ASSESSMENT OF ENERGY RECOVERY POTENTIAL OF MUNICIPAL SOLID WASTE IN KHULNA CITY

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ABSTRACT

This study highlights the energy recovery potential of Municipal Solid waste (MSW) generated in Khulna city, Bangladesh. Uncontrolled disposal of MSW can have severe negative impacts on human health and the environment which can be reduced by converting MSW into value added by-products such as fuel, boichar, biogas, and adsorbent materials. Prior to conducting pyrolysis studies the wastes of interest were air dried and characterized using thermo gravimetric analysis (TGA). The major thermal events (mass loss rate) were found approximately between 250°C and 500°C which was considered as the ideal temperature range for pyrolysis process. Pyrolysis studies conducted using MSW showed that temperature and retention time had a significant influence on the amount and composition of the products generated. 60.3% biochar (at 350°C), 45.3% biogas (at 450°C) and negligible amount of biooil were obtained from Pyrolysis. The results of Pyrolysis analysis showed significant potential for energy recovery from MSW.

Keywords: *Waste-to-energy, TGA, Pyrolysis, MSW*

1. INTRODUCTION

Municipal solid waste generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate. As a general trend, the higher the economic development, the higher the amount of municipal solid waste (MSW) generated. Nowadays, more than 50% of the entire world's population live in urban areas. The high rate of population growth, the rapid pace of the global urbanization and the economic expansion of developing countries are leading to increased and accelerating rates of municipal solid waste production (World Bank, 2012).

With proper MSW management and the right control of its polluting effects on the environment and climate change, municipal solid waste has the opportunity to become a precious resource and fuel for the urban sustainable energy mix of tomorrow: only between 2011 and 2012, the increase of venture capital and private equity business investment in the sector of waste-to-energy (WTE) - together with biomass has registered an increase of 186%, summing up to a total investment of USD 1 billion (UNEP/Bloomberg NEF, 2012).

Increasing amount of Municipal solid waste (MSW) generation due to high population growth and its lack of management has become one of the major environmental concerns in urban areas of Bangladesh. Currently, uncontrolled landfill sites are the primary destination of solid waste disposal in Khulna city. However, these disposal practices of solid waste can have negative impacts on human health and the environment. For this, alternatives to disposal of MSW can be considered as the MSW has the potential resources. Waste-to-energy (WTE) recovery process can reduce the amount of materials sent to landfills, prevents air/water/soil contamination, and cuts the fossil fuel burning for power generation. Khulna is the third largest commercial city in Bangladesh with a population of 1.9 million, which produce about 450 tons of MSW per day (Ahsan et al., 2009).

The benefits of WTE technology are the 90% volume reduction of waste, energy recovery, convenient metal recovery, destruction of organic pollutants and the ability to control hazardous emissions to the environment. Additionally, it has been shown in recent years that the contribution to global greenhouse gas emissions from WTE is 1.3 tons (of carbon dioxide equivalents) less than landfilling per ton of MSW (Themelis, 2004). A WTE plant significantly reduces atmospheric emissions of several hundred different kinds of dangerous, volatile organic compounds and chlorinated compounds which emanate from landfills (Themelis et al., 2002).

Due to the environmental benefits associated with modern WTE, there is a need to find ways to improve WTE performance and reduce the capital cost to encourage the use of this environmentally favourable technology. As international concern about global warming intensifies, the ability of WTE facilities to reduce greenhouse gas emissions, as compared to landfilling, will become an increasingly important factor when choosing a method for MSW management. There is also a large potential market for WTE technology in developing countries as they become increasingly aware of environmental issues, and work to tighten environmental legislation and regulations. Many of this cleanup process hinges, however, on the affordability of WTE.

2. METHODOLOGY

To carry the experiments, Municipal solid waste (MSW) is used. These MSW collected from KUET, Khulna and the nearby local area of Khulna city. Samples were labelled independently as dumping site, dustbin, garbage truck, slaughter house, drains and market bin after collection. The mass of solid waste sample collected during each sampling was about 10 kg throughout the study period. Determination of waste material composition was done by way of physical segregation (manual sorting) and observation of collecting waste components. Each bag of waste was weighed, and then its contents emptied, sorted and weighed again. The percentage (%) composition was categorized into four major categories. Then the waste components were thoroughly mixed, shredded and sieved to a quality size of < 2 mm which can be handled in the laboratory for further analysis.

2.1 TGA Analysis

The volatile matter content in the different wastes studied (after air drying) was determined using a thermo-gravimetric analyzers (TGA-50, Shimadzu, Japan). A fixed amount of dry waste was loaded and the instrument was purged with nitrogen. The temperature was increased from room temperature to 600°C @ 10 °C/min and the weight loss was recorded. The flow rate was 10ml/min and holding time was 05 min. The volatile matter content was calculated based on the percentage weight loss from the derivative curve.

