Journal of the Air & Waste Management Association

ISSN: 1096-2247 (Print) 2162-2906 (Online) Journal homepage: https://www.tandfonline.com/loi/uawm20

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To cite this article: Joel R. Kinobe, Charles B. Niwagaba, Girma Gebresenbet, Allan J. Komakech & Björn Vinnerås (2015) Mapping out the solid waste generation and collection models: The case of Kampala City, Journal of the Air & Waste Management Association, 65:2, 197-205, DOI: 10.1080/10962247.2014.984818

To link to this article: https://doi.org/10.1080/10962247.2014.984818

TECHNICAL PAPER

Mapping out the solid waste generation and collection models: The case of Kampala City

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This paper presents a mapping of the waste collection systems in Kampala city, using geographical information system (GIS) ArcGIS mapping software. It discusses the existing models of waste collection to the final disposal destinations. It was found that food and yard wastes constitute 92.7% of the waste generated in Kampala. Recyclables and other special wastes constitute only 7.3% of the total waste, mainly because of the increased level of reuse and recycling activities. The generation rate of solid wastes was on average, 582, 169, 105, and 90 tons/day from poor areas, upscale wealthier areas, business centers, and market areas respectively. This tonnage of waste was collected, transported, and disposed of at the city landfill. The study found that in total, residential areas of poor people generate more waste than other categories stated earlier, mainly because of their large populations. In total, there were 133 unofficial temporary storage sites acknowledged by Kampala Capital City Authority (KCCA) but not formally designated, 59 illegal dump sites, and 35 officially recognized temporary waste storage locations. This paper presents large-scale data that can help with understanding the collection models and their influence on solid waste management in Kampala city, which could be used for similar cities in developing countries.

Implications: The rapid urban population growth in Kampala City has increased the generation of waste, making it impossible for the municipal authority to manage the waste effectively due to limited financial resources. All this, coupled with the declining landfill capacities and rising real costs of disposal, has attracted the attention of the growing population, yet the health and sustainability of the environment have to be guaranteed.

Introduction

Waste management has continued to be an increasing challenge to many city authorities in most Sub-Saharan Africa (SSA) countries (Wilson et al., 2006, Rotich et al., 2006). Migration of rural population to urban areas has escalated the rate of urbanization and increased population densities, yet these cities lack the capacity to effectively and efficiently handle the waste management service due to the high costs involved (Oteng-Ababio et al., 2013). Concurrently, lack of enough resources has made it difficult to effectively implement municipal waste management policies (Cointreau, 1982). In most developing countries, especially in Sub-Saharan Africa, the limited budget for waste management is partly due to the presence of more pressing priorities such as hunger, health problems, water shortages, and unemployment (Zurbrugg, 2002). Oteng-Ababio et al. (2013) noted that this occurrence is more pronounced in the urban poor settings, where waste is left lying on the ground uncollected for weeks. Abandoned waste on streets ends up in drainage channels, is burned in the open, and when left to decompose attracts breeding pests and animals, thus causing more environmental hazards and potential health problems (Jin et al., 2006).

Kampala city has five divisions, namely, Central, Nakawa, Makindye, Rubaga and Kawempe. The population of Kampala city is rapidly increasing, with an estimated growth rate of 3.7% per annum (Uganda Bureau of Statistics [UBOS], 2002). Current estimates suggest that the nighttime population of Kampala is approximately 1,900,000 people, and this doubles during the day (UBOS, 2012). The increase in population, coupled with improved incomes as a result of economic growth in the city, has led to increased generation of waste (Pattnaik and Reddy, 2010). Income increases change the living standards of people, as well as their lifestyle and food habits, and encourage shifting to a "use and throw" culture.

It was estimated that about 2,500 tons of waste was generated in Kampala city per day, of which about 35–40% was

Journal of the Air & Waste Management Association, 65(2):197–205, 2015. ISSN: 1096-2247 print
DOI: 10.1080/10962247.2014.984818 Submitted May 13, 2014; final version submitted October 10, 2014; accepted October 28, 2014.
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collected and transported to the dumping site at Kiteezi (Kampala City Council [KCC], 2006, Mugagga, 2006). Kampala Capital City Authority (KCCA) is the government body responsible for effective management of waste but has failed to implement its duty effectively due to several factors, including fiscal, material, technical, human resource, and social (Okot-Okumu and Nyenje, 2011). To improve the efficiency of managing waste collection in Kampala, KCCA partly outsourced the service of waste collection to various private operators to provide the service more efficiently. However, in spite of this, waste collection in Kampala has not improved significantly. One of the causes of this occurrence is that the waste dumping sites in Kampala are not well known to the authorities and are thus left unattended.

Kiteezi landfill is the only authorized landfill. It was initially designed with a total surface area of 0.04 km^2, but was recently extended beyond its capacity to reach 0.11 km^2. Additionally, Kiteezi is located in a wetland and some parts of the landfill do not have a liner. Therefore, untreated leachate from the landfill discharges directly underground, threatening water supplies (National Environment Management Authority [NEMA], 2004; KCC, 2006).

The main objective of this study was to map the waste collection in Kampala city, in order to analyze the current waste management problems and practices. In addition, this work targeted waste characterization and quantification in the city of Kampala. Furthermore, the waste collection models were described, including authorized (public and private) and illegal activities.

