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ORIGINAL RESEARCH ARTICLE

ASSESSMENT OF ENERGY POTENTIAL OF MUNICIPAL SOLID WASTE FROM UNIVERSITY OF DERBY STUDENT RESIDENCE

N. S. Gukop*, J. A. Japhet, B. D. Lengs and A. Adesanmi

Department of Mechanical Engineering, University of Jos, Jos, Nigeria
**Corresponding author's email address: gukopn@unijos.edu.ng*

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ABSTRACT

Solid waste generated from the University of Derby Student Residence was used to examine the amount of thermal energy that can be reclaimed from the waste. The waste material used for the analysis was categorized into different constituents which were used for analyzing the sample, from which the recoverable energy was estimated. The calorific value of the waste mixture was found to be 34.28 MJ/kg with a corresponding thermal energy recoverable estimated to be 1532.96 MJ/day, which gave an equivalent power of 425.82 kWh/day. The findings from this study suggests the necessity for the adoption of waste management systems that will integrate energy recovery from wastes in order to supplement the increasing demand for energy.

1.0 Introduction

There has been an increasing global concern of municipal solid waste (MSW) generation rate and disposal which is due to population growth and technological advancement, with a severe consequence on public health and environment (Dolar et al., 2016; Talalaj and Biedka, 2015). The issue has become poignant in country such as the UK where there has been a growing rate of waste generation, accompanied with dependence on limited landfill area (Singh *et al.*, 2014; Chapple and Harris, 2003).

Waste is defined as "*any such material or whatever thing which the holder throw-outs or intends or is required to discard*". This is categorized into different streams containing certain types of waste which may be produced by organizations, institutions or individuals amongst which are Construction/demolition waste, Hazardous waste and Municipal waste (DEFRA 2013). Solid Waste or refuse generated from the daily activities of human are seen to possess undesirable economic value, which suggests that it is cheaper to discard than to make use of it (Pichtel, 2005). However, certain components of the waste material may at the end become valuable resources if separated from the bulk stream of waste material (Kanat, 2010).

Studies have shown that generation of waste is inevitable (Amber et al., 2012), and global waste generation have been projected to reach 2.2 billion tonnes per annum by the year 2025 (Moya et al. 2017). The management of such waste has become of great concern which has led to the harnessing of possible ways to convert it to useful resources (Tsai and Kuo, 2010). As developing nations are faced with the challenges of waste collection, transportation and disposal, the developed nations have adopted emerging technologies for converting municipal solid waste into useful resources (Moya et al. 2017). The adoption of such techniques of recycle and reuse could not totally eliminate municipal solid waste; therefore, more approaches are being developed to reduce the quantity of the waste being landfilled (Dolgen et al., 2005).

This increasing rate at which waste material that are potentially detrimental to the environment and wellbeing of human is generated has necessitated concern on the need to look into some other scientific and technical means for safe waste conversion (Shrestha and Singh, 2011). Indrawan, et al. (2020) pointed out that energy from municipal solid waste (MSW) has the potential to satisfy the electricity need of about 12% of the world's population living without electricity. The combustible fractions of the solid waste when properly screened could be of use in powering thermal plants, thereby reducing the amount of MSW sent to landfill. This has, therefore, necessitated the need to characterize the waste generated from University of Derby Student accommodation and to estimate the amount of thermal energy that could be recovered from the combustible fractions of the municipal solid waste material in the selected students' residence.

2.0 Materials and Methods

2.1 Study Area and Sample Collection

The study area, Laverstoke court, is one of the nine University of Derby Students residence, it houses 9 lodges with each having 21 beds capacity. Derby is a city in the East Midlands region of England and it is located in the south of Derbyshire which lies at coordinates: 52°55.32′N1°28.55′W.

The samples for the study were systematically drawn from the waste bins of five lodges. Ejaro and Jiya (2013), in a study suggested that repetitive selection of sample and analysis would best provide a more accurate representative data; therefore, samples were collected at the same collection points of each lodge twice in a week. In each sample point, the waste was sorted into various components and categorized, a 25kg capacity weighing scale was used for weighing the samples. Other tools like waste sacks, hand shovels, and bin bags were used in the sample collection and sorting process.

