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UTILIZATION POSSIBILITIES OF INFECTIOUS WASTE PLASTIC MATERIALS TOWARD ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

In the present work waste sanitizer containers (WSC) has been pyrolyzed to produce fuel-range compounds. The mixed plastics containers are taken as a feedstock, worn into smaller size and heated at 600 °C under a fixed heating rate of 20 °C/min in a batch type fixed bed reactor. Proximate and ultimate analyses, as well as thermogravimetric analysis are used to find the suitability of the feedstock. The process yielded maximum of 73.2 wt% liquid products with calorific value of 36.5 MJ/kg which is nearer to commercial diesel fuel. The liquid products obtained from WSC have been analyzed for its physical properties. It shows that it can be used as a medium grade liquid fuel for boiler directly or for automotive fuel after upgradation. The Fourier Transform Infrared Spectroscopy (FTIR) characteristics study was also done to investigate the chemical compositions of the liquid oil.

KEY WORDS : Waste containers, Mixed plastics, Energy conversion, Pyrolysis, Sustainability

INTRODUCTION

Plastic containers are ubiquitous in modern culture and become more popular to store all kinds of products. Many items such as food, oils, water, beverages, chemicals and medicines are packaged commonly in plastic containers. They are popular packaging material since they are strong but low weight, non-reactive, cost-effective and shatterproof. The single-serving water bottles and carbonated soft drinks bottles are made up of plastic materials. Some special grade plastics are prepared for store medical solutions. The Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) and its disease, COVID-19, have caused significant concern and anxiety in the public and government sectors all over the world. Several counter measures are being implemented to identify, control and prevent the fatal pandemic (Haritha and Siddhuraju, *et al.*, 2021). Medical, biomedical and ordinary packaging plastic wastes have risen dramatically as a result of medical treatment, diagnosis and research during this epidemic (Mofijur *et al*., 2020). Washing is the most effective approach to control the spread of diseases and reduce the chance of becoming risk. Nowadays the government is taking severe steps to create the awareness among the people towards washing hands with sanitizer.

India is the second most afflicted country with 3.25 crore individuals infected and 4.35 lakh deaths. The Indian government is putting up every effort to meet the challenge. The most important component of restricting the virus's spread locally is equipping people with correct information and urging them to follow the instructions. The corona virus outbreak has a favourable and positive impact on the hand sanitizer market. The demand for hand sanitizers has grown as a result of rising corona virus cases and growing safety concerns. Plastic resins such as polyethylene terephthalate (PET), polypropylene (PP), high-density polyethylene (HDPE) and low-density polyethylene (LDPE) are used to make plastic containers. Figure 1 shows the world plastic market by material in 2021. These materials are commonly used for packing the liquid sanitizer. After use, these containers are thrown away to the open atmosphere. In this pandemic situation, these wastes have grown by about three to six times. The majority of these wastes are composed of various polymers. The major sources of these wastes are hospitals, clinics and health-care facilities. Apart from that, wastes from home quarantine treatments are also come under this category.

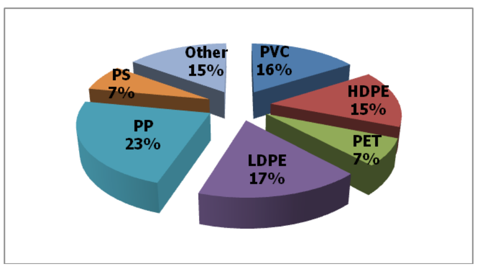

Fig. 1. World plastic market by material at 2021

The most efficient method for dealing these infectious containers is high-temperature incineration. Some advanced health care facilities are utilising chemical disinfection procedures like microwave and steam disinfection. The process of incineration destroys infectious viruses, but it releases a large number of chemicals into the environment, which have a major impact on human respiratory systems (Wang *et al*., 2020). Because of its ease of operation and low cost, land filling method is frequently used. However, it has certain negative effects, such as huge land occupancy, production of harmful gases and the risk of viral transmission (Makarichi *et al*., 2018). These approaches have not been widely used for treating plastic wastes. The clean and safe pyrolysis is the existing treatment technology utilizing for treating infectious plastic wastes. It has numerous benefits by considering economic as well as environmental concerns.

