Assessment of the impact of moisture content on the heating value of Municipal solid waste from Kabagarame dumping site in Bushenyi District, Uganda

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ABSTRACT

Modern management of waste around the world has moved from waste disposal to energy recovery through WtE. Technologies that can be utilized to recover energy from MSW mainly include thermal conversion processes such as incineration, gasification, pyrolysis, biochemical conversion processes and chemical conversion. This study focused on the impact of moisture content on the heating value of Municipal solid waste from Kabagarame dumping site in Bushenyi District, Uganda. Specifically, wet solid waste samples were analyzed and the impact of moisture content on the heating value was evaluated. This study evaluated the impact of moisture content on the heating value of the waste. The result showed that dry matter gives out more energy than wet matter. The Gross energy content of the MSW on wet basis when compared to the Gross energy content on dry basis is observed to be lower. This is attributed to the fact that the moisture content in the waste lowers the heating value of the waste by absorbing the heat thereby reducing the relative efficiency of heating when the solid waste is combusted. In, wet season, there should be a temporary roof at the dumping site to shelter the municipal solid waste so as to minimize exposure of the waste to moisture as this significantly lowers the Energy content of the waste.
Keywords: Moisture content, heating value, solid waste and dumping site

INTRODUCTION

Modern management of waste around the world has moved from waste disposal to energy recovery and recycling and this has led to a high interest in WtE [1-4]. The recovery of energy practice have advantages that are competitive and these include; occupation of land that is small, reduction of volume of waste, minor pollution, and more so it is regarded as a means of disposal of waste that is very effective in the current era and in the future [5-7]. There are several technologies that can be utilized to recover energy locked in MSW and these include; biochemical conversion, thermochemical conversion and chemical conversion [8-10]. Waste characteristics are considered in the selection of technology of WtE that can be utilized [11-13]. More so, the energy potential of waste is a very critical component that is used to identify the amount of energy that can be extracted from the waste [14-16].

A WtE plant that was established recently in Ethiopia in Africa has attracted interest from several governments in Africa towards application of technologies that can extract energy from waste [17-20]. Incineration is considered to be the

more efficient towards handling of variable characteristics in municipal solid waste in comparison to other technologies of WtE [21-25]. Incineration of municipal solid waste is currently the WtE option that is mature technologically and widely used. It has the ability of reducing the volume of waste by about 90 percent and mass by a percentage of 70 [8]. In addition to that, slag that comes from incineration in grate plant fired by biomass is fit for use directly to improve the soil due to the lower concentration of elements that are hazardous [9]. Also, the ash can be utilized as a material for construction in applications of concrete and asphalt [10]. The heat that is generated through the process of incineration can be used in operations of turbines that are vapor based and more so in the operations of heat exchangers [11-17]. There is rapid urbanization; 5.1%/annum, and rise in population; 3.3%/annum, in Uganda and this has led to new economic and social opportunities and also more advanced challenges which include management of waste which is not tallying with the growth in population, slums development, overcrowding, settlements that are informal that have solid waste management (SWM) practices that are poor. Anticipations say that urbanization in Uganda will hit 50 % by 2040 [12]. A lot of interventions to tackle poor WM have been undertaken by the country for example a credit of US$150 million for International Development Association (IDA) was approved by the World Bank Board of Executive Directors to fund the infrastructure in urban areas and develop delivery of service in 14 municipalities in Uganda [13-16] .There has not been any visible change despite all the support financially offered towards SWM [14]. A tremendous venture confronting engineers and scientists in growing nations is the search for suitable answer for the treatment, collection and disposal or re-use of home waste to produce power. Even though the energy desires have been met by the invention of the deposits of fossil fuel, the deposits are restricted in quantity, exploration and manufacturing. Centers that convert waste to energy are part of answer of the global solid waste disposal hassle. These centers, while blended with recycling of crucial material, landfilling and composting, might be a long-time period financial answer since they are developed and operated in a manner that suits the environment. Generation of energy is pivotal for the development of a nation economically, socially and intellectually. Waste to energy (WtE) is one of the ways for generation of energy sustainably. The generation of energy from waste in liquid, gas or solid form has the ability of minimizing over dependency on fossil fuels, thereby enhancing a feasible optional technique to manage most MSW. 64% of world's WtE is obtained via incineration of waste with other renewable energy forms from waste obtained from anaerobic digestion of organic waste and landfill gas [15].