Methodology

Data collection

Primary and secondary sources of data were used. Primary data were obtained from (1) KCCA staff, including the records manager, 5 collection supervisors (one of each division), 5 truck drivers, and 20 waste pickers; (2) private waste industry, including 10 waste recycling firms and 4 collection companies (Nabugabo Updeal Joint Venture, BIN IT Services, Globe Clean Services, and BINS Kampala); and (3) citizens and workers, including 10 household owners from each of the 5 divisions and 5 people working or living near temporary storage sites. Secondary data were obtained from the review of academic research journals, government documents, books, and consultancy reports.

Waste generation and composition. Waste generation data at Kiteezi landfill were collected for a period of 7 months, from December 2011 through June 2012. Trucks that collect solid wastes were weighed at the weighing bridge located at the entrance to Kiteezi landfill and the weight was recorded (W1). After tipping solid wastes, the trucks were weighed again (W2) and the solid waste load was calculated as the difference between W2 and W1. The waste from different areas was quantified and categorized according to five socioeconomic groups: poor areas, medium to upscale wealthier areas, institutions, business centers, and market areas.

To obtain waste composition, two KCCA trucks from each division were randomly picked biweekly for a period of 2 months and the waste was separated into categories of food and yard wastes, plastics, paper, glass, metals, and other special wastes like medical waste. This involved collecting, sorting, and weighing of individual categories of the waste streams. An area at the landfill about 7 m in length and 3 m wide was leveled flat by a grader, and on this, waste trucks dumped heaps of waste approximately 1 m high as directed by the researchers. The waste heaps were then spread on the flat ground using a forked hoe. This was done under researcher supervision with help from selected waste pickers at the landfill. The waste was categorized and deposited on a cleared area covered with a high-density polyethylene (HDPE) liner and then weighed. The purpose was to know the composition of waste from Kampala city.

Waste collection dumping sites. In order to determine a set of the different dumping scenarios that are common in the city, three types of dumping sites were studied:

(1) Official temporary storage sites are the sites that were demarcated as KCCA waste collection dump sites. Originally these were temporary storage sites where KCCA skips were located, but after the introduction of the compactor trucks, these skip temporary storage sites were removed. These sites are normally at the market areas, public parks, public organizations, and roadsides.
(2) Unofficial temporary storage sites are those sites that are not demarcated by KCCA but are being used by people for dumping waste such that these wastes are collected by KCCA. They are mainly along unrecognized places like roadways, open spaces, and drainage channels. They are called unofficial temporary storage sites because they were not recognized by KCCA as official temporary storage sites. A daily schedule for this type of temporary storage sites is provided by KCCA along with the legal sites, although most times, the waste from temporary storage sites is not effectively collected.
(3) Illegal dump sites are those where people dump waste and the waste is not collected by KCCA. The waste is left to rot, creating a nuisance to the community, and some of it is burned by a concerned person.

Data analysis

A geographical information system ArcGIS mapping software system was used to map out the official, unofficial, and illegal temporary dumping sites and their locations. The location points for each temporary storage site were recorded using a geographical positioning system (GPS). The stored data on the GPS captured were in Universal Transverse Mercator (UTM) readings. GIS was used to capture, store, and handle spatially referenced data.

Results

Waste generation and management

Waste composition. The major components of wastes generated were food wastes, vegetation (leaves and stalks, spoiled market residue), paper, plastic, packaging materials, construction debris, broken glass, textiles, ashes, street sweepings, and metal scrap (Table 1). A high percentage, 92.7%, was organic waste. Major foods eaten by people were bananas (*matooke*), cassava, sweet potatoes, yams, Irish potatoes, fruits, and vegetables.

Waste collection by Kampala Capital City Authority (KCCA). It is the mandate of KCCA to ensure that the waste is collected, transported, and disposed of in a manner that satisfies both public health and environmental conservation requirements. This is clearly articulated in the Kampala Solid Waste Management (SWM) ordinance of 2000 and the Local Government Act of 1997.

Before the SWM ordinance of 2000 was passed to involve the private operators in waste management, skips were provided as the official temporary collection points of waste. The skips were unsuitable because waste was scattered around them, due to delayed collection, and also residents would not accept having skips located in front of their houses.

KCCA is currently focusing on waste management due to public concerns and the impacts caused by wastes on the environment. Consequently, KCCA has awarded contracts to the private sector to manage waste, an action that is provided for in the legal framework for waste management under the Local Government Act and laws of 1997. KCCA vehicles are responsible for disposing of approximately 946 tons/day to Kiteezi landfill, and this tonnage represents about 70% of the waste generated in the city.

Waste collection by private operators. Currently, more than 35 solid waste private operators are providing the waste collection service with little or minimum regulatory framework or guidance from KCCA. For instance, the trucks used are not recommended for waste collection and on many occasions litter the city, thereby complicating the garbage collection arrangement. On many occasions the trucks are overloaded, and the waste loaders live a risky life of handling waste without protection, as well as traveling on heavily loaded trucks. Private operators hire street children who are normally picked up scavenging on the dump sites to act as waste loaders because they can be easily lured into this job with very little pay. Despite this, private operators have greatly contributed to solid waste collection in Kampala city.