Pyrolysis is considered one of the suitable technologies to breakdown of organic material under anaerobic environment. It is considered as a promising waste disposal technique for extracting energy (Dhanalakshmi and Madhu, 2019). This process can produce three types of value added products such as bio-oil, biochar and biogas (Dhanalakshmi *et al*., 2021). It is classified as slow, fast or flash pyrolysis depending on the operating conditions and product distribution (Deka *et al*., 2018). Pyrolysis is an inexpensive method for producing bio-oil and high-value-added chemical with high conversion efficiency and environmental friendly (Patil, 2020).

This study highlights the present pandemic situation by handling infectious plastic containers. The study also aims to offer efficient solutions for the present issues with regard to waste management procedures. These plastics containers are mainly made from PET, PP, HDPE and LDPE. They are commonly called as mixed plastic wastes. This paper suggests effective plastic waste management during this pandemic and the applications of their end-products. Particular attention has been paid to pyrolysis, which is efficient technique for turning these mixed plastics into useful energy products. In order to understand the utilization possibilities of these waste containers, pyrolysis experiments were performed. The study investigated the conversion behaviour of pyrolysis products and liquid properties. Such understanding is essential for recycling WSC for energy applications with improved values.

MATERIALS AND METHODS

Materials

The used waste sanitizer containers was collected from local plastic scrap vendor. Prior to the pyrolysis process, the materials were tested for its volatile compositions and component analysis. The materials are crushed and screened to obtain the size of 0.5-1.0 mm. The compositions of the plastic containers are identified from the detailed specification available from the manufacturers. They are mainly made from PET $(C_{10}H_8O_4)_n$, PP(C_3H_6)n, HDPE $(C_2H_4)_n$ and LDPE $(C_2H_4)_n$. Furthermore, these plastics are containing some types of special additives such as plasticizers, precursors, slip agents, curing agents, stabilisers in order to make them veryclear, and flexible. As a result, these waste materials are a combination of variety of additive compounds. Water and methanol are to clean the collected container wastes. This method is used to ensure that the samples were handled safely with no pathogenic contaminants are present.

Reactor setup and characterisation

The experiments are conducted in a stainless steel reactor (L:150 mm, OD: 108 mm). The reactor is comprised with electric heater, temperature controller and a condenser unit. The experiments are conducted in an oxygen-free environment. The temperature is fixed constant and controlled accurately. It is perfectly insulated and the bed temperature is measured with two K type thermocouple. The cooling water supplied to the condenser is maintained at 5 °C. The Ultimate analysis of the feed material is conducted using a CHNS elementary analyzer (Elementar Vario EL-III, Germany). The density is measured by weighing known volume of the liquid sample. Viscosity is found by BROOKFIELD LV-DV-II Pro viscometer and flash point of the sample is found by Pensky Martens closed-cup apparatus. The heating value of the obtained feed material and liquid oil is determined using Parr-6772 calorimetric thermometer. The analysis of the oil sample is performed FTIR spectrophotometer (Model: BRUKER Optik GmbH TENSOR 27) to analyse the function al group present in the liquid

Procedure

The aim of this is to identify the effect of reactor temperature on the product yields from thermal pyrolysis of mixed plastics. For that, the experiments are performed at six temperatures of 450 °C, 500 °C, 550 °C, 600 °C, 650 °C and 700 °C with a fixed amount of feedstocks. The reaction is carried out for maximum of 40 minutes at specific temperature settings. At the end of each runs, the liquid oil was collected and weighed. The char products were scooped out from the reactor and weighed. The mass of the gas fractions were calculated using equation (1), as stated by many researchers (Dash *et al*., 2015; Thahir *et al*., 2019).

$$M_g = M_f - (M_c + M_l) \quad .. (1)$$

Where

M_g- Mass of gas products
M_f- Mass of feedstock
M_c- Mass of char products
M_l- Mass of liquid oil products