2.2 Pyrolysis

2.2.1 Experimental Setup

Batch type fixed-bed fire-tube pyrolysis reactor was selected for the study. It was made of MS sheet having a length of 40 cm & the outer diameter of the unit was 16.0 cm and inner diameter of 15.24 cm. One side of the reactor was closed and the other side was connected to flanges which is connected to the electric heater and sealed properly by the use of high temperature resistance gasket. The closed chamber and pipeline were insulated by rope to prevent heat lost. A copper pipe having internal diameter 0.5 mm was used as a condenser, which is wrapped with foam to aid the processing of condensation of vapour. Nitrogen gas was supplied from a cylinder to maintain an oxygen free atmosphere inside the chamber. A pressure regulator and N_2 gas flow meter were used to control the required gas flow rate in the chamber. One end of the thermocouple wires was inserted into the chamber and other end were connected to the temperature recorders to record the temperature.

2.2.2 Experimental Procedure

1.0 kg MSW sample was taken in the reactor. Pyrolysis experiments were carried out in the reactor at various temperature ranges from 350°C to 450°C. The experiments were performed separately for two MSW sample. Before the start of the experiment the reactor was purged by the flow of N2 to remove the inside air. The reactor heater was switched on and the temperature of the reactor was allowed to rise to a desired value of 350°C, 400°C and 450°C indicated by the temperature recorder. The thermocouple sensors were placed in the reactor chamber to record the temperature, which is connected to a digital recorder. At the same time the temperature was controlled by a temperature controller. During pyrolysis nitrogen gas was supplied in order to maintain the inert atmosphere in the reactor and also to sweep away the pyrolysied vapour product to the condenser. The vapour from the reactor was condensed in a water cooled condenser and the non-condensable gas was vented to the atmosphere. The condensed oil was collected from the outlet of the condenser in a measuring cylinder and weighted. The remaining residue collected and weighted after cooling the reactor. The weight of non-condensable gases were also measured.

3. RESULTS AND DISCUSSIONS

3.1 TGA Analysis

Figure 1 shows the TGA analysis of MSW sample generated in Khulna city. A thermo Gravimetric Analysis experiment was carried out with 17.123 mg of MSW sample at different heating rates with N2 flow maintained constant at 10 ml/min.

Change in mass of the MSW sample with the temperature at 10 °C/min heating rate is shown in Figure 1. The major thermal events occurring (mass loss rate) approximately between 250°C and 500°C. The vigorous mass loss observed in the temperature that ranges 250°C and 500°C in the TGA of MSW sample can be considered as the active pyrolysis zone. TGA is a variety of methods exist for analyzing the kinetic features of all types of weight loss or gain, either with a view to predictive studies, or to understanding the controlling chemistry. Values of activation energies, obtained in this way, have been used to extrapolate to conditions of very slow reaction at low temperatures and to very fast reaction at high temperatures.

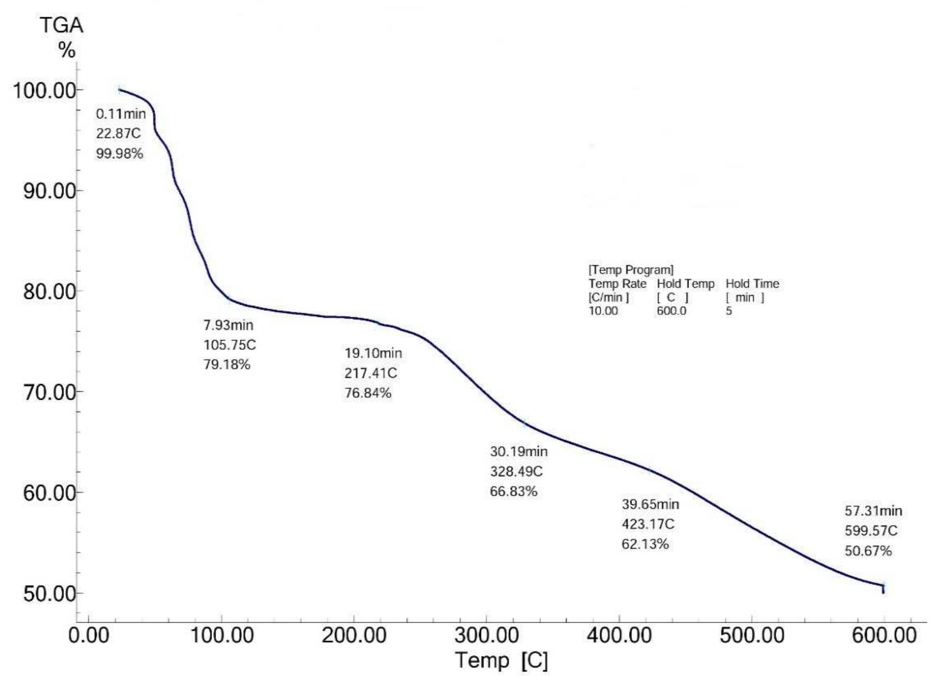

Figure 1: Thermal analysis result of MSW sample

3.2 Pyrolysis

3.2.1 Mass Balance

The raw materials used were the MSW generated in Khulna city. During Experiment 1 kg MSW were taken in the reactor chamber. The experiments were performed by varying the temperature within the range of 350°C to 450°C at every 50°C interval. The data collected during the experiment are shown in table 1.