Table 1. Percentage composition of waste generated in Kampala City between December 2011 and June 2012

Type of waste	Percentage (%)
Organics (food waste, market residuals, vegetation)	92.66
Plastics (soft and hard)	3.72
Papers (packaging)	1.62
Glass (broken glass)	0.68
Textiles (rugs)	0.50
Metals (scrap)	0.16
Others (special waste)	0.66
Total	100

Waste disposal at landfill. On a daily basis, there are more than 500 waste pickers in Kiteezi who search for recyclables of all kinds, ranging from plastics, scraps, and clothes to food leftovers, and they sell the recyclables to private middlemen and plastic recycling companies. The landfill is an open space with limited restriction for entry, especially when it comes to the waste pickers, who take all actions by themselves. However, there are no clear definitive conclusions that can be made on how much waste is recycled or reused, due to the current lack of information.

Waste collection models

The waste management system involves a number of complex processes including socioeconomic, technical, managerial, and environmental ones, such as waste generation, transportation, treatment, and disposal. A multimodel system on how waste is transported within Kampala city, from the city to the disposal area, and thereafter, from the disposal area as goods in the form of recyclables to different reprocessing destinations, is presented in Figure 1. The only materials that are buried are the rotten food waste, street sweepings, glass, batteries, rags, and some compound vegetation cuttings.

Model 1, Poor areas/households. In this model of waste collection (Figure 1), waste is first stored in primary storage bins, containers, or used plastic sacks at household level until it accumulates to about 30–50 kg. The households then transport it to unofficial collection dump sites for secondary collection by KCCA or its contractors. The distance from the household premises to the dump site normally does not exceed 300 m. The dump sites are located along the main roads, next to drainage channels, or on open land, making them unofficial dumping sites. The households are located in informal areas inhabited by low-income earners, characterized with poor accessibility and poor living conditions, and the main wastes produced are food and yard wastes. In this model, there is a community self-loading system. In this system, the KCCA trucks drive through an area and then the community members bring their stored waste and load it onto the truck. The wastes are stored in buckets and old plastic sacks. KCCA is the main operator responsible for the waste management in these areas. The main truck types operating in these areas are the compactors, dumper/tipper trucks, and tractors.

Model 2, Upscale residential areas and institutions. Model 2 includes upscale residential places and institutions (hospitals; educational centers; clinics; clubs; industries) (Figure 1), occupied by the more affluent members of society from places such as Kololo, upper Naguru, Muyenga, Bugolobi, Ntinda, and the city center. In these places, solid waste is temporarily stored in demarcated legal

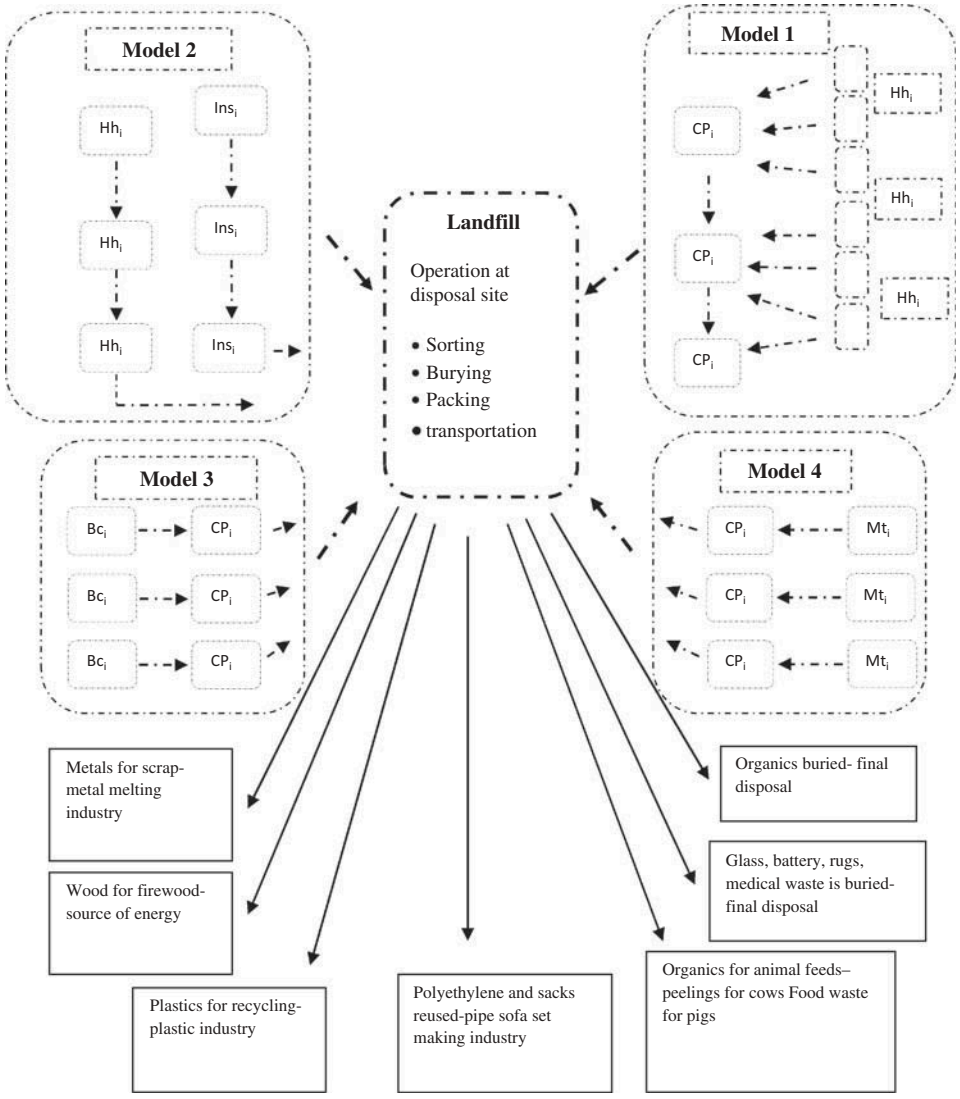

Figure 1. Multi model waste management supply chain: CP, collection point; Hh, household; Ins, institutions; Bc, business centers; and Mt, markets.