RESULTS AND DISCUSSION

Feedstock characterization

Table 1 summarize the various characteristics of the feedstock material. It contains mostly of volatile maters with low level fixed carbons. There is no ash content present in the material. The material is having higher amount of carbon and hydrogen with lower oxygen shows to yield high quality liquid products. According to the proximate analysis, the feedstock comprises 93.4 % volatile matter, which means that the majority of the feedstocks are organic elements that will burn in a gaseous form (Rasul *et al.,* 2021). The feedstock contains 6.5 % fixed carbon, which will burn in the solid form. During pyrolysis, the material with higher volatile components produce more liquid product. The higher volatile matters and the higher calorific value of the material are the crucial factors for treating plastic based container wastes.

Thermogravimetric analysis

The thermogravimetric (TGA) analysis is used to determining the feedstock's thermal stability as well as the behaviour of degradation in a controlled environment. In this study, plastic based containers were subjected to TGA under oxidising environment at the heating rates 20 °C/min. The weight of the feedstock with respect to temperature is interpreted by TGA curves (Figure 2). From the figure, the plastic containers started decomposition from 450 °C. The degradation is ended at the temperature of 720 °C with no significant residuals. The structure of the selected feedstock is not complicated as biomass, hence the considerable mass loss was found in a single phase (Çepelioðullar and Pütün, 2013). After

Table 1. Properties of WSC

Material	Proximate analysis in wt%				Ultimate analysis [a] in wt%					Heating value (MJ/kg)
	V	FC	A	M	C	H	N	S	O[b]	
WSC	93.4	6.5	0	0.1	72.48	8.02	0.17	0.4	18.93	32.61

[a]dry ash basis [b]By difference

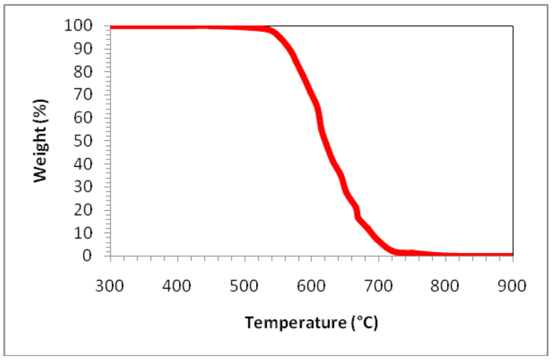

Fig. 2. TGA analysis of WSC

720 °C, the residual mass was found lower than 2 % and the result was verified with the other reports (Nisar *et al.*, 2019; Özsin *et al.*, 2019).

Product Distribution

Condensable liquid oil, char and non-condensable gaseous fraction are the primary degraded polymeric components in this thermochemical conversion process. These yields are depends on the heat transfer behaviour inside the reactor. The product distributions obtained by pyrolysis of WSC at different operating temperature is shown in Figure 3. The figure describes the pyrolysis yields obtained from WSC as a function of reactor temperature. It is seen that liquid yields of 65 to 75 wt% are reachable with the current system. The maximum liquid yields are obtained at the reactor temperature of 600 °C. The simulated results for these liquids shows that the yield become increasingly with increasing reactor temperature (Madhu *et al.*, 2017). The liquid products areenhanced from 33.5 wt% (450 °C) to 73.2 wt% (600 °C). The char yield is decreased continuously with the increase of temperature. The char yield is maximum at 450 °C (51 wt%) and lower at 700 °C (10.5 wt%). On the other side, the gas products remained nearly constant up to 650 °C then

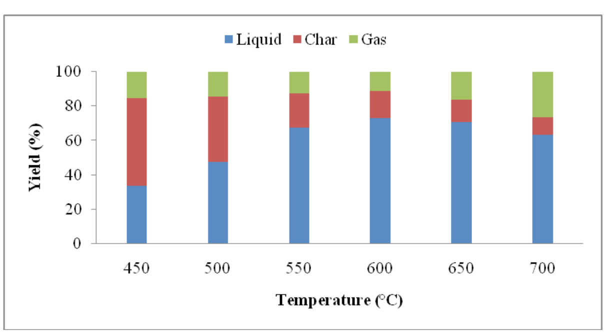

Fig. 3. Pyrolysis yields vs temperature for WSC

increased significantly at 700 °C. Generally the product yields in pyrolysis are depended on feedstock composition, reactor types, heat transfer characteristics, particle size and vapour residence time (Collard and Blin, 2014). For further study, the liquid oil acquired at optimum 600 °C is considered for characterization. Because at this point, the yield of char and non-condensable gas was minimum with maximum oil yield (Madhu *et al.*, 1999).

