JOURNAL OF ENGINEERING SCIENCES

ЖУРНАЛ ІНЖЕНЕРНИХ НАУК

ЖУРНАЛ ИНЖЕНЕРНЫХ НАУК

Web site: http://jes.sumdu.edu.ua

DOI: 10.21272/jes.2018.5(2).h2 Volume 5, Issue 2 (2018)

UDC 662.767.2

Recovery of Pyrolytic Oil from Thermal Pyrolysis of Medical Waste

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Article info:

Paper received:	May 19, 2018
The final version of the paper received:	August 15, 2018
Paper accepted online:	August 18, 2018

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Abstract. In this paper, potential of beneficial products recovery was investigated from plastic medical waste (PMW) by pyrolysis process. Disposable plastic is one of the chief items in the medical waste. High density polyethylene and Polypropylene is the main component of several PMW. These plastics have a higher latent as hydrocarbons sources for chemical industry. Pyrolysis of PMW was accomplished at a temperature range of 200–300 °C in a batch reactor make up of stainless steel. The chemical and physical properties of the pyrolysis liquid were much closer to the commercial fuel like diesel, petrol etc. The density is 840 kg/m3, the gross calorific value is $4.13 \cdot 10^4$ kJ/kg flash point is 39 °C in produces pyrolytic oil. This liquid can be used as alternative sources of fuel.

Keywords: plastic medical waste, pyrolysis, pyrolytic oil, alternative fuel.

1 Introduction

The major problems we facade these days are energy crisis and environmental concern due to the fast growth of population and industrialization. Massive quantity of solid wastes have been refused every day from various sources like household wastes, industrial wastes, municipal wastes, medical wastes, etc. These wastes can be transformed into energy by following appropriate methods; that would be usable for the next generation. Recovery of alternative fuel and reducing plastic waste, the technologies are developed day by day, which are suitable from the environmental viewpoint and cost–effective, has recognized to be an inflexible challenge because of the obscure characteristic in the recycle of polymers [1].Plastic materials, for instance, encompass a progressively increasing proportion of the municipal and industrial wastes. The yearly plastic consumption of the sphere has augmented about 20 times since 5 million tons in 1950s to approximately 100 million tons in latest time [2]. Medical wastes are categorized as solid and liquid states. Plastic medical wastes are the solid type of medical wastes, such as vials, saline pots, saline pipes, covers, medicine containers, packets, etc. Medical wastes are infectious and hazardous. It retains severe threats to the environment and needs specific treatment and management prior to its final disposal [3]. The safe dumping and handling of medical wastes has been ignored in Bangladesh. Medical waste is proficient of causing diseases and disorder to people, either through straight contact or ultimately by contaminating soil, surface water, groundwater and air [4]. Medical waste, consequently, possesses a risk to human, communities and the surroundings if not carefully handled. According to [5], the medical waste management procedure includes handling, segregation, disinfection, storage, transportation, collection and final disposal. Various methods such as land filling, biological recycling, mechanical recycling, thermo–chemical recycling, etc. are used for medical waste management. Land filling is not a suitable option for positioning plastic wastes because of their relaxed degradation rates. Mechanical recycling can be actual process but it is limited to thermoplastics, contamination level, homogeneity of the types and color similarity [6]. Chemical recycling of plastic wastes is one of the most remarkable plastic wastes management methods. Incineration and pyrolysis are usually employed to obtain bio–fuel from plastic materials. Of them, pyrolysis method is one of the most effective and promising techniques to obtain liquid fuel from the plastic medical waste. Incineration is a critical procedure, in which hydrocarbons are altered to their combustion products, whereas, pyrolysis may be employed to change them into inferior hydrocarbons, which may be made use of as fuel and other different materials [7]. Pyrolysis is a thermal method by less or deficiency of oxygen. In the pyrolysis method, the organic constituents of the decomposable material yield gaseous and liquid products, which can be used as a source of chemicals and fuels [8]. Products acquired from pyrolysis of plastics depend on the nature of plastics, residence time, feeding arrangement, reactor type, condensation arrangement and temperatures employed [9]. Very diverse experimental processes have been used to acquire liquid products from plastic–based medical waste by thermal pyrolysis method. Numerous reactor schemes have been established and used for instance batch/semi batch, fluidized bed, spouted bed, fixed bed, microwave and screw kiln. Semi–batch, batch and fixed bed reactors have been used by numerous researchers as a result of its simple design and informal operation. Consequently, we selected batch type pyrolysis reactor to convey out the process.