places or kept in polyethylene bags at the household. Waste collection from these areas is largely done by the private operators and to a small extent by KCCA, especially for tree cuttings. The garbage from the households is placed in polyethylene bags that are provided by the private operator companies. The private companies collect the polyethylene bags containing solid wastes after they have been placed along the streets by the collectors or from their houses and/institutions daily, or once to five times per week depending on the agreed collection frequency. Households pay a monthly fee that ranges from 30,000 to 70,000 Uganda shillings (United States Dollars (US$12 to US$28) and institutions pay 30,000 to 100,000 Uganda shillings (US$12 to US$40) for collection and transportation of waste that is undertaken by private operators. In both cases, the fee depends on the quantity of waste generated and the agreed frequency of collection, where more collection times per week reflect higher pay. Willingness to pay for the service in these areas is high, thereby making collection of wastes less problematic.

Model 3, City center and business areas. Waste collection in this model includes collection in the central business center and commercial areas of Kampala city (Figure 1). The business center in Kampala generates a range of wastes, from light-density waste such as the plastics from water bottles, polyethylene bags that store the products, packaging paper, and textiles, to high-density wastes that comprise biodegradables, wet ash, sand, soil, and stones, especially from the restaurants and scrap from downtown markets. The main actors in solid waste collection are KCCA and private operators. The central business areas are mainly managed by the private operators, where the beneficiaries pay a monthly fee of 10,000 to 100,000 Uganda shillings (US$4 to US$40) per shop located on a particular building. Plastic bags and bins of differing colors according to a particular private company are provided and given to the waste generators and later collected by the subsequent company.

Model 4, Market areas, public park areas, street sweepings, and drain channels de-silting. Kampala City has a total of 13

major markets that are located in the 5 divisions of the city. These markets include, among others, Nakasero market, Kiseka market, Nakawa market, Kamwokya market, Kalerwe Market, Kasubi market, Nakulabye market, and Katwe market. Waste management in the markets is undertaken by KCCA, and each division caters to its markets (Figure 1). Markets generate tons of waste every day, composed of mainly food and yard wastes. All activities involving street sweepings and drain channel de-silting generate waste that is managed by KCCA.

Comparing the models. Poor areas generate a monthly average of 17,449 tons (over 60%) to the landfill as a result of high population densities, and this is profound in the slum areas. The upscale residential areas then follow with a monthly average of 5,059 tons, and this is attributed to the fact that waste collection and transportation is done by the private operators. The business centers follow with a monthly average of 3,139 tons and the marketplaces model with a monthly average of 2,700 tons (Table 2). Waste collection was wholly done by KCCA in the poor areas and markets, totalling about 71% of the waste from Kampala to the landfill. The private operators managed about 29% of the waste collected and transported to the landfill, which came from business centers and upscale residential areas (Figure 2).

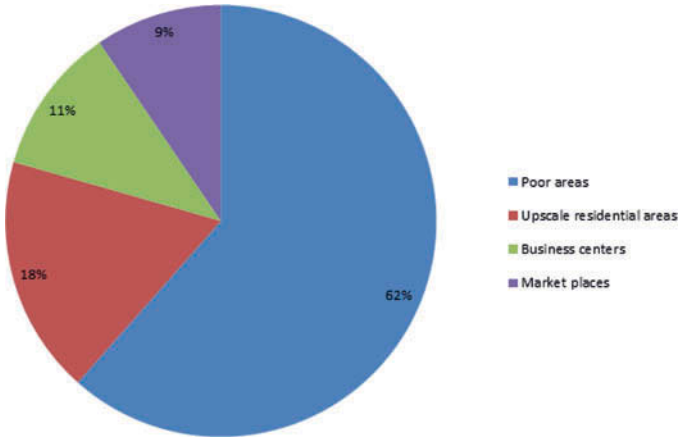

Figure 2. Comparing percentage waste collection per model.

Waste dumping types and their locations

In total, 227 dump sites were located and mapped in Kampala city. There were more unofficial temporary storage sites (133, constituting 58%) than the illegal dump sites (59, constituting 25%) and official temporary storage sites (35, constituting 17%) (Figure 3).

From the current investigation, Kawempe division had more dumping sites (89) than any other division and Makindye had the least number of dump sites (23). Rubaga division had more open spaces (30) as illegal dump sites, and the Central division had only one illegal dump site. Nakawa division recorded more official temporary storage dumping sites, while Makindye had only one official temporary storage dump site. Likewise, Kawempe division registered more unofficial temporary storage dump sites (57), compared to Nakawa with only 15 unofficial temporary dump sites (Figure 4 and Figure 5).

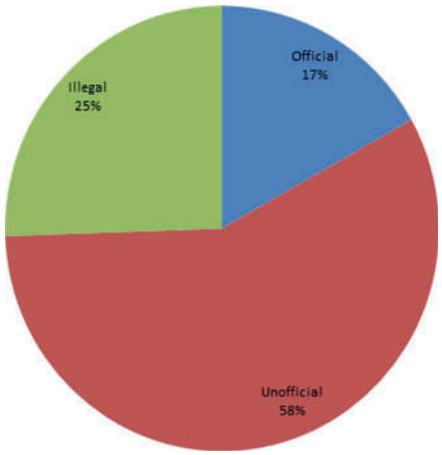

Figure 3. Percentage dumping options in Kampala City.

