

Systems analysis of municipal solid waste management and recycling system in east Africa: benchmarking performance in Kigali city, Rwanda

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Abstract. This study assessed the current status of solid waste management (SWM) in the City of Kigali (CoK), the capital city of Rwanda. This assessment was done using systems analysis methodology of “wasteaware” benchmark indicators for integrated sustainable waste management in cities. This method of assessing helps to assess the Municipal Solid Waste Management (MSWM) in a city according to its physical components and governance features. Data were collected during a 6-month period from May to October 2017, but verification took other four months (Up to February 2018). Data were obtained from official reports, legal documents, and interviews with key personnel and operators and also from official and unofficial dumpsites visits. In CoK, approximately 232,870 tons of MSW is generated per year, MSW collection and transportation is done by private companies but the only dumpsite present in Kigali is fully controlled by the City of Kigali. Residents pay waste collectors according to their social classes and their locations. There is no official recycling system; recycling activities are informally performed by private companies and some wastes, like plastic bottles, are taken to Uganda and Tanzania to be recycled. This study found that the recycling rate was 10% contrarily to the 2% which is recorded by official sources. This study has contributed by filling the gap in literature on waste management for the city of Kigali and it recommends that the Government represented by the CoK should do more in terms of investing in SWM and creating a relationship between private waste collectors and local communities, and the private sector should be mobilized to invest in SWM activities.

1 Introduction

Global Waste Management Outlook (GWMO) defined municipal solid waste as the waste from households and small businesses and institutions [1], however, the GWMO notes that the definition varies widely from country to country: that in Rwanda, the Solid waste is defined as all decayable and non-decayable solid and semi-solid wastes, such as trash, garbage, paper, refuse, rubbish, and ashes [2]. [3] mentioned that, although a lot of work has been done to control municipal solid waste disposal in low-income cities in developing countries, there is still some way to go to phase out uncontrolled disposal. In order to deal with SWM problems in developing countries, methods should be developed that can address the local complexities [4]. Furthermore, an approach known as integrated sustainable waste management (ISWM) allows municipalities or districts to manage MSW at the lowest possible cost [5,6].

1.1 City of Kigali

The CoK is the capital of Rwanda, a landlocked country situated in the central/eastern part of Africa. Rwanda is bordered by Tanzania Burundi to the south. In 2016, the gross national income (GNI) per capita was US\$700, which is classified as a lower income economy. The CoK’s population represents a tenth of the country’s population. In 2012, 1,132,686 people resided in the CoK [7]. CoK has is now a home of around 1.5 million resident. CoK consists of three districts and it serves as the economic hub of the whole country. The CoK is facing critical challenges in solid waste management. The rapid increase in solid waste generation in the city and the improper disposal of the generated solid waste result in adverse impacts on health and environment, however, there is a lack of reliable data to assist decision makers for CoK’s solid waste management. to the east, Uganda to the north, Democratic Republic of Congo to the west and

1.2 Aim of this study

This study aims at analyzing the current state of MSWM of CoK, Rwanda by applying systems analysis

methodology of “wasteaware” benchmark indicators for integrated sustainable waste management in cities [8].

2 Methodology

The methodology adopted during this study is based on the city profiling methodology introduced by [1] and developed for UN-Habitat. The methodology was tested and used in more than fifty countries [9, 10, 11; 3]. This use validates the methodology [4].

In order to document and analyse the CoK overall system, a Sankey-style material flow diagram (MFD) was constructed using STAN2.5 software [12] (Figure 1)

The city profiling methodology is based on the integrated solid waste management (ISWM) concept [3]. Data were mainly collected during a 6-month period from May to October 2017, but verification took other four months (Up to February 2018) due to the complexity of municipal solid waste management in the CoK. Data were obtained from official reports and legal documents related to SWM in Rwanda, interviews with key personnel and operators, and also from official and unofficial visits to dumpsites.

3 Material flow analysis for the combined MSWM and recycling system in Kigali

Figure 1 shows the materials flow diagram (MFD) constructed to visualize the combined solid waste and recycling system in the CoK. The sources and methods used for each estimation in the MFD are summarized in Table 1.

