percentage generation rate collected during 4 weeks from ten (10) houses of BIRYOGO CELL—UMURIMO VILLAGE. Organic waste formed the highest fraction, 78% of the entire waste stream from this cell and Glasses were not found as part of waste in this village. Higher and lower generation rate of organics waste, glasses respectively could be attributed to the socio-economic activities in the area.

Table 7 shows the various fractions of the MSW and their percentage generation rate collected during 4 weeks from ten (10) houses for KIYOVU CELL—GANZA VILLAGE. Organic waste formed the highest fraction, 59% of the entire waste stream from this cell and this fraction was less than other villages. The reason is that they manage the organic waste by using them for their gardens as fertilizer.

Table 8 shows the various fractions of the MSW and their percentage generation rate collected during 4 weeks from ten (10) houses of KIYOVU CELL—MUHABURA VILLAGE. Organic waste formed the highest fraction, 54% of the entire waste stream from this cell and this fraction was less than other villages. The reason is that they manage the organic waste by using them for their gardens as fertilizer.

Table 4. Agatare cell—Umurava village.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	2.8	2.4	3.2	1.9	10.3	1%
Papers	1.3	5	1.6	0.9	8.8	1%
Cartons	6	1.8	0.9	1.2	9.9	1%
Glasses	5	2.1	2.4	2.8	12.3	1%
Metals	0.9	4.2	1.3	0.9	7.3	1%
Biodegradable Organic waste	175	174.5	162.5	140	652	73%
Others (clothes, shoes, bones, hairs, pampers.)	37.5	46.5	57	53	194	22%

Table 5. Biryogo cell—Biryogo village.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	7.1	3.35	3	4.7	18.15	2%
Papers	9	5.1	2.9	4.2	21.2	2%
Cartons	3.3	1.81	3.7	2.9	11.71	1%
Glasses	0.01	0.01	0	0	0.02	0%
Metals	1	0.38	0.4	1.48	3.26	0%
Biodegradable Organic waste	190	146.3	161	163	660.8	78%
Others (clothes, shoes, bones, hairs, pampers.)	23.2	25	57.7	27.5	133.4	16%

Table 6. Biryogo cell—Umurimo village.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	7.5	3.5	3	3.7	17.7	2%
Papers	8.7	3.9	4.8	4.4	21.8	3%
Cartons	2.8	3.3	3.9	5.4	15.4	2%
Glasses	0	0	0.5	0	0.5	0%
Metals	3	1.01	0.27	10.41	14.69	2%
Biodegradable Organic waste	123.5	151	161	148	583.5	78%
Others (clothes, shoes, bones, hairs, pampers.)	7.7	19.9	37.2	25.8	90.6	12%

Table 7. Kiyovu cell—Ganza village.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	17	10.7	8.9	6.2	42.8	9%
Papers	9	1.6	6.5	2.3	19.4	4%
Cartons	29	4.5	6.4	2.6	42.5	9%
Glasses	21.5	6.5	7	6.2	41.2	9%
Metals	6	5.8	0.5	1.1	13.4	3%
Biodegradable Organic waste	76	55	68	76.5	276	59%
Others (clothes, shoes, bones, hairs, pampers.)	0	13	12.5	4.2	29.7	6%

Table 8. Kiyovu cell—Muhabura village.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	24	20.3	15.5	15	74.8	16%
Papers	12	5.50	9.5	9	36	8%
Cartons	10.7	10.60	11	2.5	34.8	8%
Glasses	5	0.02	5.2	7	17.22	4%
Metals	5	2	1.3	2.5	10.8	2%
Biodegradable Organic waste	86.5	63.7	50	47	247.2	54%
Others (clothes, shoes, bones, hairs, pampers.)	9	9.2	9	6	33.2	7%

According to this survey, the average waste generated from the various types of households in Kigali city is summarized in **Table 9.**

Table 9 shows the summary of complete survey data of solid waste in Kigali city generated from different categories of model houses. The table shows different fractions of solid waste generated from surveyed Villages during the survey period of 4 weeks. From **Table 5** and **Table 6**, it was seen that the waste generated from the households, the organic wastes are most generated at a rate of 78%. Kiyovu Villages (Ganza 59% and Muhabura 54%) generate a low quantity of organic waste than other villages. The reason is that they manage the organic waste by using them for their gardens as fertilizer.