Discussion

Waste generation and management issues

Waste generation in Kampala city has increased with an increase of population. About 1500–2500 tons/day of waste is generated in the city (KCC, 2006; NEMA, 2008). This is consistent with our data from the study of 946 tons/day that

Table 2. Generation of wastes per model and quantity of waste collected

Model number	Model system	Average monthly collection (tons)	Waste collection per day (tons)	Percentage distribution (%)
1	Poor areas	17 449	582	62
2	Upscale residential areas	5059	169	18
3	Business centers	3139	105	11
4	Market places	2700	90	9
Total		28 347	946	100

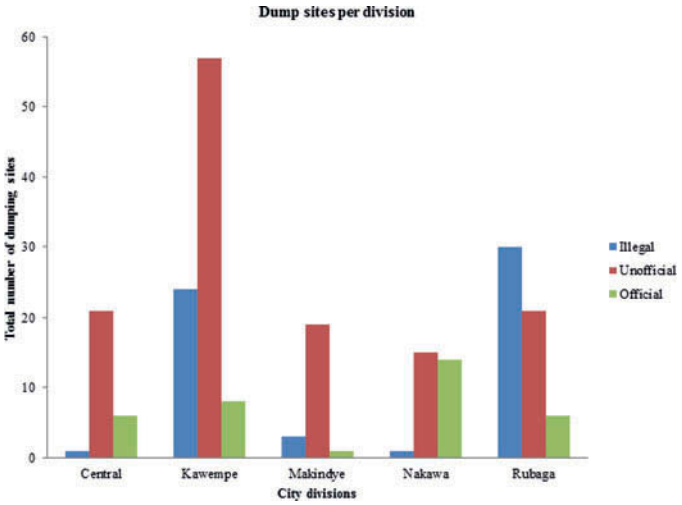

Figure 4. Comparative distinction of dump sites within the divisions of Kampala.

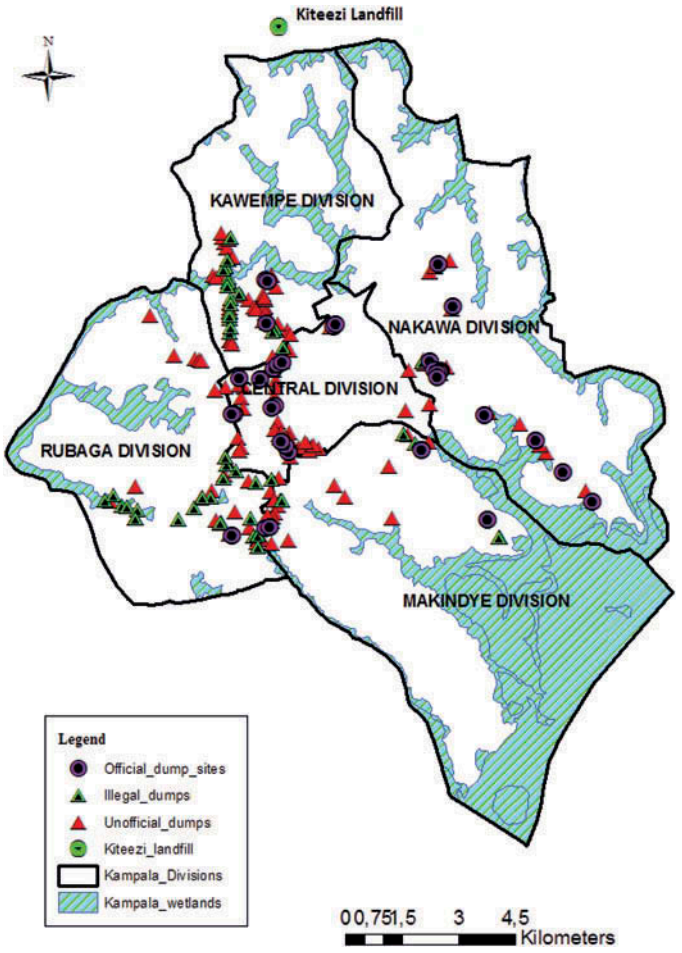

Figure 5. Locations of dumping sites within the 5 Divisions in Kampala city.

was collected and transported to Kiteezi landfill, which represents about 40% of all waste generated. Solid waste collection is lacking in slum areas, given the low collection frequency and inadequate services by the Kampala Capital City Authority (KCCA). KCCA is responsible for the collection, transportation, and disposal of all wastes generated in Kampala city, to satisfy both public health and environmental conservation requirements. Most of the houses in slums are inaccessible by refuse collection vehicles due to poor road network (Hui et al., 2006; Hazra and Goel, 2009). The refuse management situation in these areas is therefore very pathetic, with garbage strewn all over the place. The study established that the largest percentage of waste generated constituted food and yard wastes, and this was in line with both Mukwaya (2004) and Mukisa (2009).

Uncollected waste was illegally and indiscriminately dumped in open spaces along roadsides and streets, water bodies, and drainage channels that are eventually blocked, leading to a filthy environment. The filthy environment is prone to flooding, and diseases like cholera and diarrhea, as well as to mosquito breeding, which exacerbates the malaria situation. This poor waste management has caused unpleasant sanitary conditions (Kanat, 2010). Additionally, the scattered waste takes more time to load into the collection vehicle, resulting in lower vehicle productivity.