Not much written in the literature about the pyrolysis process to produce fuel from waste plastics. Butler et al. [10] discussed the review of waste polyolefin plastics. Dash et al. [11] studied on the thermal pyrolysis of medical waste (plastic syringe) for the production of useful liquid fuels. However, nobody explored the present issue as of conversion of plastic medical waste into energy in details, so far.The objective of the work was to manage plastic wastes as well as to reduce environmental emissions. The aim of this research is to explore an alternative source of energy from plastic medical wastes through thermal pyrolysis method using a fixed-bed reactor. The properties of the fuel has been studied and compared with commercial fuels.

2 Research Methodology

2.1 Raw materials

Plastic–based medical waste, used as feed material throughout the experiment, was collected from the local Hospital of Bangladesh. The plastic materials were cleaned successively with water and hydrochloric acid and finally washed with distilled water. They were shredded into four different sizes such as 0.65, 0.975, 1.3, and 1.95 cm^3. Every plastic content were chopped cross–section wise. Then they were used as raw material for thermal pyrolysis process.

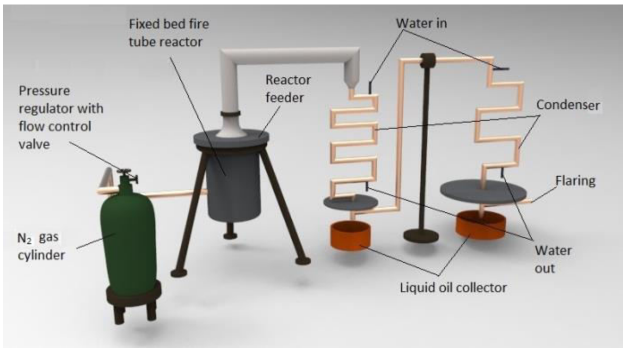
2.2 Experimental procedure

The layout of the experiment can be seen in Figure 1. The apparatus used in the pyrolysis of wastes plastic consisted of batch reactor made of carbon steel of 8 cm length, 14 cm inside diameter and 28 cm outside diameter. Thermocouple (type K) with digital temperature recorder connected to the reactor of 10 cm deep was used to measure inside temperature of the reactor. The heat was supplied to the reactor by 2 kW external electrical heaters (1.5 kW heater in the bottom of the reactor and 0.5 kW heater surrounding the reactor) to get the required reaction temperature. At the top end of the reactor, a tubing system was connected with two gate valves.

Figure 1 – Feed material for pyrolysis

All tubes, having a diameter of 0.5 inch made by copper, were used as condenser. Pyrolysis of medical waste (plastic content) was conducted by a batch type fixed–bed system. This procedure was conducted for variety of feed quantity and temperature. The plastic–based medical wastes were shredded into equal size which was fed (1 kg) to the reactor. The thermal recycling pyrolysis process carried out under inert atmosphere. Prior to starting the experiment, the pressure cooker was purged by flowing N_2 gas for 5min to remove air inside. During the experiment, the pressure in the flow meter and reactor chamber were remained same but slightly higher than that of atmospheric pressure just to maintain continuous flow of N_2 gas.

The heat was supplied (room temperature to 500 °C) in consistence basis and vapor forms in the reactor. The gas movement line was completely opened from the reactor to the condenser. Cooling water was supplied on the surface of the condenser on continuous basis. At the outlet of reactor, a condenser was attached to condense the vapors coming out of it. The condensed vapors were collected in a container as the liquid product, whereas, there was some amount of non–condensable gases which were simply left out. The schematic diagram of fixed bed pyrolysis plant is shown in Figure 2.



Fiureg 2 – Schematic diagram of a fixed bed pyrolysis plant

When the pyrolysis process of all samples was completed, supply of N_2 gas was stopped and switched off the heater of the reactor. Then wait for a while to cool the reactor and collected the char product. After that the char product and liquid were weighted. The weight of the gas was determined by subtracting the total weight of char product and liquid obtained after condensation of vapor from the full amount of feedstock.

3 Results and Discussion

3.1 Elemental and proximate analysis of PMW

Elemental and proximate analysis PMW is very important to determine numerous properties of PMW. The heating rate and volatile constituents are the vital factors for PMW pyrolysis. The Elemental and proximate analyses of PMW with higher calorific rate are showed in below Table 1.

Table 1 – Proximate and elemental analysis PMW, wt %

Proximate analysis		Elemental analysis	
Moisture	0.82	Carbon (C)	72.56
Volatile	62.70	Hydrogen (H)	11.17
Fixed carbon	32.31	Nitrogen (N)	5.82
Ash	4.17	Sulphur (S)	0.23
H.C.V, MJ/kg	33.30	Others	10.22

3.2 Effect of temperature on pyrolysis product yield

Pyrolysis of medical waste (plastic) in batch type fixed-bed reactor, the experimentations was directed in the temperature range of 200–300 °C. The investigations were directed to detect the significance of pyrolysis temperature on yield.

