Analysis of Extracted Bio-Fuel from Plastic based Solid Medical Waste through Pyrolysis

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Abstract

Due to rapid growth industrialization and population, the demand for energy and production of non-bio degradable waste increasing at a very high rate in Bangladesh. Maximum demand for energy is fulfilled by fossil fuel which is harmful to the environment and will no longer be available at future. To overcome the energy crisis as well as manage the solid wastes pyrolysis can be an alternative solution. A proposal has comforted as solution to produce alternative fuel from pyrolysis of non-bio gradable solid waste materials. Solid medical waste is one of the most common types of wastes. Every year a tonne of solid medical waste is produced which is very threatening for the ecosystem. However, it is a very high-quality bio-mass source and available at very low cost. To extract fuel from the waste a fixed bed type mini pyrolysis reactor is designed and constructed. After extracting fuel, quality and quantity of the fuel are measured and compared with a pyrolytic oil obtained from tire waste. The physical properties of the pyrolytic oils were found to be very close to diesel and gasoline.

Keywords: *Pyrolysis, Bio-nondegradable, Alternative-fuel, Medical waste.*

1.0 INTRODUCTION

Global energy consumption increases significantly in 2018-2019 and 90% energy demand is fulfilled by non-renewable energy which source is limited. Only 10% of energy comes from biomass which is a great source of renewable energy [1]. Medical waste is a kind of waste that contains infectious material (or material that's potentially infectious). This definition includes waste generated by healthcare facilities like physician's offices, hospitals, dental practices, laboratories, medical research facilities, and veterinary clinics. [2]. Medical wastes are infectious and hazardous. It poses serious threats to environmental health and requires specific treatment and management prior to its final disposal [3]. Medical wastes are arising from diagnosis monitoring and preventive, curative or palliative activities in the field of the veterinary and human medicine [4]. The new developments medical services are precisely made for the prevention and protection of public health. In various operations for diseases treatment, the using of sophisticated instruments is increasing. Such improvement and advances in scientific knowledge have resulted in per capita per patient generation of wastes in healthcare units [5]. The safe disposal and treatment of medical waste have been ignored in Bangladesh. Medical waste poses contamination for both human being and environment. Medical waste is capable of causing diseases and illnesses to people, either through direct contact or indirectly by contaminating soil, groundwater, surface water and air. Pathogens and hazardous materials can be carried by the wind from these dumps. Domestic animals are allowed to graze in open dumps, there is a risk of reintroducing pathogenic microorganisms into the human body through the food chain. Medical waste poses a risk to individuals, communities, and the environment if not carefully handled [6].

There are many processes of extracting fuel from biomass. Pyrolysis is one of them. It is a thermochemical process. It is a developing technology, but a very common and popular type process. For pyrolysis a suitable type of reactor, heater arrangement is required. Usually, liquid fuel and solid char are the final product at the end of the process. A huge amount of non-condensable gas is produced which can be used in heat exchanger or boiler in case of the large scale of the pyrolysis process. The main purposes of this works are investigating the suitability of solid medical waste as biomass and introduce a new way of medical waste management.

2.0 METHODOLOGY

Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content (liquid fuel) & char [9]. Pyrolysis methods can be grouped into two large categories, slow and fast (or flash) pyrolysis. Slow pyrolysis Consists of slow heating rates of 0.1–1 °C/s, a residence time anywhere from hours to

minutes, and a temperature range of 400–600 °C. It has been used for centuries to produce methanol and yields approximately equal quantities of char, gas, and liquid [7-8]. Fast pyrolysis is a relatively new, promising technology involving a high liquid yield achieved through rapid heating rates of 10 to >1000 °C/s, short residence times of <2 s, temperatures of 400–650 °C, and rapid quenching of the vapours. The pyrolysis of solid tire wastes has received increasing attention since the process conditions may be optimized to produce high energy density oils, char and gases. In addition, oil products can be stored until required or readily transported to where it can be most efficiently utilized [9]. The following equation is showing the products are obtained from pyrolysis.

Waste Material ⟶ Char + Pyrolytic Oil (Liquid) + Gas

3.0 DESIGN AND CONSTRUCTION OF PYROLYSIS APPARATUS

3.1 Design of pyrolysis apparatus

There are various types of pyrolysis reactor. According to the feeding and product removal process, the pyrolysis reactor can be- Batch reactor, Semi batch reactor, Continuous reactor, Fixed bed reactor, Fluidized bed reactor, Screw kiln reactor etc.

In this research, a mini fixed bed plant is constructed. The main parts of this plant are the following:

i. Reactor.
ii. Heater arrangement.
iii. Temperature sensor.
iv. Condenser arrangement.