Table 1: Experimental Data of paralyzing 1.0 kg of MSW for Various Temperatures

No. of Observations	Temperature in ^{0}C	Product			Residence Time (min)
		Char (Kg)	Oil (Kg)	Gas (Kg)	
01	350	0.603	0.03	0.367	66
02	400	0.552	0.039	0.408	56
03	450	0.5	0.047	0.453	47

3.2.2 Effect Of Temperature On Product Yield

The effect of temperature on the pyrolysis products obtained from MSW has been shown in Table 2. The tests were performed from temperature 350°C to 450°C and data was collected every 50°C interval. The results have been plotted in Figure 2.

Table 2: Effect of Temperature on Product Distribution of Pyrolysis of MSW

No. of Observations	Temperature in ^{0}C	Weight (Kg)	% of Product		
			Char	Oil	Gas
01	350		60.3	3	36.7
02	400	1.0	55.2	3.9	40.8
03	450		50	4.7	45.3

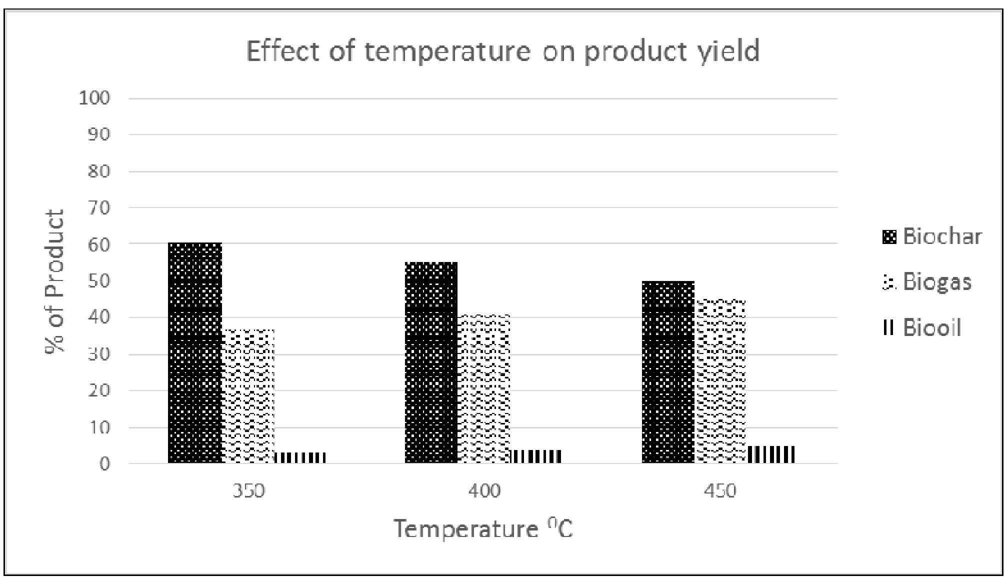

Figure 2: Effect of temperature on product yield

In this case with the increase of temperature both bio-oil and bio-gas were increased but bio-char decreases gradually. Bio-Char can be used as adsorbent which can remove pollutants, contaminants and other impurities from water, air, food and beverages, pharmaceuticals and more. Bio-Gas can be used as a fuel. It can also be used in a gas engine to convert the energy in the gas into electricity and heat. Bio-fuel can be used as a pure fuel or blended with petroleum in any percentage. 60.3% biochar (at 350°C), 45.3% biogas (at 450°C) and negligible amount of biooil were obtained.

4. CONCLUSIONS

In TGA analysis, the major thermal events occurring (mass loss rate) were found approximately between 250°C and 500°C which was considered as the ideal temperature range for pyrolysis process. A significant amount of biochar and biogas but negligible amounts of biooil were obtained from the sample by the process of Pyrolysis. 60.3% Biochar (at 350°C), 45.3% Biogas (at 450°C) and negligible amount of Biooil were obtained. Biochar can be used as adsorbent which can remove pollutants, contaminants and other impurities from water, air, food and beverages, pharmaceuticals and more. Biogas can be used in a gas engine to convert the energy in the gas into electricity and heat. Biofuel can be used as fuel and/or can be blended with other petroleum.

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