2.2 Characterization and Estimation of Waste Generated

The ASTM Test Method D5231-92 was used for characterization and estimation of waste generated. These waste materials were classified into main components which comprise mainly of materials of similar characteristics and are classed as paper/cardboards, plastic related materials, food/organic waste, polythene/polystyrene food packs, non-combustible waste and textile materials. The waste component generated per day (kg/day), percentages by mass to the total amount of sample was determined in accordance with the ASTM Method D5231-92 (2016).

2.3 Determination of Calorific Value

The ASTM E711-87 Standard test method for calorific value of refuse-derived fuel was used (ASTM 2012). The heat content was then calculated from the equation below

$$CV = \frac{K \times \Delta T}{m} \tag{1}$$

Where: ΔT = the change in temperature (^{O}C)
K = the calorimeter calibration factor
CV = the calorific value (kJ/kg)
m = mass of test sample (kg)

The energy content of the sample was evaluated using equation (2).

$$E = CV \times m \tag{2}$$

where: m = mass of sample (kg),
CV = calorific value of the waste sample (kJ/kg) and
E=energy content (kJ)

The kilowatt equivalent was obtained using equation (3)

$$K_e = \frac{E_S}{3.6 \times 10^6} \tag{3}$$

Where: E_S= Energy in Joules (J),
K_e = Kilowatt equivalent (kWh)

3.0 Results and Discussion

3.1 Waste Generation

The rate of mass contribution of waste material by each site is presented in the Figure 1.

The result shows the total average generated waste of 53.40kg/day. From Figure 1, Lodge, A contributes 21.93%, Lodge B has 26.01%, Lodge C has 15.36%, and Lodge D has 15.36% while Lodge E has 19.29% of the total rate of generation. The difference in percentage generation from each lodge is due to the different sizes of population living in each lodge, the higher the population in a lodge, the higher the percentage contribution. Sharma and Jain (2020), also showed similar trend which pointed that the rate of waste generation is proportional to population size.

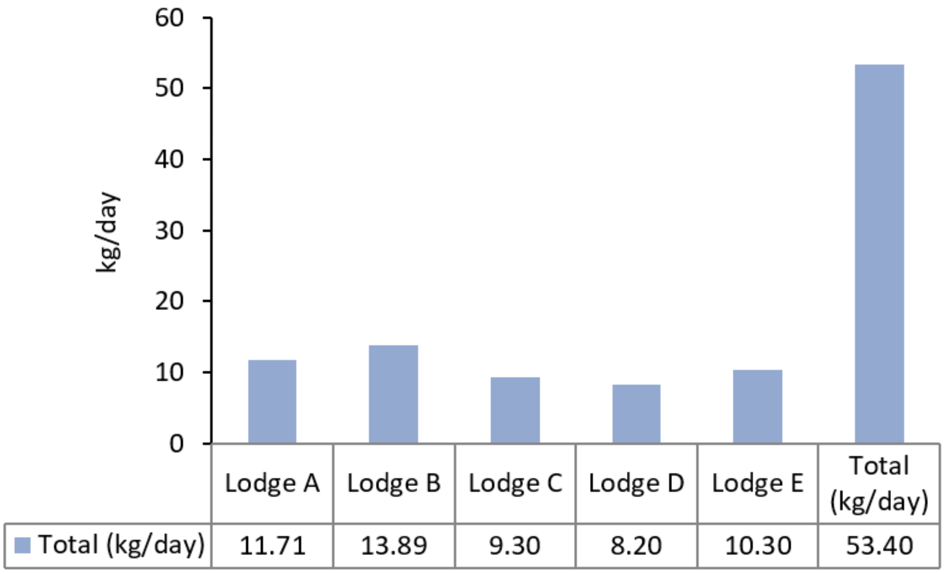
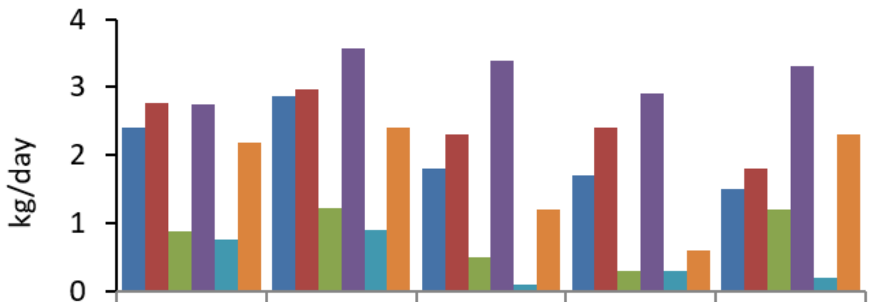


