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Recovery of Liquid Fuel through Thermal Pyrolysis of Medical Waste (Waste Syringe) in a Batch Reactor

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ABSTRACT
Various types of plastic materials are important items of medical waste one of which is syringe wastage covers an important fraction of plastic medical waste. These plastic syringes have a great potentiality to be used as liquid or gaseous fuel as well as source of hydrocarbon. High density Polyethylene and Polypropylene are the main components of syringes. The pyrolysis process was accomplished in a batch reactor. Gas Chromatography-Mass Spectrometry and Fourier Transform Infra-Red Spectroscopy analysis of pyrolysis liquid were carried out in this study which specified the presence of aromatic compounds, alkenes and alkanes. The chemical and physical properties of the pyrolysis liquid were much closer to commercial fuel like diesel and gasoline. The density, viscosity and calorific value of the liquid product were 758 kg/m^3, 4.75 cSt and 39.561 MJ/kg. The maximum amount of liquid yields was 53 wt. % at 220°C and char yields 70.00 wt. % at 180°C respectively. The gas yield increased from 10 to 18 wt. % over the whole temperature range, while char yield decreased from 70 to 29 wt. %.It could be used as an alternative source of energy.

Keywords: Medical Waste, Plastics Syringe Wastage, Pyrolysis, Liquid Fuel, Batch Reactor

1. Introduction

Due to fossil fuel crisis in past decade, mankind has to focus on developing the alternate energy sources. The focused alternative technologies are bio-ethanol, bio-diesel, bio-fuel, waste oil recycling, pyrolysis, gasification, dimethylether, and biogas [1]. Plastic plays a significant role in improving our lifestyles in several sectors such as healthcare, packaging,construction, automotive, electronic, food industry and many more. The growth of the world population hascaused the requirement of commodity plastics to further increase. According to statistic, the worldwide productionof plastic has reached about 299 million tons in 2013 and has enlarged by 4% over 2012 [2].Although medical wastes (plastic syringe) represent a comparatively small segment of the total plastic waste generated in a society, medical waste supervision is considered a vital issue worldwide [3]. The percentage of plastic medicalwaste ended up in landfill is still very high. Plastics may possibly take up to millions of years to degrade in nature.They degrade steadily since the molecular bonds containinghydrogen, carbon, nitrogen, chlorine and few other elements that make plastic very long-lasting. The continuous dumpingof plastic in the landfill would unquestionably cause seriousenvironmental problem [4]. Healthcare division is rising at a very speedy pace, which in turn has led to inconceivable increase in the amount of medical waste production in developing countries, especially by clinics, hospitalsand other healthcare establishments.

As a developing country, Bangladesh produces a large amount of medical waste every day. A study on Khulna City Corporation (KCC) reveals that there are about150 health care facilities in KCC and the totalwaste generation in Khulna city is about 520 ton/day and theamount of clinical waste generation is 2.5 ton/day [5]. Another study on Rajshahi City Corporation (RCC) suggests that theamount of medical waste collected by the RCC is 2-2.5 ton/day[6].A further study on Jessore Municipality focused on the regular generation rate of Health Care Waste (HCW) which was0.49 kg/patient/day, 1.59 kg/bed/day and 0.11 kg/test/day [7].Plastics have turn out to be a key threat because of their non-biodegradabilityand high visibility in the waste stream. Litteringalso results in minor problems such as blockage of drains andanimal health troubles. Their occurrence in the waste stream poses a severe problem when there is lack of well-organized end of lifemanagement of plastic waste [8].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 [9].Until now, there was no efficient structure for suitable medical waste management in Bangladesh to safeguard our environmental health dangers [10].