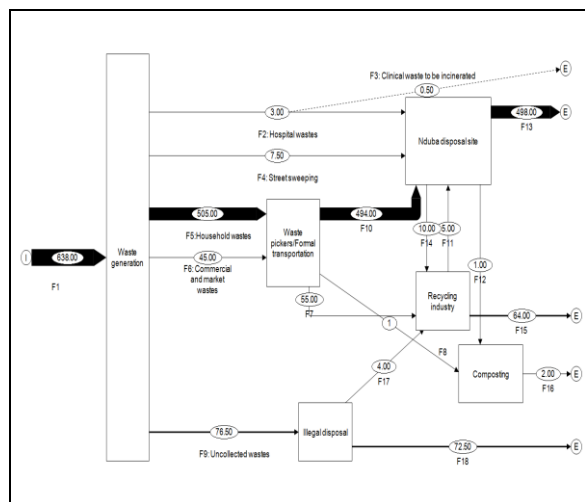


Fig 1. Sankey type material flow diagram (MFD) for MSW in the City of Kigali (the thickness of the flow corresponds to the waste value.)

There is an acute lack of data on waste management and recycling in CoK. There are no weighbridges in daily use, so use had to be made of data on the number of vehicles arriving at the site from each source and on average loads. In 2014, vehicles were weighed at Nduba disposal site and only two types of vehicles were

distinguished: one type carries 10 tonnes on average and the other 5 tonnes. Total waste generation is seldom measured. Here it is back-calculated from estimates of the quantities of waste collected and of collection coverage (see Table 1).

Table 1. Basis for calculating the waste flows for Kigali in the MFD

Flows	Description	Calculation	Basis for data
F1	Total Quantity of waste generated in Kigali-City	Official data give collection coverage as 88% $F1=(F2+F4+F5+F6)/0.88$	Back-calculated from collection coverage and other flows in MFD
F2	Waste from official Health Centers and Hospitals	Calculated based on the average load delivered by the vehicle. 3 vehicles a week each carrying average load of 5 tonnes. 15 tonnes over 6 days, 2.5 tpd collected.	Vehicle numbers and load size provided by the person in charge of Nduba disposal site
F3	Hazardous clinical waste (Incineration is used as treatment process)	Assumes 0.25 kg per bed per day (cf WHO guideline 0.2 (Haifete et al., 2016)). There are 2000 beds in the 5 main hospitals.	Estimate by authors, informed by WHO data
F4	Waste from street sweeping/ street litter bins	9 vehicles per week each carries 5 tonnes. 45 tonnes over 6 days = 7.5 tpd	Vehicle numbers arriving at Nduba disposal site
F5	Waste collected from door to door by the contracted private companies.	30 vehicles per day carrying 10 tonnes + 41 vehicles per day carrying each 5 tonnes.	Vehicle numbers and sizes arriving at Nduba disposal site
F6	Waste collected from commercial areas/markets	9 vehicles per day carrying each 5 tonnes	Vehicle numbers arriving at Nduba disposal site
F7	Wastes collected by the	Estimated at 10% of flows F4 and F5	Estimate by authors based on observation and

	private companies and separated by their employees for recycling	$F7 = 0.1 * (F5 + F6) = 0.1 * 550 = 55 \text{ tpd}$	interviews
F8	Organic wastes collected directly from the source and transported to compost plant	Very small flow. Estimated at 1 tpd	Estimate by authors based on observation and interviews
F9	Uncollected wastes	Waste collection coverage equals 88%. So, 12% is not collected. Then $F9 = 12\%$ of $F1$	Collection coverage calculated from official data
F10	Waste delivered to the dumpsite site from households, commercial areas and markets	Waste collected less the quantity separated for recycling $F10 = F5 + F6 - F7$	Calculated from the MFD
F11	Reject materials from recycling sent to Nduba disposal site	Estimate	Estimate by authors based on observation and interviews
F12	Organic waste sorted by waste pickers from Nduba disposal site, taken to composting plant	Estimate	Estimate by authors based on observation and interviews
F13	Dumpsite materials	$F13 = (F2 - F3 + F4 + F10 + F11) - (F14 + F12)$	Calculated from the MFD
F14	Waste sorted for recycling by pickers at the dumpsite site.	Estimate. Mainly plastic bottles, exported to Uganda and China	Estimate by authors based on observation and interviews

F15	Recycled materials	$F15 = (F7 + F17 + F14) - F11$	Calculated from the MFD
F16	Fertilizer from Compost plant.	$F16 = F8 + F12$. Quantities very small, so no attempt to correct for process losses.	Calculated from the MFD.
F17	Waste sorted for recycling by waste pickers on illegal dumpsites	Estimate	Estimate by authors based on observation and interviews
F18	Waste left in illegal dumpsites after waste picking	$F18 = F9 - F17$	Calculated from the MFD

4 Systems analysis of the MSWM and recycling in Kigali

4.1 Waste generation and composition

According to the most recent Rwanda Population and Housing Census (RPHC4), the population of Kigali in 2012 was 1,132,686 [7]. The growth rate since 2002 has been 2.6% per annum [7]; using this to extrapolate forward to 2017, the population used here is 1,574,000.