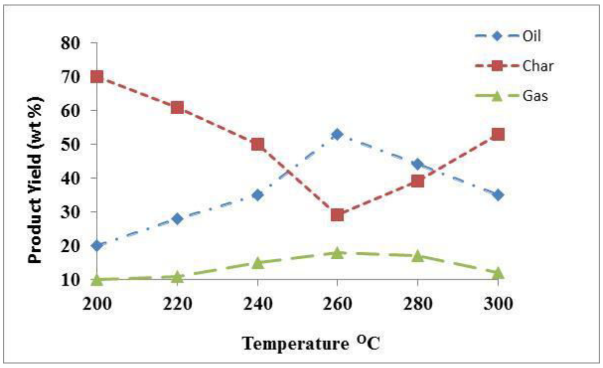


Figure 3 – Effect of temperature on pyrolytic yields for feedstock size 0.65 cm^3

At diverse temperature of numerous feedstock sizes (0.65, 0.975, 1.30, and 1.95 cm^3), there were achieved three types of pyrolysis yields such as liquid oil, solid and gas are presented in Figure 3 for feedstock 0.65cm^3 due to straightforwardness. It is stated from the figure that when the escalation of temperature occur, the rate of liquid manufacture augmented up until it attained a maximum value and formerly reduced. All the data denote alike nature. Among the 4 sample sizes, the excellent result was attained for the feed size of 0.65 cm^3. When the temperature augmented from 200 to 260 °C, the production of liquid augmented first from 20 wt % to a maximum value of 53 wt % and then reduces to 35 wt % at a temperature of 300°C. The gas production augmented from 10 to 18 wt % over the entire temperature range, whereas char yield declined from 70 to 29 wt %, formerly remain residues were almost constant. It is pragmatic that a properly sharp optimum occurs in temperature at which supreme production of liquid was attained possibly because of strong cracking of plastic at 260 °C temperature. The gas manufacture augmented over the whole temperature range to a uppermost value of 18 wt % at 260 °C, whereas, char yield decayed up to 300 °C and formerly remained just about constant.

3.3 Fuel properties of the liquids

The obtained synthetic oil obtained from pyrolysis of plastic content of medical wastes had strong acrid smell and appears dark brown with. Comparison to commercial fuel kerosene oil and diesel, the fuel properties of the pyrolysis oil which are generally consumed in Bangladesh, are shown below in Table 2. This table shows that the pyrolysis oil density was found approximately similar to other commercial oil like diesel fuel and kerosene oil.

Table 2 – Fuel properties of the pyrolysis oil compared to commercial fuels

Property	Pyrolytic oil	Diesel	Kerosene
Density, kg/m^3	840	870–950	780–810
Gross calorific value, kJ/kg	41 325	44 800	35 000
Flash point, °C	39	52	37–65
Pour point, °C	14	–9…+9	–40

4 Conclusions

Recovery of liquid fuel from PMW through thermal pyrolysis was explored in the present issue quite effectively that added value to the energy sector. A limited number of trial runs were done at several operating conditions for the maximum liquid yield. The maximum yield of pyrolysis oil from the medical plastic waste was 53 wt % at a temperature of 260 °C with the feed size of 0.65 cm^3. It was observed that fuel properties of pyrolysis oil were comparable to that of diesel and furnace oil. There was possibility to have some impurities in the oil such as wax, water, higher hydrocarbons, etc. need to be removed. The pyrolysis oil can be suggested as a probable alternative fuel to commercial diesel as well as successful management of PMW toward safe environment.

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Відновлення піролітичної олії з термічного піролізу лікарських відходів

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Анотація. У роботі досліджено потенціал відновлення корисних продуктів із пластичних медичних відходів (ПМВ) за допомогою піролізу. Одноразовий пластик є одним з найважливіших предметів у медичних відходах, а поліетилен високої щільності та поліпропілен – основними компонентами деяких ПМВ. Ці пластмаси мають більш високі приховані джерела вуглеводнів для хімічної промисловості. Піроліз ПМВ здійснювався в інтервалі температур 200–300 °C у паровому реакторі з нержавіючої сталі. Хімічні та фізичні властивості піролізної рідини були суттєво ближчими до комерційного палива, зокрема дизельного палива та бензину. Властивості піролітичної олії: густина 840 кг/м^3, питома енергоємність $4.13 \cdot 10^4$ кДж/кг, температура займання 39 °C. Також отриману рідину можна використовувати як альтернативне паливо.

Ключові слова: пластичні медичні відходи, піроліз, піролітична олія, альтернативне паливо.