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Full Length Research Paper

Energy potential of Municipal Solid Waste in Kampala, a Case Study of Kiteezi Landfill Site

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Less than 10% of the population have access to electrical and thermal energy in Uganda and there is a heavy dependence on wood fuel as a source of energy. In this study, the energy potential of Municipal Solid Waste at Kiteezi landfill, Kampala was qualitatively determined by carrying out Municipal solid waste (MSW) characterization, proximate analysis, and calorific value measurements. The samples were picked on different days and for each day, waste was randomly selected from five garbage trucks coming from residential areas (private trucks) and commercial areas (Kampala City Council Authority trucks). It was then sorted, weighed and packed in polythene bags and take to the laboratoty for analysis. Waste from the commercial areas consisted of 87.3 % food and yard waste, 2.0% papers, 0.4% plastics, 3.6% polyethylene, 2.2% water bottles, 0.9% textiles, 1.9% Glass, 0.2% metals, and 1.6% others. Whereas the waste from residential areas comprised of 94.4% food and yard waste, 1.2% papers, 0.3% plastics, 2.3% polyethylene, 0.6% water bottles, 0.4% textiles, 0.3% Glass, 0.1% metals, and 0.4% others. The organic waste on average had moisture content (8.69 wt. %), volatile matter (73.3 wt. %), fixed carbon (3.22 wt. %), and ash content (13.65 wt. %) on a dry basis. The organic waste also had a gross energy content of 19.26 MJ/Kg of dry matter. It was concluded that the organic waste generated in Kampala city can contribute positively to the energy sector.

Key words: Municipal solid waste, energy potential, electrical and thermal energy.

INTRODUCTION

Uganda has limited access to electrical and thermal energy with less than 10% of the population, (Saundry, 2009) and there is a heavy dependence on wood fuel as a primary source of energy for heating, cooking and lighting which has led to continuous deforestation hence climate change. There has been a drop in the water level of Lake Victoria which has caused a major decrease in electricity supply. Many efforts have been made to introduce other sources of renewable energy like using gas, solar etc., but have since failed because they require a lot of capital investment. Alternative environmentally friendly and cheaper energy sources thus have to be explored from the available resources such as municipal solid waste (MSW). The renewable energy policy of Uganda promotes the extraction of energy from municipal waste, recognized as a renewable source of energy (Anon, 2002).

Kampala is approximately 198 Km^2 with a population of 1.6 million (UBOS, 2011). This number is expected to grow with expansion of the town. Kampala City Council Authority (KCCA) is responsible for collection, transportation and disposal of municipal waste to the landfill. The landfill is located in Kiteezi and it covers an area of 29 acres (Mboowa et al., 2015). However, KCCA still faces a challenge on how to manage the waste effectively and appropriately. This is due to inadequate

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data such as; number of private collectors, estimated tonnage of garbage expected to be generated and collected, the composition of solid waste stream and number of households (Anon, 2010; Anesa et al, 2006). In 1997, KCC made an effort to involve the public sector in refuse collection. A number of private firms were invited to register and provide refuse collection services in high income areas at a fee. There are currently about 20 small to medium private firms that provide door to door waste collection services from residential areas at a fee ranging from Uganda Shillings (Shs) 20,000 to 30,000 per month for a bi- weekly service. They normally provide their clients with waste bags that are collected at agreed frequencies.

Municipal solid waste (MSW) refers to waste that includes; refuse from households, market wastes, street sweepings, non-hazardous solid waste from industrial, commercial and institutional establishments (Schübeler 1996). Solid waste management is becoming a major public health and environmental concern in urban areas of many developing countries (UNEP, 2006). The situation in Africa, particularly in the capital cities is severe and Kampala is not exception (UNEP, 2006). About 1,200 to 1,500 tons of waste is generated daily in Kampala. Only 40 % (400 to 500 tons) of this waste is disposed of at landfill (Anon, 2010). Thus there are usually heaps of uncollected garbage on the streets, drainage channels, water channel courses, manholes, unfit places, and dustbins in Kampala (NEMA, 2004). Poor management of MSW has led to negative environmental and health impacts. These include; bad odour, pollution of air, soil and water, and respiratory diseases from uncontrolled burning of garbage.

The poor management of MSW in Kampala is raising concerns of both the government and the public. To overcome poor management of waste, characterization is the first step to proper waste management. The previous studies which have been done on MSW characterization from Kampala municipality focus mainly on the waste composition (Kyambadde, 2009; Amanyire, 2011; Agaba, 2011). Further still, 100 % of the MSW in Uganda is land filled (UNEP, 2006) with no energy extraction. The current energy gaps in Uganda call for alternative energy sources, of which MSW is viable and cheaper. This study thus seeks to fill the information gap as potential of MSW as energy.