Pyrolysis is a process with comparativelylittle cost from which anextensive distribution of products can be gained. It is one of the most operative and hopeful procedure to acquire liquid fuel from the medical plastic waste [11].In the procedure of pyrolysis, where heatingof raw material occurs in the nonexistence of

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oxygen, the organic compounds are decayed generating liquid and gaseous products, which can be used as alternative fuels and / or sources of chemicals. Meanwhile, the inorganic substance, free of organic matter, remains unaffected under the solid portion and can be re-used later [12]. Thermal crackingoccupies the scission of extensive polymer moleculessimply by exposure to elevated temperatures under inertatmospheric conditions. This type of process generatesa heterogeneous hydrocarbon (HC) mixture, whoseaccurate composition depends mainly on process circumstances and plastic type [13].Catalytic pyrolysis has quite a few advantages over the thermal process although catalysts are expensive and the design of the reactor has to consider the opportunity of avoiding catalyst poisoning and deactivation by the adulterants in the feedstock. To avoid these difficulties thermal pyrolysis process has been used in this experiment [14].
The purpose of the current study has been to analyze the effectof thermal cracking on the products obtained bythermal pyrolysis of Polyethylene and Polypropylene, focusing on the composition of liquidfractions, variations with the physical and chemical properties and the compoundtype. The percentage of various yields has also been studied.A detailed discussion ismadewith results obtainedby different experimental procedurethatmay contribute to animproved understanding of the potential of thethermal pyrolysis process as a promising medical waste recyclingprocess.

2. Materials and Methods

2.1 Collection and Preparation of Raw Materials

In thisstudy, only the plastic portions of syringe waste have been used. Plastic-based medical wastes, used as feed material throughout the experimental investigations which were collected from Doratana Hospital that is located at JessoreSadar in Jessore district.Syringe wastes were chopped cross-section wise varied size like 2 cm × 1.5 cm × 0.75 cm =2.25 cm^3. Fig. 1 shows the cutting tool and the size of the prepared raw materials compared with a coin.

Fig. 1 Preparation of Raw Materials

2.2 Experimental Set-up and Method

In this study a fixed-bed pyrolysis reactor was used. Fig. 2 shows the (2-D) schematic view of the experimental unit which consists of reactor body and condenser as well as other parts. The N_2 gas inlet and heat sensor unit was positioned at the below portion of the reactor. Two 10 mm diameter tube heater of a total capacity of 1 kW were fixed in equal spacing inside the reactor.The experiment was performed for plastic syringe waste. The temperature inside the chamber was recorded by thermocouple sensors and 1.5 kg raw material was taken for the experiment. Before starting the operation, air inside the reactor was removed by flowing N_2 gas for 2 minutes.

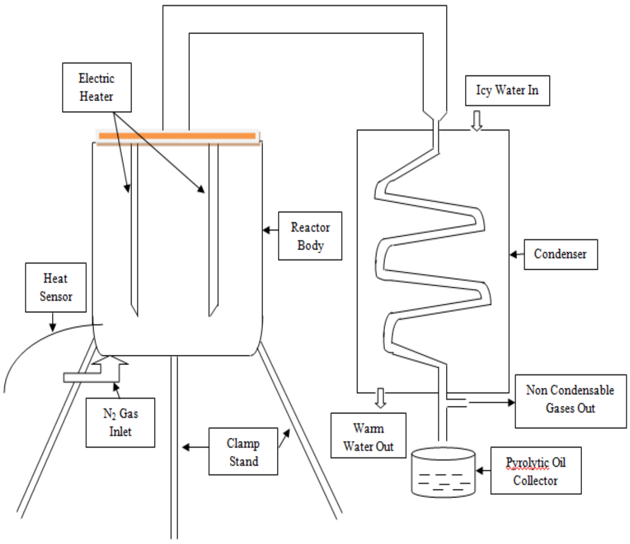

Fig. 2 Schematic diagram (2-D) of the Experimental Set-up

The reactor heater was switched ON and the temperature of the reactor was allowed to raise 250°C indicated by the temperature recorder as the melting temperatures of Polypropylene (PP) and High Density Polyethylene (HDPE) are 166.01 and 132.39°Crespectively[15]. After the decomposition of plastic based materials the pyrolyticvapour created and was passed through the condenser pipes. Condensable gases were condensed and collected as liquid form in the oil collector. Non condensable gases were flown away in the atmosphere.
For GC-MS analysis, Shimadzu GCMS- TQ8040 with inbuilt database library was used in this study. The carrier gas was Helium of 99.9999% pure and 5% diphenyl95% dimethyl polysiloxane (Rxi-5ms) of 0.25μm with dimension of 30m and 0.25mm ID was used as column.The obtained pyrolytic oil was filtered through 0.45μm membrane syringe filter and then 1 μl was injected into the instrument.The following program was adopted for the GC/MS experiment.
Table 1, 2 and 3 shows the Gas chromatography condition, Oven temperature program and mass spectrometry condition respectively.