The Third National Development Programme (NDP III) aim is to increase consumption and accessibility to clean energy. Access to services of sustainable energy is very crucial for growth of the economy, reduction in the poverty rates, and more so transformation of the society both socially and culturally. The development of energy is very critical for utilizing of the key opportunities for growth through facilitation of the agenda of industrialization by developing sustainability, business cost reduction, allowing production, thereby leading to an increase in the competitiveness, growth of the economy that is sustainable and an improvement in the quality of life. More so, The Uganda Vision 2040 aims to have access to energy that is clean, affordable and reliable so as to facilitate industrialization, among others.

According to The Third National Development Programme (NDP III), the country's energy mix is dominated by biomass which contributes 88%

(charcoal, firewood, crop residues). 120, 000 hectares of forest cover is lost annually with 72,000 hectares (60%) lost through firewood and charcoal. Currently, the country suffers a $2.3 billion biodegradation loss with wood fuel contributing 25%.

Similarly, [16] asserts that the policy of renewable energy in Uganda encourages the utilization of municipal solid waste as a resource of renewable energy. Technologies that extract energy from waste are able to minimize the quantity by a percentage of 90, and this depends on the composition, by extracting the energy locked in the Municipal Solid Waste thereby providing means of utilizing alternative renewable energy resources and thus reduce the use of precarious energy and ensure both environmental protection and energy security [17]. In Uganda waste generation is between 0.3 kg/capita/day for low income earners and 0.66 kg/capita/day for high income earners in urban areas [18]. In 2008 a memorandum of understanding (MOU) on SWM was signed by Bushenyi–Ishaka Town Council and the Gemert-Bakel Municipality with an aim to promote the segregation of non-biodegradable and biodegradable waste at the level of households. Over Shs. 150 million was invested in the project, and two centers that are separate for treatment of waste were put up in the municipality; Nyaruzinga center which was to be utilized for waste that is biodegradable waste and Kabagarame site which was to be utilized for non-biodegradable waste [18]. In accordance to the designs that are in place for both the compost plant and site for landfill that were acquired from the physical planner of the municipal that were approved in 2009, both the sites fulfilled the guidelines as per the national and international guidelines. However, most of the infrastructure that were specified in the design have not been implemented. Currently, a private operator only recovers the plastics and exports them to processing plants in Kampala. For the rest of the municipal solid waste, land filling that is uncontrolled and unsanitary has been mainly adopted and this subsequently can cause health, environmental and aesthetic hazards. The fraction of the waste that is organic is responsible for the pollution by leachate, and methane generation, and therefore the removal of this biodegradable waste from the waste stream would reduce the emissions at the dumpsite. This can be achieved through the conversion of this waste into energy. This can be a powerful means that can ensure the reliability and stability of energy systems in the region particularly for several tea factories as this energy can be harnessed for its production processes. However, this can be achieved after a thorough study to ascertain feasibility of the Municipal waste for generation of energy and this justifies the need for this study.

Aim of the research

The aim of this research was to evaluate the impact of moisture content on heating value of Municipal solid waste from Kabagarame dumping site in Bushenyi District, Uganda.

Figure 1: Kabagarame dumping site

MATERIALS AND METHODS
Research Design

This study utilized quantitative research design. This was characterized by collecting data which was expressed numerically. Such data was solved by statistical tools such as bar graphs, pie charts.

Sampling Design

This involved taking samples of solid waste that are representative from the dumping site having the composition and properties of the mass of waste from where it was collected. The method of spot sampling was used in the process of sampling. Wet solid waste samples were taken from dump site from five spots where an amount of waste (1500g) was taken per spot and the total amount collected formed a sample size of about 7500g per week.