As shown in **Table 10**, the solids waste generated daily is about 174.634 kg for 60 households. According to [7], the households in Kigali city have a much higher average consumption than those in other provinces. The number of households in Kigali city is about 309,947 households where the total households

in urban areas (using Nduba dump site for waste disposal) is about 76% [7] corresponding to 235,560 households. However, the daily waste generated in Kigali city is about 685,613.8 kg.

Table 11 indicates the total quantity of biodegradable organic waste generated daily, monthly and annually.

Figure 2 shows that almost all waste generated in Umucyo village is organic waste and those from others (clothes, shoes, bones, hair, pampers) are the second largest proportion of material in Umucyo village. Comparing the composition of wastes generated, it is shown that the organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at high rate.

Table 9. Sectors' summary.

Waste Components	Quantities (Kg) for 10 households on weekly basis				Quantity of individual components collected for 4 weeks from 10 households	Percentage of the individual component in the entire waste stream
	W1	W2	W3	W4		
Plastics	64	44.45	36.8	32.6	177.85	4%
Papers	46.2	24.2	28.2	23	121.6	3%
Cartons	55.7	24.21	26.6	16.6	123.11	3%
Glasses	34.21	8.73	15.4	16.3	74.64	2%
Metals	19.6	15.29	5.67	16.805	57.365	1%
Biodegradable Organic waste	854.5	772.3	725.9	699.7	3053.4	73%
Others (clothes, shoes, bones, hairs, pampers.)	106.4	145.7	196.4	135.3	583.8	14%

Table 10. Total quantity of solid waste generated in Kigali city.

	Households in hall Kigali City for 4 weeks from 60 households	**Households in hall Kigali City (309,947)**	**Urban Households use Nduba dumpsite (235,560) for 4 weeks**
Quantity of solids waste collected for 4 weeks 24 days (kg)	4191.755	21,653,749.77	16,456,869.39
Quantity of solids waste collected per day (kg)	174.656875	902,239.5739	685,702.8913

Table 11. Total quantity of biodegradable organic waste generated in Kigali city.

	Households in hall Kigali City for 4 weeks from 60 households	**Households in hall Kigali City (309,947)**	**Urban Households use Nduba dumpsite (235,560) for 4 weeks**
Quantity of Biodegradable organic waste collected for 4 weeks 24 days (kg)	3053.4	15,773,202.83	11,987,648.4
Quantity of Biodegradable organic waste collected per day (kg)	127.225	657,216.7846	499,485.35