Table 1 Gas Chromatography (GC) Condition

GC Condition	
Column Oven Temperature	75°C
Injection Temperature	250°C
Injection Mode	Split less
Pressure	79kPa
Total Flow	12.2 ml/min
Column Flow	1.2 ml/min
Purge Flow	5.0 ml/min

Table 2 Oven Temperature Program

Rate	Temperature (°C)	Hold time (min)
-	75.0	0.0
5.00	150.0	1.0
10.0	240.0	1.0
5.00	270.0	3.0

Table 3 Mass Spectrometry (MS) Condition

MS Condition	
Ion Sourde Temperature	230°C
Interface Temperature	250°C
Detector Gain	1.13 kV + 0.2 kV
End Time	35 min
Acq. Mode	Q3 Scan
Event Time	0.5 sec
Scan Speed	2000
m/z Range	50- 1000

For FTIR analysis, Shimadzu IRPrestige-21 ranging from 400- 4500 nm equipped with liquid sample holder having cell thickness of 0.5 mm with NaCl window was used for the FTIR analysis. The sample was injected into the cell and analyzed in the instrument.

3. Result and Discussion

Results and the discussions of the present study are described below:

3.1 Comparison of Evolved Pyrolytic Liquid Properties with other Commercial Fuels

The properties of evolved pyrolytic oil from syringe waste are very important for understanding the quality of the pyrolytic liquid. Table 4 compares some physicochemical properties ofpyrolytic oil with diesel and gasoline. Density of pyrolytic oil is lower than diesel but higher than gasoline. Kinematic viscosity of the pyrolytic oil is similer with diesel but higher than gasoline. Gross calorific value of the produced oil in this study is slightly lower than Diesel and Gasoline.

Table 4 Comparison of Properties of Pyrolytic Oil with Diesel and Gasoline [16-18]

Physical Properties	Present Study (Syringe Waste)	Literature Value	
		Diesel	Gasoline
Density (kg/m^3), 30°C	758	820 to 860	780
Kinematic Viscosity at@40°cSt (centistokes)	4.75	3 to 5	1.17
Gross Calorific Value (MJ/Kg)	39.561	42 to 44	42.5

3.2 Gas Chromatography-Mass Spectrometry (GCMS) Analysis

The major products of plastic syringe waste are condensable liquids. It is difficult to identify the different and numerous components of the liquids. GC/MS analysis is a very resourceful process as it quantifies the components effectively. GC/MS analysis wascarried out for pyrolytic oil obtained from this experiment.The purpose of the test was to get an idea of the nature and types ofcompound of such liquids, in order to determine the possible ways of treating and recycling them.