Physical characterization of liquid

Then elemental composition and higher calorific value of the oil samples obtained at maximum yield condition (600 °C) is displayed in Table 2. The density of the liquid measures 895 kg/m^3. The viscosity is identified as 3.51 cSt at 40 °C. The decreased oxygen content (15.32 %) improved heating value of the liquid to 36.5 MJ/kg. Some of the properties of the liquid products are nearer to diesel fuel, further it can be upgraded to improve the calorific value in order to use as a fuel of IC engines (Islam *et al.*, 2018). Figure 4. Shows FTIR spectrum of the oil.

Table 2. Physical properties of the liquid

Properties	WSC liquid	Unit
Density	895	kg/m^3
Viscosity at 40 °C	3.51	cSt
Flash point	55	°C
Carbon	75.3	wt%
Hydrogen	9.3	wt%
Nitrogen	0.05	wt%
Sufur	0.03	wt%
Oxygen[a]	15.32	wt%
H/C molar ratio	1.471	-
O/C molar ratio	0.152	-
Empirical formula	$CH_{1.471}N_{0.0005}O_{0.152}$	-
Heating value	36.5	MJ/kg

[a]By difference

FT-IR analysis

The C-H vibration at 2940.74 cm^{-1} and $-CH_2-$ bending vibration at 1445.33 cm^{-1} indicate the presence of alkane group. The stretching vibrations represents =C–H and C=C appeared at 2940.74 cm^{-1} and 1640.87 cm^{-1} also indicates alkene group. The O–H bond found at 3485.11 cm^{-1} indicates alcohol groups. The C–O bond found at 1121.88 cm^{-1} representing alcoholic in the oil sample. The stretching vibration at 1739.87 cm^{-1} indicates the compounds belong to ester group. The C–O

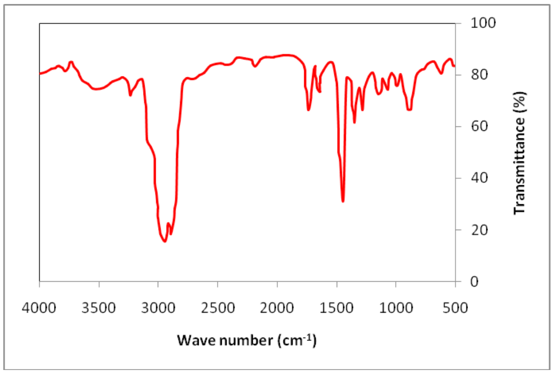

Fig. 4. FTIR spectrum of the oil

stretching vibrations at 1150 cm^{-1} showed the presence of aliphatic ether. The absorbance vibration at 878.53 cm^{-1} represents C=C bending vibration indicative of alkene. The FTIR study revealed that the oil is more complex due to the disintegration of cellulosic biomass with plastic components.

CONCLUSION

Plastic based waste sanitizer containers were effectively used as a possible feedstock for liquid oil production. The feedstock was pyrolyzed in a batch type fixed bed reactor at temperature of 600 °C to extract maximum oil yield of 73.2 wt%. The liquid product obtained through this study has heating value of 36.5 MJ/kg which is acceptable compared to biomass bio-oil and diesel fuel.According to FTIR analysis, the oil is identified with various functional groups such as alkanes, alkenes, alcohols, esters and aliphatic rings. The oil obtained in this study needs further treatment in order to use as a clean fuel. Finally, the pyrolysis process, rather than an incinerator can produce value-added products with reduced environmental impact.

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