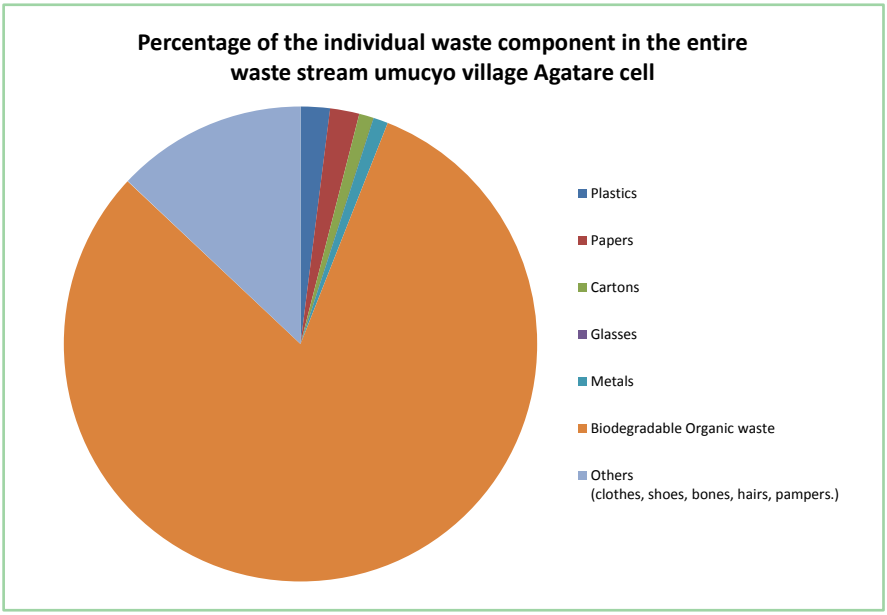

Figure 2. Percentage of individual waste component in the entire waste stream Umucyo village—Agatare cell.

Figure 3 shows that almost all waste generated from Umurava village is organic waste. Waste from others (clothes, shoes, bones, hair, Pampers) is the second largest proportion of material in Umurava village. Comparing the composition of wastes generated, it is shown that organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at high rate.

Figure 4 shows that almost all waste generated from Biryogo is organic waste and those from others (clothes, shoes, bones, hair, Pampers) make the second largest proportion of material in Biryogo village. Comparing the composition of wastes generated, it is shown that organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at high rate

Figure 5 shows that almost all waste generated from Umurimo village is organic waste and those from others (clothes, shoes, bones, hair, Pampers) make the second largest proportion of material in Umurimo village. Comparing the composition of wastes generated show that organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at high rate.

Figure 6 shows that almost of all Ganza village waste generated is organic waste and those others (clothes, shoes, bones, hair, Pampers) are the second largest proportion of material in Ganza village. Comparing the composition of wastes generated, it is shown that organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at high rate.

Figure 7 shows that almost all waste generated from Muhabura village is organic waste and those from others (clothes, shoes, bones, hair, Pampers) make

the second largest proportion. Comparing the composition of wastes generated show that organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at high rate.

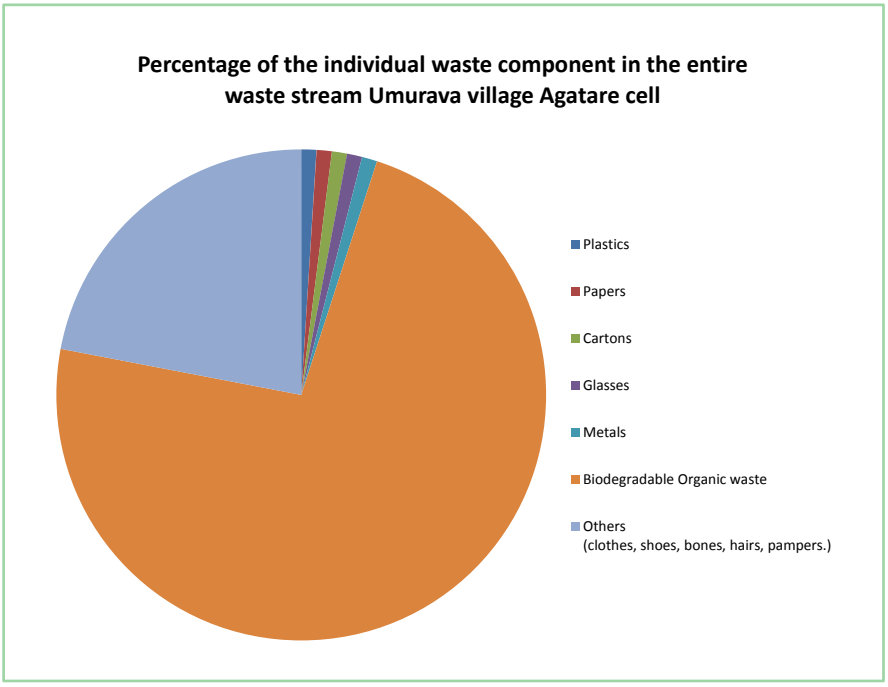

Figure 3. Percentages of individual waste component in the entire waste stream in Agatare cell—Umurava village.