Waste management in Kampala city is characterized by exposure of waste collectors to hazards; for instance it involves carrying heavy loads comprised of rotting organic matter that is contaminated with pathogens and other hazardous substances, especially from medical waste (Sharholy et al., 2008). Furthermore, unofficial dumping sites were invaded by scavenging people and animals, paving the way for even more pollution and transmission of diseases. This was attributed to limited financial resources provided by governments to effectively collect waste (Pearce and Turner, 1994; Zurbrugg, 2003; Teixeira et al., 2004).

Unplanned waste transport caused delays due to traffic congestion. Moreover, the locations of most of the dumping sites along the roads made it difficult to load waste. In most cases, the trucks parked in the road while loading, causing traffic problems. Bad road conditions led to the breakdown of trucks due to many potholes. Most municipal waste collection and transportation vehicles were unreliable because they were not suited for the work they did or the conditions they worked in, or because they were not properly maintained. There was no scheduled planning of vehicles arriving at the final disposal site, and of those that were available, in most cases trucks were in poor condition and were driven carelessly or misused in other ways, causing constant breakdowns on the roads and also leading to high costs to operate, as reported by Imam et al. (2008).

Okot-Okumu and Nyenje, (2011) noted that through decentralization, there is equitable distribution of resources between the central government and its local governments; this will lead to efficient and effective solid waste management, if properly implemented. The challenge is how the approaches of decentralization and privatization are delivered. For instance, in the context of Kampala, the operations of most of the waste management contractors face political interference, according to particular political parties that win the elections, in terms of who to award the contract to. Besides, some private companies come up with models copied from the developed world with a totally different technical, financial, and organizational framework from that of Uganda.

However, involvement of the private sector in solid waste collection is contributing tremendously to solving the solid waste management problem in the city of Kampala. About 30% of the total waste that reached the landfill was collected by private operators. Contracting private operators in solid waste collection will mean high efficiency because they capitalize on the weakness of KCCA and give better services. However, the private sector operators should be closely monitored by KCCA. They normally charge highly for the service of waste collection.

The collected waste was disposed of in the uncontrolled open and partially lined landfill. This provides susceptibility to both surface-water and groundwater pollution (Kaseva and Mbuligwe, 2005). The landfill was located in a wetland, and although it had a leachate treatment plant, leachates were normally seen flowing into the nearby water streams. Another scenario at the landfill was that the waste pickers washed their picked items in the streams, thus increasing the pollution load. Waste pickers play an important role in reducing the amount of waste produced through separation and sale of recyclable materials. However, by this practice, waste pickers are exposed to hazardous waste and harmful gases, as well as risking injury by garbage trucks when struggling for the recyclable items.

At the landfill, solid waste that was combustible was burned by the scavengers, which reduced its volume. But this is dangerous because the waste is not segregated, thus including a mixture of different wastes like medical and industrial wastes, which when burnted produce dioxins, furans, and other substances. If inhaled, these substances cause health hazards to the surrounding community (Hu et al., 2002; Jang et al., 2006). Source separation could be the easiest and simplest solution, involving a systematic division of waste into designated categories. This will reduce incidences of cross-contamination with dangerous waste streams. Therefore, source separation should be advocated for and undertaken at household level to avoid contamination with medical, industrial, and farm wastes.

Models of collection systems

The Model 1 collection system is detailed in the Results section. The areas of operation were characterised by a narrow road network, where trucks cannot reach and if they reach, then they soon breakdown due to potholes. Hence, the waste that was generated had to be transported to a nearby dump site. Waste collection in these areas was very irregular and unreliable (Vidanaarachchi et al., 2006, Gupta et al., 1998). A lot of illegal dumping was evidenced in this model. Consequently, spillages and littering were frequent, and these cause environmental health risks. The major factor for inefficient collection was the inadequate resources by the government and authorities to comprehend the implications that arise from the pollution caused by solid waste. Model 2 was undertaken by the private companies, who provided storage bags to the households and later picked up the waste at an agreed collection frequency. The problem with the storage polythene bags issued by the private collectors was that they are subject to scavenging animals and people, because they are normally left outside the residential house (Wilson et al., 2006) The affluent members of the society who stay in such places normally work in high-profile government offices and may influence political decisions, making it easier to intervene in the waste collection in their areas. In Model 3, collection was done by both KCCA and the private companies. The temporary storage sites are legally demarcated by the two collection parties (KCCA and the private operators) but then KCCA plays an extra role through the collection of waste that has been indiscriminately dumped or left uncollected by the private operators. This happens with private companies that are incompetent in service delivery.

Another challenge that leaves uncollected wastes was that some private operators transfer waste from their designated collection points and take it to KCCA temporary collection sites, which adds more burden to the KCCA waste management approach. Model 4 was managed by KCCA as it was responsible for keeping the city clean. However, it was faced with challenges in the management of wastes, including, among others, bureaucracy and delays from the division headquarters to provide vehicles to transport the wastes, limited communication between the division waste supervisors and municipal administration, and political interference by leaders who do not follow strategic planning and policies but rather engage in daily waste management. In the case of illegal dumping site in this model, the frequency of collection is determined by the rate of waste decomposition and the offensive odors emitted, according to subjective judgment. The greater the odor emitted, the more attention is given by KCCA, and then the collection is organized.