The waste samples were filled in polyethene bags so that they could be weighed and then stored. The polyethene bags were labelled with identification numbers for indicating the spot from which the sample was collected and the period of sampling. Five samples of 1500g each of the raw solid waste were taken from five spots from the dump site per week and this was done during a 13-week period.
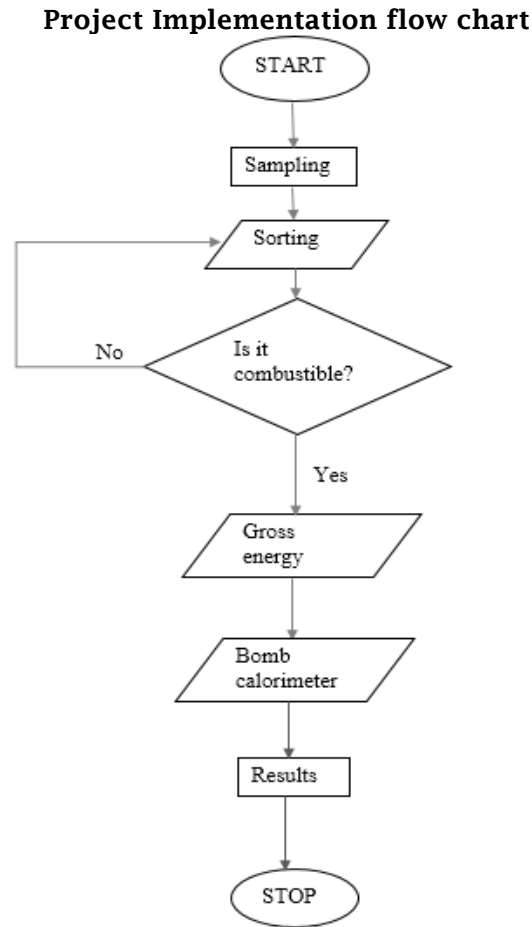
Project Implementation flow chart

Figure 2: Project Implementation flow chart

The number of samples to be sorted were estimated on the basis of ASTM D5231 method of calculation.

$$n_0 = \left(\frac{t \times s}{e \times x}\right)^2 \tag{1}$$

Governing component; other organics. At 95% confidence interval;
$for: n = \infty, t = 1.960, s = 0.06, e = 0.3, x = 0.05$

$$n_0 = \left(\frac{1.960 \times 0.06}{0.3 \times 0.05}\right)^2$$
$$or \quad n_0 = 61$$

From Table 2.3, at 95% confidence interval the value of t statistic corresponding to $n = 61$ is 2.000. Hence n' is obtained by;

$$n' = \left(\frac{1.960 \times 0.06}{0.3 \times 0.05}\right)^2$$
$$or \quad n' = 64$$

n_0 And n' do not differ by more than 10% and hence 64 samples were chosen
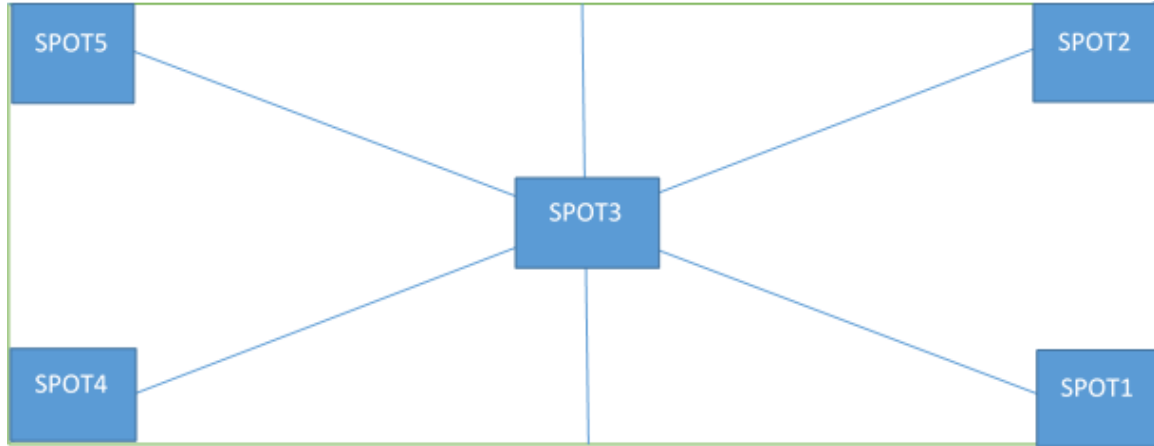
Figure 3: Illustration of sampling spots

Sorting

This involved determining the individual components available in the mass of waste and their distribution by mass. The polyethene bags containing the waste samples were emptied onto a clean flat leveled area with the electronic scale positioned on the same area. Hand Sorting was used for sorting of the Waste into various component categories as described in table below;