Figure 1: Rate of waste generation by individual collection site

3.2 Waste Characterization

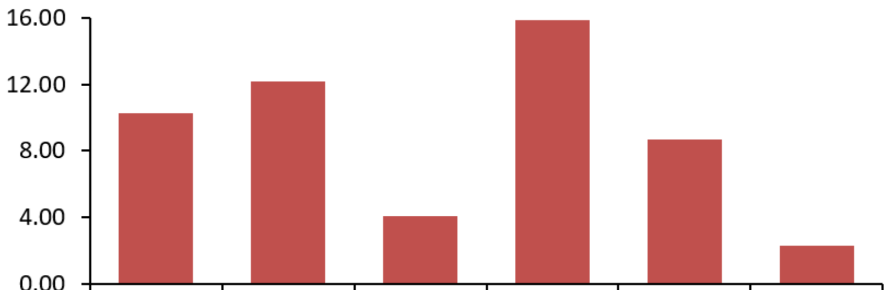
Figure 2 presents the composition of the waste material in different sites of the University Student Hall, with average daily generation of each waste component of each lodge. The pattern of these waste components in each of the sites is observed to exhibits a similar profile; this is an indication that the waste materials are generated by community of similar lifestyle in terms of waste generation. Ibikunle et al. (2019) also showed that there is a strong corelation between the type of waste generated and lifestyle. People of same lifestyle, similar and class and similar income are most likely to generate similar types of waste stream and waste volume.



	Lodge A	Lodge B	Lodge C	Lodge D	Lodge E
cardboard/paper	2.40	2.86	1.80	1.70	1.50
polythene	2.76	2.96	2.30	2.40	1.80
food waste	0.88	1.21	0.50	0.30	1.20
plastic materials	2.74	3.57	3.40	2.90	3.30
textile	0.76	0.89	0.10	0.30	0.20
incombustible	2.18	2.40	1.20	0.60	2.30

Figure. 2: Component characteristic of waste generated by each site

Figures 3 and 4 presents the total composition of the sorted components of the waste material shows that paper materials contribute 19.2%, polythene, 22.88%, food waste 7.66%, plastics 29.79%, incombustibles 16.25% and textile material 4.21% of the total generated waste.



	paper/cardboard	polythene	food waste	plastics	incombustibles	textile
kg/day	10.26	12.22	4.09	15.91	8.68	2.25

Figure 3: Distribution of individual waste composition by mass

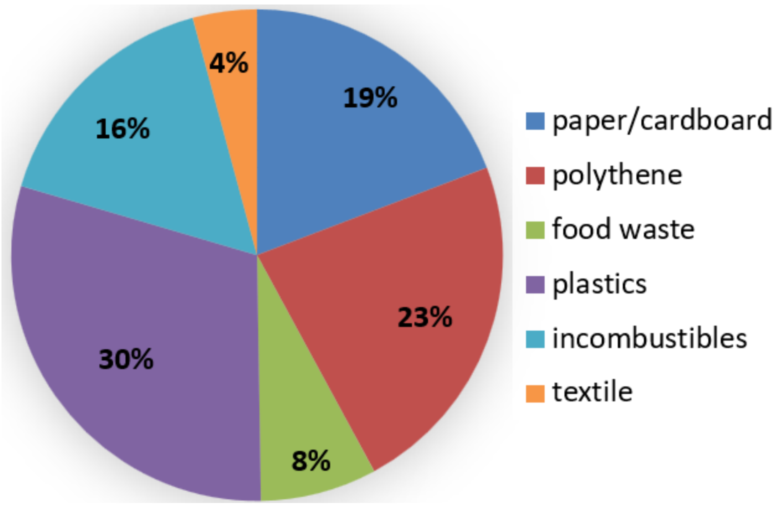


Figure 4: Percentage composition of waste materials

It is seen from this study that plastic constitute the highest proportion by mass of the total waste generated with textile material having the lowest contribution by mass. Adeniran et al. (2017), Oladejo et al. (2018) and Ugwu et al. (2020), also showed dominance of plastic related waste materials in student residence. Figure 5 also shows the total composition of the combustible and incombustible fraction of the waste sample.