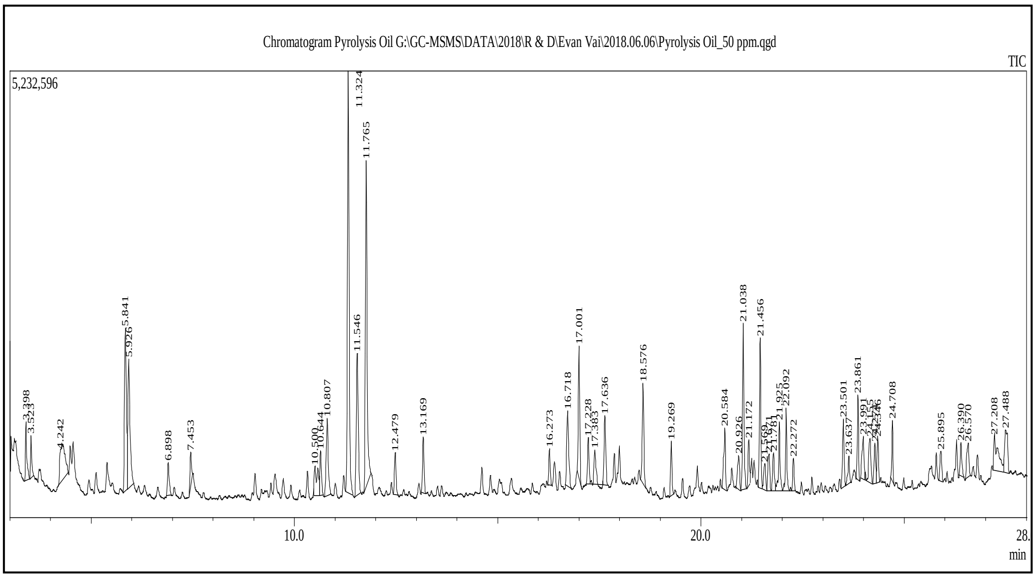

Fig. 3 Chromatogram of pyrolysis liquid derived from syringe waste

Fig.3 demonstrates the chromatogram of pyrolytic liquid obtained from syringe waste. It is a two-dimensional plot with the ordinate axis giving concentration in terms of detector response and the abscissa represents the time. The detector gives response as a peak whose height should be ideally reliant on concentration of the particular component.

Table 5 shows the most probable compounds allocated and their area percentage compared to the total area of thechromatogram, which gives an idea of their relative concentration in the pyrolytic liquids. It can be seen that evolved pyrolysis liquids have a higher concentrations ofIsodecyl methacrylate,11-Methyldodecanol etc.

Table 5 GC/MS characterization of pyrolysis of syringe waste

Retention Time	Area %	Compounds Name
4.242	2.84	2-Decene, 4-methyl-, (Z)-
5.842	4.86	Isodecyl methacrylate
5.925	4.33	2-Undecene, 4,5-dimethyl-, [R*,S*-(Z)]-
6.9	0.86	n-Tridecan-1-ol
7.45	0.77	(2,4,6-Trimethylcyclohexyl) methanol
10.5	1.61	Butyric acid, 2-phenyl-, dec-2-yl ester
10.642	1.06	Dodecane, 4,6-dimethyl-
10.808	2.44	9-Eicosene, (E)-
11.325	10.92	11-Methyldodecanol
11.55	4.44	11-Methyldodecanol
11.767	8.72	11-Methyldodecanol
12.483	1.01	1-Heptanol, 2,4-diethyl-
13.167	1.32	Bicyclo[2.2.1]heptane-2,5-dione, 1,7,7-trimethyl-
16.273	0.80	Decane, 1-iodo
16.718	2.27	2,4 -Di-tert-butylphenol
17.001	2.95	1-Decanol, 2-hexyl-
17.228	1.11	1-Decanol, 2-hexyl-
17.383	0.94	Eicosane
17.636	1.84	1-Decanol, 2-hexyl-
18.576	2.42	n-Nonenylsuccinic anhydride
19.269	1.16	2,5-Cyclohexadien-1-one, 2,6-bis(1,1-dimethyl-)
20.584	1.68	Eicosane
20.925	1.03	1-Cyclopentyleicosane
21.042	3.70	Hexatriacontyl trifluoroacetate
21.175	1.00	Heptacos-1-ene
21.458	3.27	1-Decanol, 2-hexyl-
21.567	0.81	Nonadecylpentafluoropropionate
21.675	1.08	1-Cyclopentyleicosane
21.925	1.66	1-Decanol, 2-hexyl-
22.092	1.77	10-Dodecen-1-ol,7,11-dimethyl-
22.272	0.74	Cyclononasiloxane, octadecamethyl-
23.501	1.65	Tetrapentacontane
23.633	0.74	Cyclohexane,1,2,3,5-tetraisopropyl-
23.858	1.63	Triacontylheptafluorobutyrate
23.991	1.31	11-Methyltricosane
24.158	1.52	Octatriacontylpentafluoropropionate
24.275	1.02	Ethyl14-methyl-hexadecanoate
24.35	1.11	Cyclohexane,1,2,3,5-tetraisopropyl-
24.708	1.02	Cyclohexane, 1,2,3,5-tetraisopropyl-
25.892	0.82	Hexacosylnonyl ether
26.392	0.81	Tetrapentacontane, 1,54-dibromo-
26.567	1.19	tert-Hexadecanethiol
27.208	2.43	Cyclohexane, 1,2,3,5-tetraisopropyl-
27.488	1.93	Cyclononasiloxane, octadecamethyl-
29.330	1.52	Cyclodecasiloxane, eicosamethyl-
31.194	1.40	Cyclodecasiloxane, eicosamethyl-
33.140	1.46	Tetracosamethyl-Cyclodecasiloxane