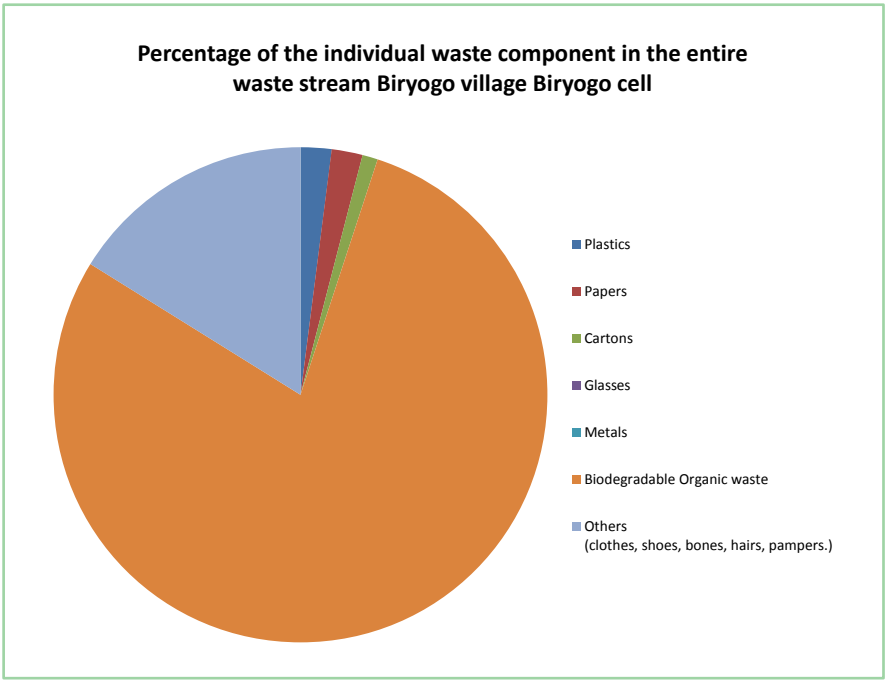

Figure 4. Percentages of individual waste component in the entire waste stream in Biryogo cell—Biryogo village.

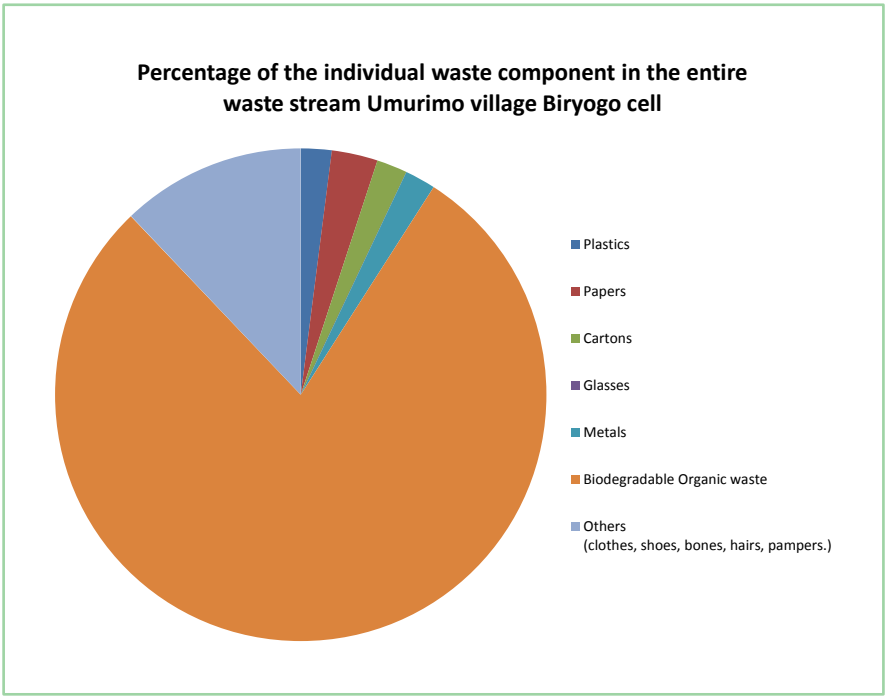

Figure 5. Percentages of individual waste component in the entire waste stream in Biryogo cell—Umurimo village.