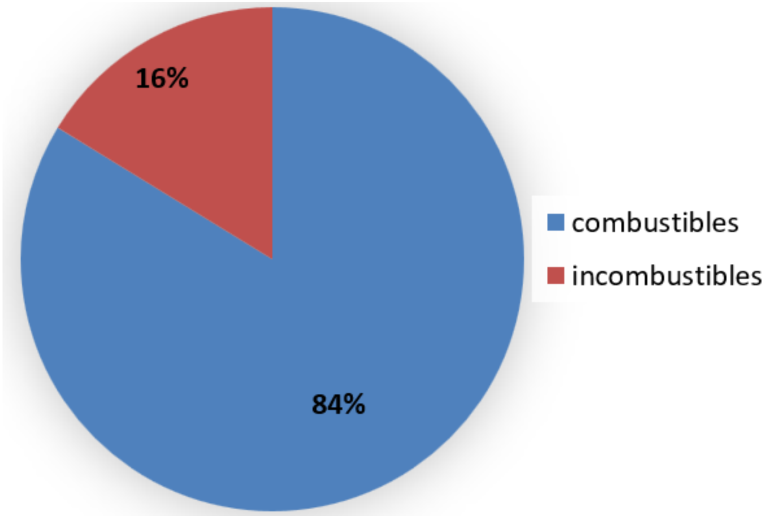


Figure 5: Proportion of total combustible and non-combustible

The total composition of the combustible materials is shown in Figure 6 with plastics having the highest contribution by mass of combustibles of 35.58%

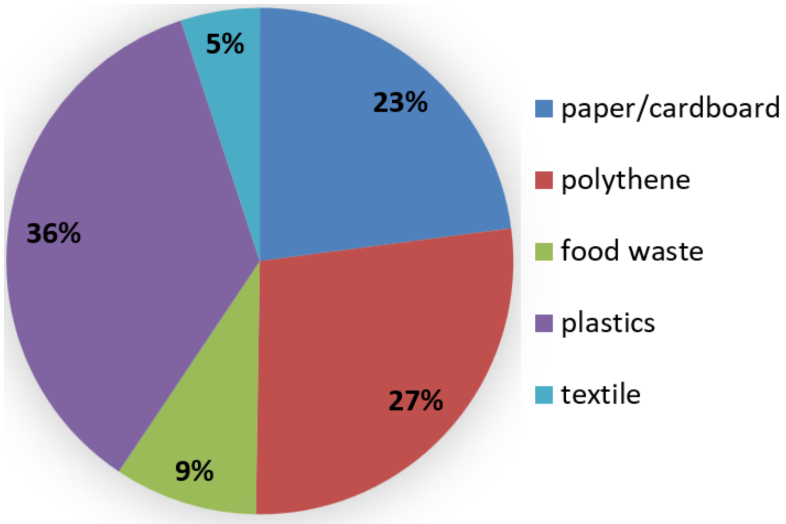


Figure 6: Composition based on total combustibles

3.3 Calorific Value and Thermal Energy Potential

The calorific values of the individual analysis sample are presented in Table 1. It shows that plastic material having the highest value of 46.23MJ/kg and paper and cardboard material with the lowest at 14.18MJ/kg, this trend is similar to a study conducted by Olisa and Ajoko (2018) and Nwoke et al. (2020) which also showed that plastic and paper materials possesses highest and lowest calorific value respectively. The calorific value of the combustible mixture in this study was however found to be 34.28MJ/kg this is lesser than plastic which has the highest value component wise, and this is due to the contribution of individual components composition in terms of mass and caloric values which ranges from 2.25kg/day to 15.91 kg/day, and 14.18MJ/kg to 46.23MJ/kg respectively.