The MFD (Figure 1) estimated waste generation at 638 tonnes per day, or 233,000 tonnes per year. This corresponds to a per capita MSW generation of 0.41 kg/day, or 148 kg/year. No specific data could be located for waste composition in Kigali or Rwanda. We have used data from a 2012 planning study, which did not measure waste composition directly but instead used figures ‘typical for a low income country’: organics 70% by weight; paper 6%; plastic 5%; and metals 3% [13]. No data are available for waste density, moisture content or calorific value.

4.2 Waste collection

The official report from the Office of the Auditor General of State Finances, Rwanda mentioned that only 2% of solid waste is recycled, but our investigation has shown the recycling rate to be 10% (55 tonnes per day). The 10% rate represents separated wastes collected by private companies, from households and commercial areas for recycling. The basic system is that householders store their waste in individual containers, which are collected door-to-door once a week; while commercial areas and markets use communal containers (sizes of containers are 60, 120, 240, 660, 1100 liters) or walled collection bays (sizes of walled collection bays is

7x4x2.5 m³), from which waste is collected daily. The system works reasonably well, with three medium/high compliance scores of 15/20 and three of 10/20, giving an overall score of 63%, i.e. a medium/high assessment for the quality of waste collection and street cleaning.

4.3 Waste treatment and disposal

There is only one disposal site in Kigali city, called Nduba after its location in Gasabo district. The site started operations in 2012 and is run by the City. Nduba scores 5 or 10/20 on the three ‘quality criteria’, which categorises it as semi-controlled, below the threshold set for controlled disposal. As there is no controlled disposal facility in use in Kigali, the Wastaware ‘controlled disposal’ indicator is 0%. The quality indicator is rated Medium/Low (30% score)

4.4 Resource Management

The overall assessment is Low/Medium, with a score of 33% In the CoK, awareness support for waste separation at the source (householders and offices) is very high but people do not separate waste at the source. In the past, communities used to sort and separate the waste at the source, but due to irregular collections they lost trust in the waste collectors. Regular collection of the sorted waste increases trust from service users [14].

4.5 Governance

4.5.1 User Inclusivity (UI)

The benchmark indicator for user inclusivity assesses citizens’ and other waste generators’ inclusion in the waste management system. The overall assessment is medium/high, with a score of 71%. Access of users to services is generally good. Numerous systems are in place for citizens to make their voices heard, including environmental committees at 4 levels of local government from the ‘cell’ upwards, which then pass on their concerns either at formal monthly meetings with CoK officials, or through the monthly ‘Umuganda’ community service day. The CoK carries out proactive public awareness and education, but is constrained by lack of resources. The evidence for people actually ‘doing the right thing’ is also strong.

4.5.2 Provide Inclusivity (PI)

The score here was found to be 55 which represents medium as an overall assessment. Generally In the CoK, private companies in charge of SW collection provide high quality *service*.

4.5.3 Financial Sustainability

Financial sustainability benchmark indicators assess how the city’s SWM service is financially sustainable. Total score is 50% which corresponds to medium as an overall

assessment. According to one in charge of SWM under the CoK, the budget allocated to SWM is not sufficient.

4.5.4 Sound institutions and proactive policies: National SWM Framework

These benchmark indicators assess the adequacy of the national solid waste management framework; this assessment also includes the degree of implementation. The overall assessment is medium, with a score of 58%. In Rwanda there are a lot of legislations and regulations on SWM but their enforcement is weak (for example there is prohibition of manufacturing, importation, use and sale of polythene bags in Rwanda but still some people use plastic bags illegally entered into Rwanda).

4.5.5 Sound institutions and proactive policies: Local Institutional Coherence

These assess the institutional strength and coherence of the city’s solid waste management functions. The overall assessment is medium, with a score of 50%.

The level of collaboration between governmental institutions and private companies is sufficient. Data availability is limited at Nduba disposal site (no weighbridge, nothing about waste generation etc...). There is an urgent need to improve data collection, reporting methods and monitoring methods.

5 Discussion

This study has assessed the CoK’s MSWM. People in the CoK generate wastes equal to 232,870 tonnes/year and waste generation per capita is equal to approximately half (405g/capita/day) of a higher waste generating city (above 1 kg/capita/day). This explains that the CoK belongs to lower generating cities and then there is no urgency of waste reduction, apart from the issue to take critically the diversion from treatment and disposal to recycling.