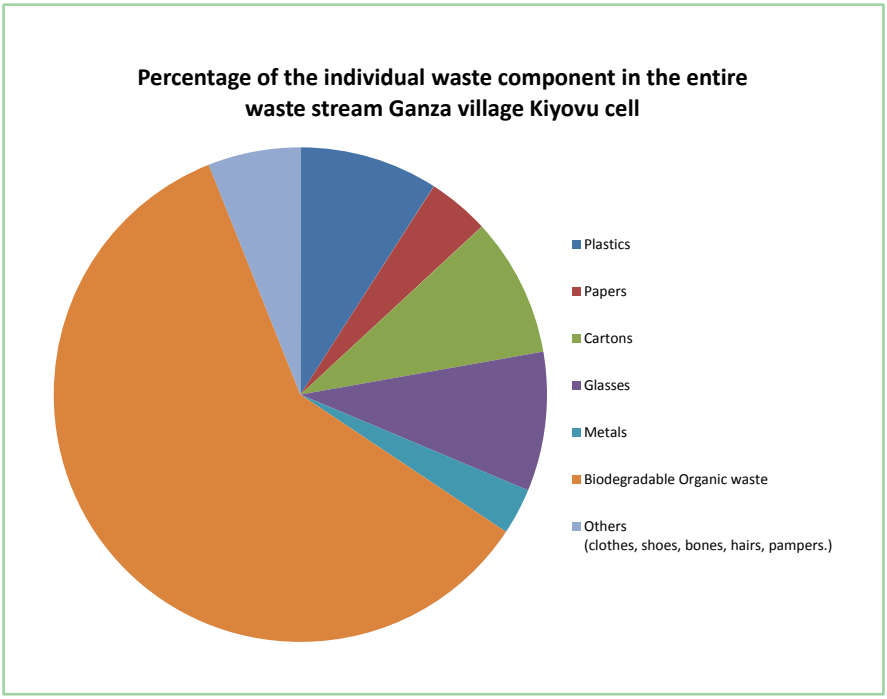

Figure 6. Percentages of individual waste component in the entire waste stream in Kiyovu cell—Ganza village.

Figure 8 shows that almost all waste generated is organic waste and those from others (clothes, shoes, bones, hair, pampers) are the second largest proportion of material in surveyed area. Comparing the composition of wastes gener-

ated, it is shown that organic waste has higher rate than the other components. These differences reflect the biodegradable waste produced in the residential house at higher rate.