Table 1: Calorific value of waste component

Waste component	Paper/ cardboard	Polythene bags/sachets	Plastic material	Food waste	Incombustibles	mixture of all Combustibles
CV (MJ/kg)	14.18	45.33	46.23	14.31	-------------	34.28

The wastes mixture inclusive of incombustible with higher mass possess lower calorific value compared to those of the waste mixture without incombustible and with lower mass as shown in Figure 7. This is due to the quality of mixture, and this suggest that the calorific value depends largely on the quality of the combustible constituents than in the general mass of the constituents as reported elsewhere (Nwoke et al. 2020). The quality of the combustible fraction affects the amount of recoverable thermal energy from the mixture as shown in Figure 8. Lower mass with higher calorific value gives almost the same energy as compared to lower mass with higher calorific value.

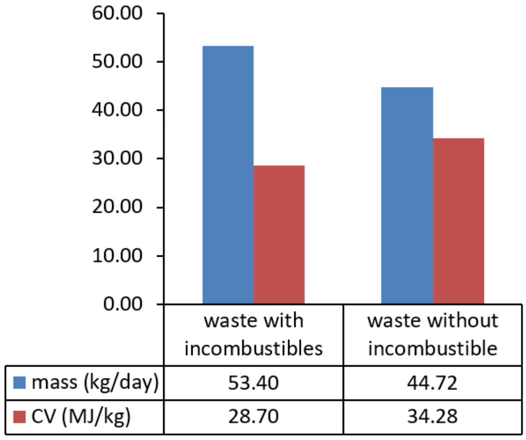


Figure 7: Mass and heat content

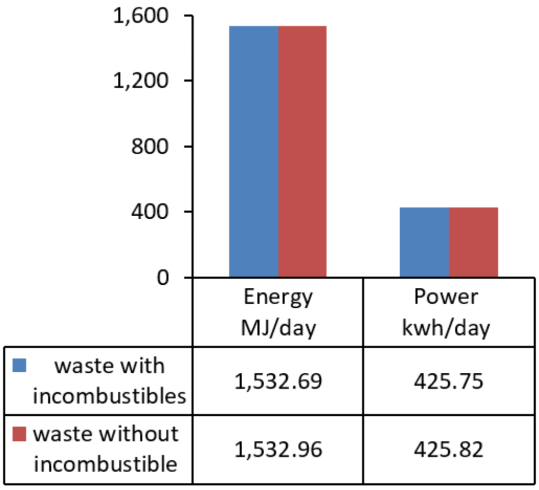


Figure 8: Recoverable energy and power from waste

Figure 9 shows the power consumption of the study area as compared to power generatable from the combustible solid waste material from the study area. Figure 9 shows that the power from the waste material is equivalent to 15.5% of the consumption of the area.

Corresponding author's e-mail address: gukopn@unijos.edu.ng

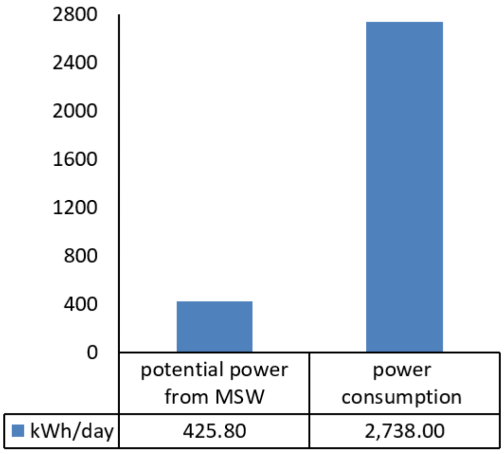


Figure 9: Power recoverable from waste and power consumption for study area

4.0 Conclusion

The Assessment of municipal solid waste was carried out in this study using the waste generated in some selected university student residence. The study carried out determined the characteristics of the waste material generated in terms of composition, calorific value and thermal energy potential. Findings from the study showed that 53.4kg/day of waste is generated of which 84% are combustible material. The assessment of the waste components estimated the energy recoverable from plastics material to be 735.47MJ/day, polythene 553.93MJ/day and cardboard the least with 145.46MJ/day corresponding to 51.26%, 38.60% and 10.14% respectively of the total energy potential. the result of the assessment estimated the amount of energy recoverable from the generated waste to be 1532.96 MJ/day which corresponds to 425.82kWh/day, these recoverable energy contributions are affected by rate of generation of the individual waste component and quality of combustible material. The findings of this study suggest the existence of abundance of energy that could be recovered from the various components of the waste material generated from the study area which can contribute about 15.5% of the locations' consumption.

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