Table 1: Condensed Municipal Solid Waste Categories

Category	Description
1. Food waste	Comprised of all the wastes of food that include bones
2. Mixed paper	Office paper, magazines, computer paper, waxed paper and paper that lies in the corrugated and newsprint categories.
3. Wood	Comprises of all kinds of wood
4. Other organics	rubber, textiles, leather, and materials that are burnable primarily, and materials included in the yard waste category
5. Glass	Comprises of all kinds of glass
6. Other inorganics	ceramics ,sand, rock, plaster , dirt, and metals that are in the categories of aluminum and ferrous
7. Plastic	This comprises of all kinds plastic

Source: ASTM D5231-92(2003)

Heating Value (Calorific Value)

The Heating Value of the solid waste is the amount of heat released during combustion of a specific amount of waste and this was measured using a Bomb calorimeter instrument. This was determined on both wet and dry basis. For the dry basis, the Wet solid waste samples were subjected to thorough drying. This was done by subjecting the samples of mass (2.00g-2.40g) in an oven maintained at a temperature of $105^{\circ}C$ for a period of 12 hours. The samples were then retrieved and the moisture content as well as percentage of dry matter were obtained as follows;

$$Mass\ of\ Moisture\ Content = (crucible\ mass + sample\ mass) - oven\ mass$$

Similarly,

$$\%\ of\ dry\ matter = \frac{sample\ mass - mass\ of\ moisture\ content}{sample\ mass} \times 100$$

The Heating Value was obtained as follows for both wet and dry matter; 0.99g-1.00g of solid waste sample was prepared into a fuel cup that was then lowered onto the fuel cup holder of the bomb.

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(a) 15 Calories of Fuse wire were cut .The wire was then attached between the leads/arms of the cradle and then pointed into the fuel contained in the fuel cup .This was done while ensuring that the fuse wire does not make any contact with the fuel cup. This is because the fuse cannot ignite if it makes contact with the cup.

(b) Two milliliters of distilled water were then added to the bomb.

(c) The assembly of the bomb was then lowered into the bomb carefully after which it was screwed to a fit that is comfortable.

(d) The bomb was then positioned at the bench and 30 bars of oxygen were pumped into the bomb from the oxygen tank.

(e) The bucket was filled with two liters of distilled water after which the bomb vessel was gently placed into the bucket. This was done while ensuring that the bomb was not tipped and the feet of the bomb were aligned with the notches at the bucket.

(f) The initial temperature of the water in the bucket was read from a thermometer

(g) The power cable of the bomb calorimeter was then plugged into the power supply and switched on.

(h) The Fire button was then pushed until a temperature rise was recognized from the thermometer.

(i) The temperature was closely observed till the change in temperature decreased and reached a constant state. This temperature was read and noted as the final temperature.

(j) The power supply to the bomb calorimeter was then switched off.

(k) The bomb was then lifted from the water bucket, depressurized, unscrewed, disassembled and the bomb head carried to the stand.

(l) The Heating Value of the remaining fuse wire was then noted

(m) The above steps were done for all the solid waste samples

(n) The Calorific Value of the solid waste sample on Wet basis was then obtained from;

$$Gross\ energy\ (kcalg^{-1}) = \frac{(\Delta T \times e) - W}{(m \times 1000)} \qquad (2)$$

Where; ΔT, Temperature rise (°C), e, Energy equivalent of the Bomb $(2465J)$, W, Fuse wire used (Cal), m, sample mass (g)

The Calorific value of the solid waste sample on dry basis was obtained from;

$$Gross\ energy\ on\ dry\ basis = \frac{Gross\ energy\ on\ wet\ basis\ \times 100}{percentage\ of\ dry\ matter}$$

Figure 4: The researcher collecting solid waste samples from the dumping site, packing and quantifying the samples

Table 2: Gross energy of waste on wet basis and dry basis

Category	Average % Dry matter	GE_{wet} (MJ/kg)	GE_{dry} (MJ/kg)
Other organics	49.06	12.82	26.22
Food waste	59.81	9.89	16.51
Wood	84.68	13.66	16.14
Paper	84.42	14.04	16.60