METHODOLOGY

Study area

The study was carried out from Kiteezi landfill site. The site is located to the north of Kampala city, an average distance of 13km from the city centre. The present access to the site from Kampala city is through Kampala -Gayaza road, then branch off to the left at Mpererwe and follow the Namere road for about 4 km. Currently, it is the only landfill site at which Kampala waste is disposed of. It was opened in 1996, and covers an area of about 29 acres in total. In 2007, KCCA acquired an additional 6 acres to the south of the existing landfill for purposes of waste disposal. All waste received is spread and compacted in layers within a confined area and covered according to the practical requirements and content aspects the cover material. There is continuous collection and treatment of leachate to the required NEMA standard after which it’s released to the environment.

Field sampling and measurements

The ASTM D5231, (2004) method was used for the sampling process. The Kampala Capital City Authority solid waste vehicles from commercial areas and the private solid waste truck residential area of Kampala entering Kiteezi landfill site were randomly selected for analysis using a random number sheet. A flat and level area was secured for discharge of the vehicle load. This surface was swept clean prior to discharge of the load. The scale was positioned on a clean, flat, level surface to accurately weigh the waste samples. The garbage from the truck was physically sorted and separated into the different individual components. The sorted waste constituents were placed in polyethylene bags and then weighed, recorded and percentage mass of each component tabulated. The organic fraction was also picked randomly and weighed up to 5 kilograms. It was later laying down on a 5 by 1 m grid swept ground, from which and 5 samples of 1 kilogram were randomly extracted. These samples were then mixed, and a final one-kilogram sample was drawn for proximate and ultimate analysis.

Laboratory analyses

Moisture content was determined by drying a 10 g each sample for 5 hours at 105 0C following the method explained by Mboowa et al. (2015). The average moisture content for the ten replicates was taken as the sample moisture content. The proximate analysis was carried out on a 5 g organic waste sample following the procedure as described by ASTM D3172 (2004) to determine the percentage composition of volatile matter, moisture content, fixed carbon, and ash content. The procedure was repeated for the ten replicates and average values recorded. The calorific value of waste was carried out on a 1 g of dried sample and determined following a procedure as described by ASTM D5468 (2007) using a bomb calorimeter (6100 Compensated Jacket Calorimeter, Parr). This was repeated for other 10 replicates and mean values was taken as the sample heating value.

Data analysis

The collected data was subjected to statistical analysis in

Table 1. Mean composition of Municipal solid waste of Kampala collected from both residential and commercial areas (Mean ± CV)

Sampled area	Food and yard waste	Papers	Plastics	Polyethylene	Water bottles	Textiles	Glass	Metal	Others
Residential	94.4 ± 1.6	1.2 ± 0.7	0.3 ± 0.2	2.3 ± 1.1	0.6 ± 0.3	0.4 ± 0.3	0.3 ± 0.1	0.1 ± 0.1	0.4 ± 0.2
Commercial	87.3 ± 5.8	2.0 ± 1.9	0.4 ± 0.2	3.6 ± 1.5	2.2 ± 0.7	0.9 ± 0.6	1.9 ± 2.6	0.2 ± 0.1	1.6 ± 1.4
Average	90.85	1.6	0.35	2.95	1.40	0.65	1.10	0.15	1.00

MS Excel to determine the mean and standard deviation. R statistical software was later used at 95% family-wise confidence level for one-way ANOVA, two-way ANOVA and Tukey test to check whether there was any significant difference in the mean results obtained.

RESULTS AND DISCUSSION

Physical composition of waste

The mean percentage of waste composition (by weight) for both residential and commercial areas (Table 1) revealed that the most dominant waste fraction is food and yard waste (90.8%). The other fractions weighed as papers (1.6%), plastics (0.3%), polyethylene (2.9%), water bottles (1.4%), textiles (0.6%), Glass (1.1%), metals (0.1%), and others (1.0%). These figures are comparable from those reported by Komakech et al. (2014), Mboowa et al. (2015), and Ayaa et al. (2014) in their studies that were conducted at Kiteezi landfill site.

These fractions were further analysed for significant difference between both the residential and commercial areas of Kampala, Uganda. One way ANOVA showed no significant differences (P>0.05) in the percentage composition of the replicates of food and yard waste, papers, plastics, polyethylene, water bottles, textiles, glass, metals, and others for both residential and commercial areas. Two way ANOVA, also showed no significant difference (P>0.05) in the percentage fraction for paper and plastics between the commercial and residential areas. However, the same test showed a significant difference (P<0.001) in the percentage fraction of water bottles and food and yard waste, a significant difference (P<0.05) in the percentage fraction of polyethylene, textiles, glass, and metal, and finally a significant difference (P<0.01) in the percentage fraction of others.

Further analysis by Tukey tests revealed that the residential areas had significantly higher (P<0.001) percentage of food and yard waste than commercial areas, and also the same tests also revealed that residential areas had significantly lower (P<0.05) percentage of polyethylene, textiles, glass, and metal. The percentage of others was significantly higher (P<0.01) for commercial areas while the percentage of water bottles was significantly (P<0.001) for residential areas as compared to commercial areas.