The reactor is a cylindrical, fixed bed reactor made of mild steel. The top side of the reactor can be open for feeding the raw material and solid residue (char) can be removed at the end of the experiment. An exit pipe at the top carries away the evolved gases during pyrolysis. During the reaction, the top side is kept closed by a cover plate tightly secured to the flanged opening. Three U shaped electrical dry heaters are mounted on the top part of the reactor. Each heater is 500W-220V. The temperature inside the reactor is measured by a K-type thermocouple. The range of thermocouple used for this experiment is 0^{o}C to 800^{o}C.A simple gas to water heat exchanger type condenser is provided to condense the volatile gases produced from thermal decomposition. Gas carried by copper tube and incondensable gases is passed through a bypass pipe under the condenser. Bended copper tube is merged in water which is contained by a container.

3.2 CAD model of the setup

On the basis of the design a CAD model drawn in a professional software DSS Solid works 2014 is given below. In figure no 1(a) is a heater arrangement and it is in inside of the reactor and figure 1(c) is a condenser arrangement and it is in inside of the condenser part.

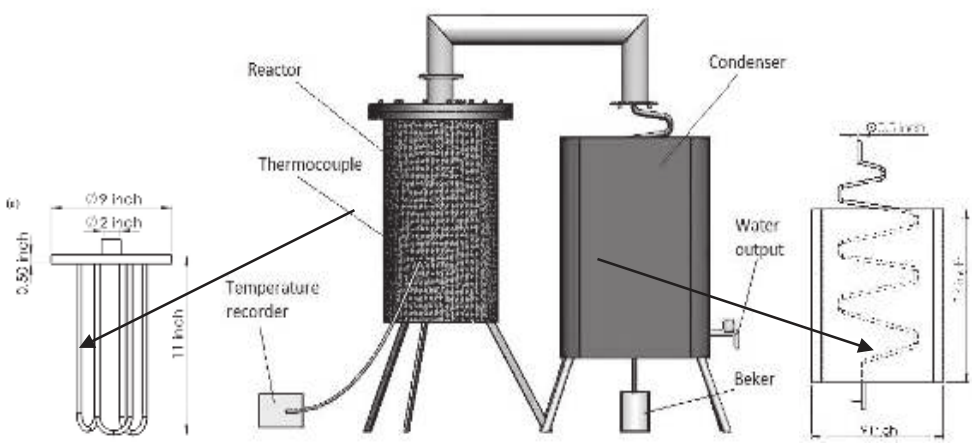

Fig. 1: CAD model of the Mini Scale Pyrolysis Apparatus

4.0 RESULT AND ANALYSIS

4.1 Data collection

The waste material collected and a fixed amount of waste is placed inside the reactor. Around 1 kg of medical waste was placed in it. The experiment was performed three times. The data collected during the pyrolysis process is shown in Table 1.

Table 1: Table of percentage of extracted products through experiment with respect to time

No of Obs.	Mass of Feed (kg)	Condenser Temp. (Initial Temp. (°C)	Condenser Final Temp. (°C)	Starting Temp. (°C)	Final Temp. (°C)	Time (min)	Inconde nsable Gas (%)	Amount of Ash	Amount of Liquid (%)
1	1	20	26	58	312	30	55.4	28.6	16.0
2	1	20	28	56	340	45	55.8	30.2	14.0
3	1	19	26	64	333	36	60.4	25.8	13.8
4	1	19	27	60	335	38	56.8	26.0	17.2
5	1	20	27	65	340	35	59.4	24.9	15.7

4.2 Analysis

Various physical properties of pyrolytic oil obtained from medical waste were determined in laboratory of Khulna University of Engineering & Technology (KUET). The oil extracted from tire waste was black in colour and the oil extracted from medical waste was brown in colour. The oil has an acidic smell and it reacted with the human skin. The oil is collected in a glass jar and the properties of oil didn't change. Properties of the obtained oil are compared with pyrolytic oil from tire waste [10], Diesel and Gasoline in table 2.

Table 2: Properties comparison of extracted biofuel with pyrolytic oil from tire waste, Diesel and Gasoline

Property	Pyrolytic oil from medical waste	Pyrolytic oil from tire waste [10]	Diesel	Gasoline
Flash point (°C)	48	37	53 – 80	N/A
Density (kg/m^3)	1133.33	912	820 – 850	719-780
Gross calorific value (kJ/kg)	39,220	39,000	42,000	43,200
Kinematic viscosity (cSt), 40°C	12.22	5.5	2 - 4.5	1.95 – 3.3

From the obtained properties of the pyrolytic oil of waste material, it is seen that the density of the oil is very close to the diesel and the gasoline range. The kinematic viscosity is higher than diesel and gasoline. It is observed that Calorific value is lower than diesel and gasoline. The flashpoint of both pyrolytic oil is lower than that of diesel.

5.0 CONCLUSION

Pyrolysis process of non-biodegradable solid medical waste was investigated. Thermal decomposition of non-biodegradable solid waste materials was studied. Pyrolytic oil obtained from the non-biodegradable medical solid waste material through pyrolysis was performed by heating the waste at a high temperature in the absence of oxygen in a fixed bed reactor and condensing the volatile material. Thermal decomposition of the waste depends on the size of the reactor and the relative size of the waste. The oil obtained through pyrolysis is not pure. It contains impurities like water, wax etc. If these impurities can be separated oil properties maybe enriched.

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