For public health-waste collection category, CoK showed a strong performance. Regarding, the environmental control-waste category, CoK performs well, however, there is still more to be done, CoK should make efforts to improve environmental protection measures, a waste treatment plant should be built at Nduba disposal site, leachate should be controlled and workers at Nduba disposal site should be protected. The score for recycling rate was low and this shows that Rwanda needs a strong improvement in order to increase the recycling rate. For CoK, 3R (reduce, reuse, and recycle) quality indicators scored 33%. This score is classified as low-medium performance and in order to improve 3R quality indicators the CoK should urgently start concentrating its efforts on recycling activities.

Table 2. Wastaware benchmark indicator results for Kigali city

No	Category	Indicator		
	City		Kigali	
	Country		Rwanda	

Background information on the city			
	Country income level	World Bank income category	Low
B1		GNI per capita	\$700
B2	Population	Total population of the city	1,574,434
B3	Waste generation	MSW generation (tones per year)	232,870
Key waste-related data			
W1	Waste per capita	MSW per capita (kg per year)	148
W2		Waste composition	
W2.1	Organic	Organic (foods and green waste)	70%
W2.2	Paper	Paper and card	6%
W2.3	Plastic	Plastic	5%
W2.4	Metals	Metals	3%
Physical components			
1.1	Public health-waste collection	Waste collection coverage	88% (M)
1.2		Waste captured by the system	88% (M)
1C		Quality of waste collection service	63% (M/H)
2	Environmental control-waste	Controlled treatment and disposal	79 (M)
2E		Degree of environmental protection in waste treatment and disposal	30 (L/M)
3	Resource management- reduce, reuse and recycle	Recycling rate	10% (L/M)
3R		Quality of 3Rs- Reduce, reuse, recycle-provision	33% (L/M)
Governance factors			
4U	Inclusivity	User inclusivity	71% (M/H)
4P		Provider inclusivity	55% (M)
5F	Financial sustainability	Financial sustainability	50% (M)
6N	Sound institutions	Adequacy of national SWM framework	58% (M)
6L	Proactive policies	Local institutional policies	50% (M)

For user inclusivity qualitative indicator (4U), the score was good (71%) and only needed improvement in the consideration of local communities' contributions to decisions. Regarding the provider inclusivity qualitative indicator (4P), the score was 55%. The most needed improvements are the representation of the private sector and the integration of the informal sector into the formal WMS because they have knowledge on waste composition and recyclables [4].

The score for financial sustainability was found to be 50% and below for four cities out of five except Maputo which scored 67%, this shows that the financial sustainability of the SWM system is a major challenge in the CoK and in other cities of developing countries [4]. This financial sustainability challenge can be overcome by sensitizing the private sector to invest in solid waste management and sensitize local communities to work closely with the private sector. In the eyes of local communities, private companies in charge of waste collection are seen as companies which are only after money. A lot of effort should be made to build a strong relationship between the private sector and local communities. The city has good policies, strategies, legislation and regulations but the problem is the implementation. For example, CoK has ten sets of good strategies but none of them has been implemented so far

(6N). Government institutions and the CoK (6N and 6L) in particular have to make sure that all those good strategies and policies are fully implemented.

6 Conclusions and recommendations

This paper has presented the SWM profile of the CoK. The country has adopted a lot of strategies to protect the environment such as the legal ban on use of non-biodegradable plastic bags. Despite making a lot of effort towards SWM improvements, there are still considerable improvements to be made. The study showed that data such as moisture content and solid waste density are not known. In order to raise the standard of solid waste management in the CoK, this lack of data problem should be addressed.

In order to conduct this study a systems analysis methodology of "wasteaware" benchmark indicators for integrated sustainable waste management in cities was applied. For allowing a visualization of the MWMS in the CoK a MFD diagram was provided to accompany the "wasteaware" benchmark indicators.

This study estimated the MSW generation rate in the CoK at 0.405 kg/capita/day with a total 638 tonnes per day of waste. In order to estimate the waste generation per capita, the number of vehicles bringing waste at Nduba disposal site of the City of Kigali were used. The major information found during this study is the recycling rate of 10%, which is contrary to the recycling rate from official sources (2%). In terms of sound institutions and proactive policies, both national SWM and local institutional coherence are rated medium (the scores were 58% and 50% respectively). The only needed improvement here is to monitor the implementation of suitable proposed policies/strategies.

Government represented by the CoK should do more in terms of creating a relationship between private waste collectors and local communities so that local communities stop looking at these private companies as only money-oriented companies. The private sector should be sensitized to invest in SWM activities. The CoK and private waste collecting companies should also improve working conditions for their workers.

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