The commercial area generate more Polyethylene, water bottles, Textiles, Glass, Metals, and others than the residential areas. This could be due to the typical facilities, activities and points where this type of waste is generated. For example, there are many shops, stores, restaurants, markets, office buildings, hotels, motels, service centre shops and many others which generate such type of waste as compare to the residential areas. This significant difference mostly in plastics and textiles can also be attributed to the increased number of shopping malls and supermarkets that provide its customers with both plastic and textile carrier bags for their merchandise. The significance difference in the food and yard waste between the residential and commercial areas of Kampala, can best be explained by the cooking patterns associated with families that reside in these residential areas, According to UBOS (2014), Kampala has over 600,000 households and all these have to buy food every day from market places in addition to other organic materials that come along with food preparation.

Proximate analysis and calorific value of MSW.

The proximate analysis and calorific value from the samples taken from the organic waste delivered from both the residential and commercial areas of Kampala city are summarized in Table 2. The proximate analysis results were reported on a dry basis and on average consisted of a moisture content (8.69 wt. %), volatile matter (73.3 wt. %), fixed carbon (3.22 wt. %), and ash content (13.65 wt. %). These figures are comparable from those reported by Ayaa et al. (2014) in the study that was conducted at Kiteezi landfill site.

One way ANOVA showed no significant differences (P>0.05) in the results of replicates of moisture content, volatile matter, fixed carbon, and ash content analyses. Two way ANOVA showed a significant difference (P<0.01) in moisture content of the organic waste from residential and commercial areas. Further analysis with Tukey tests showed that moisture content was significantly higher (P<0.01) in the waste emanating from commercial areas than that of residential areas. Two way ANOVA also showed no significant difference (P>0.05) in the percentage composition of volatile matter, fixed carbon and ash content.

The measurements of the calorific value showed that

Table 2. Mean results obtained from proximate analysis (Mean ± CV).

Type of waste	Moisture content (wt. %) DB	Volatile matter (wt. %) DB	Fixed Carbon (wt. %) DB	Ash (wt. %) DB	Calorific value (MJ/Kg DM)
Residential	7.82 ± 0.4	71.27 ± 0.2	3.63 ± 0.1	14.98 ± 0.3	21.31 ± 0.4
Commercial	9.56 ± 0.9	75.32 ± 0.1	2.80 ± 0.5	12.32 ± 0.7	17.20 ± 0.2
Average	8.69	73.30	3.22	13.65	19.26

Note: DM, dry matter; DB, dry basis; Wt, weight

commercial waste has high calorific values (21.3 MJ/kg DM) compared to residential waste (17.2 MJ/kg DM). Two way ANOVA showed a significant difference (P<0.01) in calorific value of the organic waste from residential and commercial areas. Further analysis with Tukey tests showed that calorific value was significantly higher (P<0.01) in the waste emanating from residential areas than that of commercial areas.

Moisture content had an effect on the calorific value with the residential waste which has got a low moisture content (7.82%) having a high calorific value (21.3 MJ/Kg DM) as compared to the waste from commercial areas. This is in line with the same findings of UNEP (2006), where they investigated that the moisture content reduces the calorific value of waste.

The average gross energy from waste delivered at Kiteezi landfill site is 19.26 MJ/Kg DM (Table 2). This result is quite similar to 18.0 MJ/Kg DM and 17.3 MJ/Kg DM as reported by Bingh (2004) and Komakech et al., 2014 respectively. According to Heylighen (2001), calorific value results for other fuels like coal ranged between 37 – 40 MJ/Kg DM. In comparison with the results of this study, it means that the energy that can be produced by 1 Kg of coal, is equivalent to that produced by 2 Kg of municipal solid waste. Even though the calorific value of waste is lower than that of coal, waste utilization as an alternative renewable energy source is reflected as free source and therefore it is economical to use waste as source of energy (Khamala & Alex., 2013). If this organic material is processed in a biogas plant and 60% of the gas produced is methane, 11.56 MJ/Kg DM of biogas could be produced. According to Anon (2010), on average 450 tons of waste is disposed of at the kiteezi landfill on a daily basis. Therefore Kiteezi landfill has a capacity of producing 1,445 MWh on a daily basis if a biogas plant is installed at the site. This could be a source of green energy for electricity and cooking gas production.

CONCLUSION AND RECOMMENDATION

The analysis of physical compositon of municipal solid waste of Kampala revealed that the major components is the organic waste. It composed of, food and yard waste (90.8%), papers (1.6%), plastics (0.3%), polyethylene (2.9%), water bottles (1.4%), textiles (0.6%), Glass (1.1%), metals (0.1%), and others (1.0%). The average proximate analysis values were moisture content (8.69 wt. %), volatile matter (73.3 wt. %), fixed carbon (3.22 wt. %), and ash content (13.65 wt. %). The waste also had a gross energy of 19.26 MJ/Kg DM. The physical composition of waste, proximate analysis results, and calorific values varied depending on whether the waste sampled was from commercial or residential areas of Kampala. Based on the findings in this study, the MSW in Kampala can contribute positively to the energy sector The organic composition of waste showed that energy recovery is possible through incineration due to its low moisture content. Further studies need to be conducted on assessing the potential of organic waste as a manure. Also since waste generated in Kampala can also vary according to seasons like dry and wet seasons, festival and non-festival seasons, a detailed study should be carried out to show the seasonal variations of energy generated from the MSW.

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