Waste dumping sites

Generally, most of the temporary storage dumpsites are located along the main roads of the city or next to drain channels. The essence of this was that there was no accessibility to many of the places where a waste dump may be located. This is more pronounced in the slum towns of Kampala city. For quite a long time, KCCA was the sole organization responsible for the collection, storage, and disposal of solid waste by law (Katusiimeh et al., 2011; Mugagga, 2006). However, the introduction of private waste operators in 2006 has seen an increase in waste collection (Mugagga, 2006; Okot-Okumu and Nyenje, 2011; Kaseva and Mbuligwe, 2005). The study revealed that private operators collected and transported approximately 30% of the waste to the landfill. However, there are limited private waste collectors in the slum areas, due to the anticipated poverty levels and the lack of willingness to pay for the services (Mugagga, 2006; Katusiimeh et al., 2011). Waste collection on a private basis in the slum areas is mostly done individually or by some youth group that approaches a particular household so as to provide the service of waste collection at a low fee. The wastes are then collected and mostly deposited at a dumpsite that is an unofficial temporary storage dump site where KCCA later collects and takes the wastes to the landfill.

Many unofficial temporary storage sites were found in the Kawempe, Makindye, and Rubaga divisions because these areas are inhabited by low-income earners who are unwilling to pay for waste collection, and the vast majority of these people live in unplanned inaccessible areas, which cannot be

reached by KCCA trucks. Illegal dumpsites were more prevalent in Rubaga and Kawempe divisions because these areas have vast open bare land, which gives the opportunity for people in these areas to indiscriminately dispose of solid waste (Figure 5).

The official dumpsites that KCCA demarcated as its waste collection sites that it would serve were few because KCCA contracted private operators to handle waste. Nakawa division had more of the official dumpsites due to the availability of many institutions, and the division had the highest share of the annual budget allocated to solid waste management, compared to the other divisions (KCC, 2006). The division is home to many affluent people who have the capacity to politically influence waste management strategy.

There was no integrated legal framework to deal with waste management in Kampala city. The available legal provisions related to solid waste management are weak, fragmented, and not specific, such as laws for public hygiene, environmental conservation, and health. This situation has hindered the effective implementation of waste management operations (Marshall and Farahbakhsh, 2013). Coupled with organizational and structural problems, the lack of an effective legal system and technical standards has affected waste management. For instance, recycling is not typically undertaken on a formal municipality-wide scale, yet this existing trend should be encouraged, improved, and legitimized by local governments. An enforcement mechanism that aims at reorganizing urban environmental programs that will incorporate capacity building between the public and private partnership, targeting public health and hygiene, should be emphasized. The privatization process has already been in place in Kampala with the aim of improved waste handling services, but the private companies are more centered on profit making. This reason explains why private companies do not operate in the low-income areas.

Conclusion

The total solid waste generated from Kampala city that reaches the Kiteezi landfill is, on average, 946 tons/day, and this represents about 40% of the total wastes generated. By source, the solid waste comprises 582 tons/day from the poor areas, 169 tons/day from upscale residential areas, 105 tons/day from business centers, and 90 tons/day from markets. The composition of waste generated in Kampala city was mainly organic, including food leftovers from households, market residual, leaves, stalks, and vegetation cuttings amounting to 92.7%, and the remaining 7.3% was papers, plastics, metals, glass, and other wastes.

Solid waste management in Kampala is characterized by inefficient collection methods, insufficient coverage of the collection system, and improper disposal of municipal solid wastes. Waste collection in Kampala is done by KCCA and private companies that are contracted by KCCA. About 70% of the waste collected and transported to Kiteezi landfill is handled by KCCA and about 30% by private operators.

Officially designed dump sites by KCCA were few (35) compared to the unofficial (59) and illegal ones (133). Most of the official sites were found located in Nakawa division due to the high share of waste management budget and availability of institutions, while the unofficial temporary storage sites were more in the Kawempe, Makindye, and Rubaga divisions. Illegal dump sites were most numerous in Rubaga and Kawempe divisions because of the available open spaces that lure the community to dump waste.

The identified models of solid waste collection in the city were four. In Model 1, common in poor areas, the waste is collected by KCCA and is up to 62% of the waste dumped in Kiteezi landfill. Model 2 has the upscale residential places and institutions, and collection is dominated by private operators, who deliver 18% of the landfill's waste. Model 3 includes waste from the city center and business areas, where both KCCA and private operators collect and deliver 11% of the landfill waste. Model 4 comprises waste from markets, public areas, street sweepings, and drain channel de-silting, collected by KCCA, which deliver 10% of the waste received at Kiteezi landfill.

Funding

The research was funded by the Swedish International Development Cooperation Agency (Sida) under the Sida-Makerere University bilateral cooperation research program.

References

Cointreau, S. 1982. Environmental Management of Urban Solid Wastes in Developing Countries: A Project Guide. Urban Development Technical Paper No. 5. Washington, DC: International Bank of Reconstruction and Development/The World Bank.