3.3 Compositional Group Fourier Transform Infra-Red (FTIR) Spectroscopy Analysis

From the FTIR analysis it is discovered that the oil obtained from syringe wastes are mostly the hydrocarbon compounds containing both aliphatic and aromatic compounds. Effect of aromatic compounds in evolved pyrolytic oil is enrichment of cyclic group as well as octane number. The FTIR results are shown in Fig.4 and Table 6.

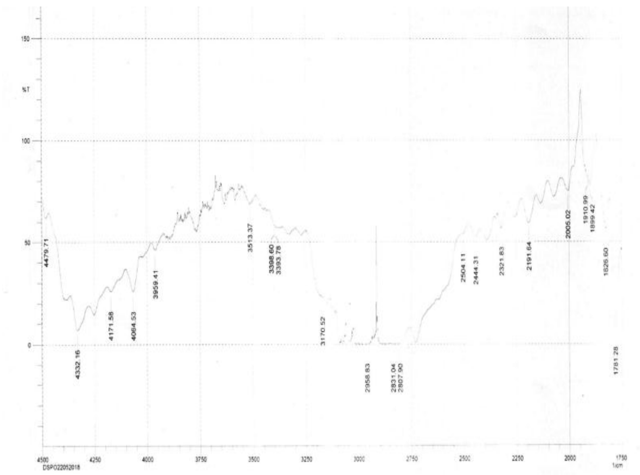

Fig. 4 FTIR Spectra of pyrolytic liquid derived from plastic syringe waste

Fig. 4 gives us an idea about FTIR spectra of pyrolytic oil produced from plastic syring waste. The different absorbance range (cm^{-1}) represents special functional groups and respective class of compounds.

Table 6 illustrates the indicated compounds of the pyrolytic oil. Absorbance peaks between 4000-4500 cm^{-1}absorbance range indicates the presence of aliphatic and aromatic compounds. Similarly absorbance peaks among 3500-4000 cm^{-1}indicate the presence of alcohol and phenol functional groups.

Table 6 FTIR Functional Groups and Indicated Compounds of Pyrolytic Oil

Absorbance Range (cm^{-1})	Functional Group	Class of Compound	Present Study (Syringe Waste)
4050-4500	C-H	Aliphatic, Aromatic	4064-4479
3500-4000	O-H	Hydroxyl Group	3513-3959
3150-3400	N-H	Amines	3170-3398
2190-2510	C≡C	Alkynes	2191-2504
1800-2010	C=O	Aldehyde, Ketone	1826-2005

4. Conclusion

In this study, pyrolysis of medical wastes (waste syringe) was experimented. The density, viscosity and calorific value of derived pyrolytic oil are promising compared with diesel and gasoline. The percentage of the solid, liquid and gaseous products was also measured.From the scrutiny of theGC-MS data the liquid yield of product werecontaining considerable amount of cyclic and aromatic groups. The presence of Isodecyl methacrylate,11-Methyldodecanol suggests that it can be used in various chemical and painting industries as well as oil and gas industries. FTIR results shows upper absorbance range asit specifies the presence of aliphatic and aromatic class compounds.The pyrolytic oil produced from this experiment can be proposed as a feasible unconventional resource for various kinds of chemical, oil and gas industries. This study also suggests a sustainable way of medical waste management towards a safe and healthy environment.