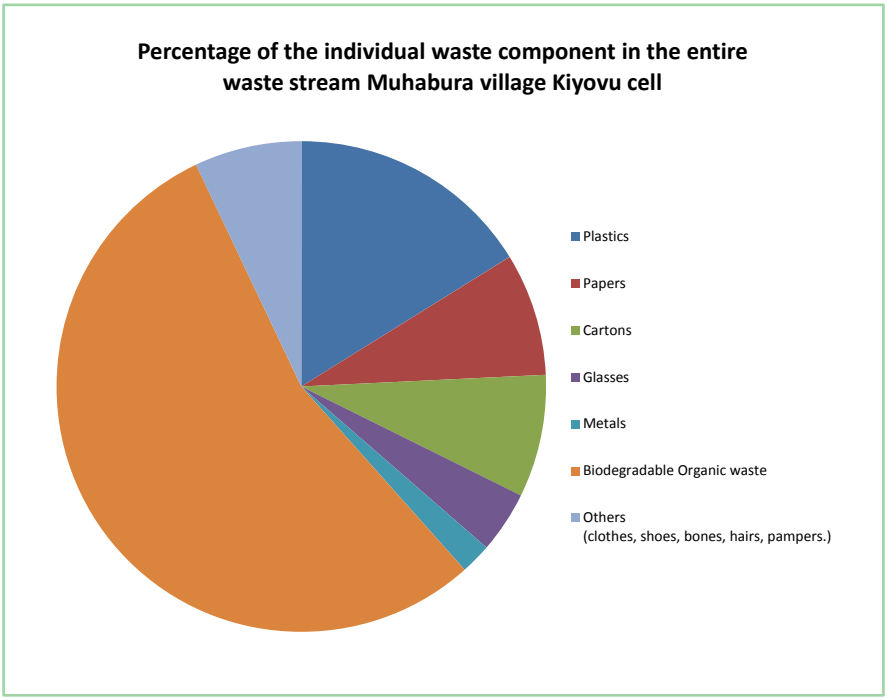

Figure 7. Percentages of individual waste component in the entire waste stream in Kiyovu cell—Muhabura village.

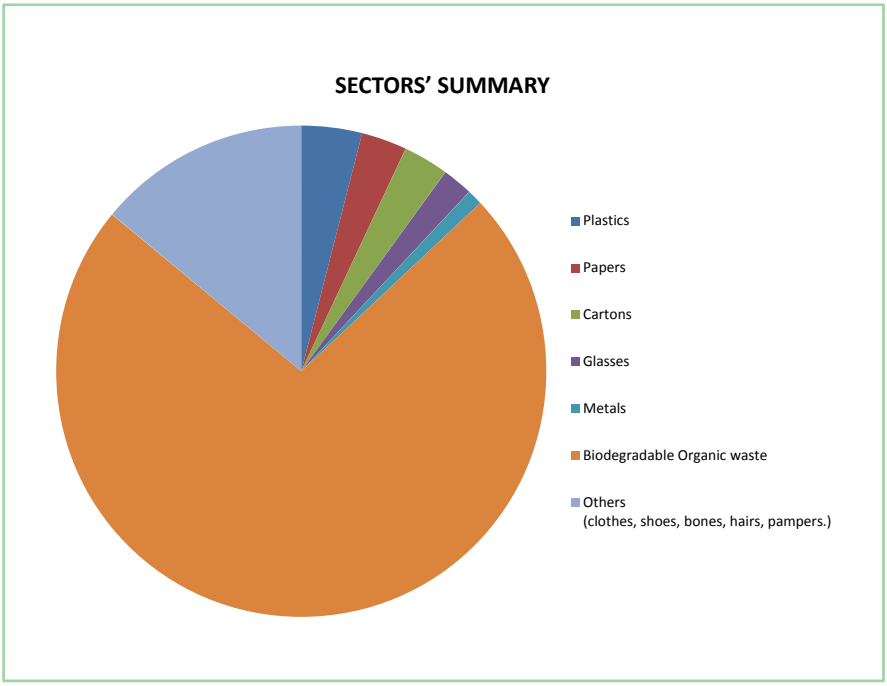

Figure 8. Percentages of individual waste component in the entire waste stream in Agatare, Biryogo, and Kiyovu cell.

5. Conclusion

The research was conducted in order to estimate quantification of municipal solids waste in Kigali city. A solid waste generation survey was carried out in 6 selected villages of Nyarugenge sector, in Nyarugenge district of Kigali city municipality. The survey was conducted every week for four weeks corresponding to a month, to estimate the quantity of municipal waste discharge over a day. The random sampling methodology was used for selecting the house to be surveyed and sorting-and-weighing methodology was used for assessing the waste composition and quantity from each of the sample households for each week. We successfully characterised and quantified the municipal organic solid waste and presented them to be higher than the other solid wastes. The results of this study demonstrated the challenge faced by Kigali city in terms of solid waste management and inspired the importance of focusing more efforts in managing municipal waste generated by recycling and using them for other intents such as electricity generation, briquettes production among others.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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