The summary of the results of the Gross energy on wet and dry basis is indicated Table 2 and plotted on a graph showing the variation of gross energy of the waste on wet and dry basis (Figure 5).
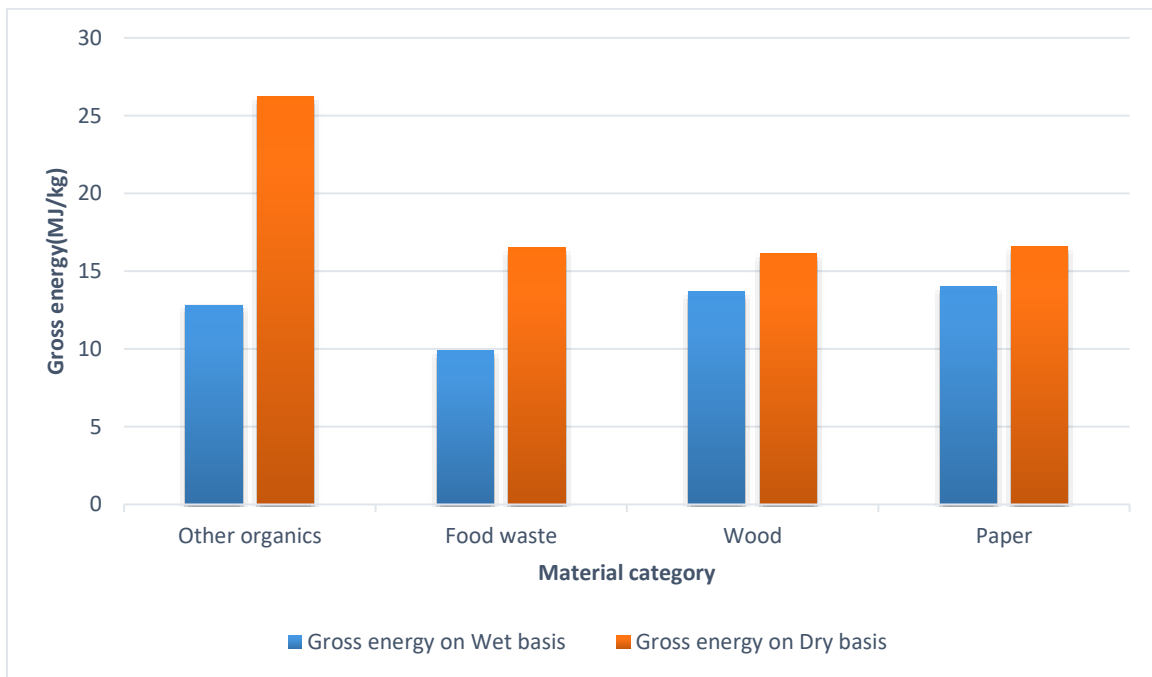

Figure 5: Variation of Gross energy of the waste on wet and dry basis

DISCUSSION

This study evaluated the impact of moisture content on the heating value of the waste. The study also clearly indicates that dry matter gives out more energy than wet matter. The Gross energy content of the MSW on wet basis when compared to the Gross energy content on dry basis is observed to be lower. This is attributed to the fact that the moisture content in the waste lowers the heating value of the waste by absorbing the heat thereby reducing the relative efficiency of heating when the solid waste is combusted.

CONCLUSION

In a wet season, there should be construction of a temporary roof at the dumping site to shelter the municipal solid waste so as to minimize exposure of the waste to moisture as this significantly lowers the Energy content of the waste.

LIST OF ACRONYMS

CV   Calorific Value
CC   Correlation Coefficient
IDA   International Development Association
WtE   Waste to Energy
SWM   Solid Waste Management
MOU   Memorandum of Understanding
MSW   Municipal Solid Waste
ASTM   American Society for Testing and Material
HHV   Higher Heating Value
SWMS   Solid Waste Management System
RCRA   Resource Conservation and Recovery Act
C   Carbon
H   Hydrogen

O	Oxygen
N	Nitrogen
S	Sulphur
VM	Volatile Matter
FC	Fixed Carbon
TGA	Thermogravimetric Analysis
MC	Moisture Content
RDF	Refuse-Derived Fuel
GPM	Geometric Programming Model
RMSE	Root Mean Square Error
SPSS	Statistical Package for the Social Sciences
GPS	Global Positioning System

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