REFERENCES

[1] B. K. Kumar, N. L. Deepak, P. Avinash, Performance and Emission Characteristics of Bio-Diesel using Tyre Pyrolysis Oil, *International Journal of Mechanical Engineering*, Vol. 2, pp 27-35 (2015)

[2] S. D. A. Sharuddin, F. Abnisa, W. M. A. W. Daud, M. K. Aroua, Pyrolysis of Plastic Waste for Liquid Fuel Production as Prospective Energy Source,*IOP Conf. Series: Materials Science and Engineering*, 334 (2018)

[3] Y.W. Cheng, F.C. Sung, Y. Yang, Y.H. Lo, Y. T. Chung, K. C. Li, Medical waste production at hospitals and associated factors, *Waste Management*, Vol. 29, pp440–444 (2009)

[4] S. D. A. Sharuddin, F. Abnisa, W. M. A. W. Daud, M. K. Aroua, A Review on Pyrolysis of Plastic Wastes, *Energy Conversion and Management*, Vol. 115, pp 308–326 (2016)

[5] S. Arifurrahman, A. S. M. Akid, M. Majumder, S. Khair, Scenario of Clinical Waste Management: A Case Study in Khulna City,*Global Journal of Researches in Engineering Civil and Structural Engineering*, Vol. 13, pp 01-07 (2013)

[6] M. Z. Alam, M. S. Islam, M. R. Islam, Medical Waste Management: A Case Study on Rajshahi City Corporation, *J. Environ. Sci. & Natural Resources*, Vol. 6(1), pp 173 - 178 (2013)

[7] M. S. Rahman, C. Moumita, K. Rikta, Medical Waste Management System: An Alarming Threat (A Case Study on Jessore Municipality, Bangladesh), *Journal of Environmental Science & Natural Resources*, Vol. 6(2), pp 181-189 (2013)

[8] A. K. Panda, R. K. Singh, D. K. Mishra, Thermolysis of waste plastics to liquid fuel A suitable method for plastic waste management and manufacture of value added Products-A world prospective, *Renewable and Sustainable Energy Reviews*, Vol. 14, pp 233-248 (2010)

[9] PRISM Bangladesh: Survey Report on Hospital Waste Management in Dhaka City, *Unpublished Report Dhaka: PRISM Bangladesh* (2005)

[10] U. Som, M. S. Hossain, Medical Waste Management is Vital for Safe Town Development: An Incident Study in Jessore Town, Bangladesh, *European Journal of Sustainable Development* Research, Vol. 2(3), pp 36 (2018)

[11] U. Som, F. Rahman, S. Hossain, Recovery of Pyrolytic Oil from Thermal Pyrolysis of Medical Waste, *Journal of Engineering Sciences*, Vol. 5(2), pp H5-H8 (2018)

[12] D. Almeida, M. F. Marques, Thermal and Catalytic Pyrolysis of Plastic Waste, *Polimeros*, Vol. 26(1), pp 44-51 (2016)

[13] M. S. Abbas-Abadi, A. G. McDonald, M. N. Haghighi, H. Yeganeh, Estimation of Pyrolysis Product of LDPE Degeneration using Different Process Parameters in a Stirred Reactor, *Polyolefins Journal*, Vol. 2, pp 39-47 (2015)

[14] S. M. Al-Salem, A. Antelava, A. Constantinou, G. Manos, A. Dutta, A review on thermal and catalytic pyrolysis of plastic solid waste (PSW), *Journal of Environmental Management*, Vol. 197, pp 177-198 (2017)

[15] J. Lin, Y. Pan, C. Liu, C. Huang, C. Hsieh, C. Chen, Z. Lin, C. Lou, Preparation and Compatibility Evaluation of Polypropylene/High Density Polyethylene Polyblends, *Materials*, Vol. 8, pp 8850-8859 (2015)

[16] M. S. Hossain, A. Abedeen, M. R. Karim, M. Moniruzzaman, M. J.Hosen, Catalytic Pyrolysis of Waste Tyres: the influence of ZSM-catalyst/tire ratio on Product, *Iranian Journal of Energy and Environment*, Vol. 8(3), pp 189-193 (2017)

[17] Md. ShameemHossain and A. N. M.M. Rahman, Catalytic Pyrolysis of Tire Wastes for Liquid Fuel. Iranica Journal of Energy and Environment 8 (1): 88-94 (2017)

[18] N. U. Hasan, M. M. Rahman, R. I. Rahat, Characteristics comparison of pyrolysed oils obtained from waste of plastic, tyres and biomass solid, *Proceedings of the 2017 4th International Conference on Advances in Electrical Engineering (ICAEE)*, 28-30 September, Dhaka, Bangladesh