Gupta, S., K. Mohan, R. Prasad, S. Gupta, and A. Kansal. 1998. Solid waste management in India: Options and opportunities. *Resources Conserv. Recycling* 24:137–54. doi:10.1016/S0921-3449(98)00033-0

Hazra, T., and S. Goel. 2009. Solid waste management in Kolkata, India: Practices and challenges. *Waste Manage.* 29:470–78. doi:10.1016/j.wasman.2008.01.023

Hu, T.L., J.B. Sheu, and K.H. Huang. 2002. A reverse logistics cost minimization model for the treatment of hazardous wastes. *Transport. Res. Part E Logistics Transport. Rev.* 38:457–73. doi:10.1016/S1366-5545(02)00020-0

Hui, Y., W. Li'ao, S. Fenwei, and H. Gang. 2006. Urban solid waste management in Chongqing: Challenges and opportunities. *Waste Manage.* 26:1052–62. doi:10.1016/j.wasman.2005.09.005

Imam, A., B. Mohammed, D.C. Wilson, and C.R. Cheeseman. 2008. Solid waste management in Abuja, Nigeria. *Waste Manage.* 28:468–72. doi:10.1016/j.wasman.2007.01.006

Jang, Y.-C., C. Lee, O.-S. Yoon, and H. Kim. 2006. Medical waste management in Korea. *Journal of Environmental Manage.* 80:107–15. doi:10.1016/j.jenvman.2005.08.018

Jin, J., Z. Wang, and S. Ran. 2006. Solid waste management in Macao: Practices and challenges. *Waste Manage.* 26:1045–51. doi:10.1016/j.wasman.2005.08.006

Kanat, G. 2010. Municipal solid-waste management in Istanbul. *Waste Manage.* 30:1737–45. doi:10.1016/j.wasman.2010.01.036

Kaseva, M.E., and S.E. Mbuligwe. 2005. Appraisal of solid waste collection following private sector involvement in Dar es Salaam city, Tanzania. *Habitat Int.* 29:353–66. doi:10.1016/j.habitatint.2003.12.003

Katusiimeh, M.W., A.P.J. Mol, and K. Burger. 2011. The operations and effectiveness of public and private provision of solid waste collection services in Kampala. *Habitat Int.* 36:247–52.

Kampala City Council. 2006. Solid Waste Management Strategy Report. Kampala, Uganda: Republic of Uganda.

Marshall, R.E., and K. Farahbakhsh. 2013. Systems approaches to integrated solid waste management in developing countries. *Waste Manage*. 33:988–1003. doi:10.1016/j.wasman.2012.12.023

Mugagga, F. 2006. The public–private sector approach to municipal solid waste management. How does it work in Makindye division, Kampala district, Uganda? Academic thesis, Department of Geography, Norwegian University of Science and Technology, Trondheim, Norway.

Mukisa, P.K. 2009. *Public participation in solid waste management: Challenges and prospects: a case of Kira Town council, Uganda*. Master's thesis, University of Agder, Kristiansand, Norway.

Mukwaya, I.P. 2004. Urban change in Uganda: The challenge of managing urban areas in a global environment. International Conference on Globalism and Urban Change, Chicago, IL.

National Environment Management Authority. 2004. State of environment report for Uganda. Kampala, Uganda: National Environment Management Authority

National Environment Management Authority. 2008. State of environment report for Uganda. Kampala, Uganda: National Environment Management Authority.

Okot-Okumu, J., and R. Nyenje. 2011. Municipal solid waste management under decentralisation in Uganda. *Habitat Int*. 35:6. doi:10.1016/j.habitatint.2011.03.003

Oteng-Ababio, M., J.E. Melara Arguello, and O. Gabbay. 2013. Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana. *Habitat Int*. 39:96–104. doi:10.1016/j.habitatint.2012.10.010

Pattnaik, S., and M.V. Reddy. 2010. Assessment of municipal solid waste management in Puducherry (Pondicherry), India. *Resources Conserv. Recycling* 54:512–20. doi:10.1016/j.resconrec.2009.10.008

Pearce, D., and R.K. Turner. 1994. Economics and solid waste management in the developing world. 'Whose Environment,' New Directions in Solid Waste Management Conference, University of Birmingham, Birmingham, UK.

Rotich, H.K., Z. Yongsheng, and D. Jun. 2006. Municipal solid waste management challenges in developing countries—Kenyan case study. *Waste Manage*. 26:92–100.

Sharholy, M., K. Ahmad, G. Mahmood, and R. Trivedi. 2008. Municipal solid waste management in Indian cities—A review. *Waste Manage*. 28:459–67. doi:10.1016/j.wasman.2007.02.008

Teixeira, J., A.P. Antunes, and J.P. De Sousa. 2004. Recyclable waste collection planning—A case study. *European J. Operational Res*. 158:543–54. doi:10.1016/S0377-2217(03)00379-5

Uganda Bureau of Statistics. 2002. The 2002 Uganda population and housing census, population size and distribution. Kampala, Uganda: UBOS.

Uganda Bureau of Statistics. 2012. Statistical abstract of Kampala. Kampala, Uganda: Government Printers, Kampala.

Vidanaarachchi, C.K., S.T. Yuen, and S. Pilapitiya. 2006. Municipal solid waste management in the Southern Province of Sri Lanka: Problems, issues and challenges. *Waste Manage*. 26:920–30. doi:10.1016/j.wasman.2005.09.013

Wilson, D. C., C. Velis, and C. Cheeseman. 2006. Role of informal sector recycling in waste management in developing countries. *Habitat Int*. 30:797–808. doi:10.1016/j.habitatint.2005.09.005

Zurbrugg, C. 2002. Urban solid waste management in low-income countries of Asia how to cope with the garbage crisis. Presented at the Scientific Committee on Problems of the Environment (SCOPE) Urban Solid Waste Management Review Session, Durban, South Africa.

Zurbrugg, C. 2003. Solid waste management in developing countries. SWM introductory text on www.sanicon.net.

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