International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 11 | Nov 2023 www.irjet.net p-ISSN: 2395-0072

Optimizing Yields & Properties of Byproducts from Microwave Pyrolysis of COVID Healthcare Waste

Mayan Yadav[1]

[1]*M. Tech, School of Infrastructure, Indian Institute of Technology Bhubaneswar,*
Arugul, Jatani, Odisha, India.

***

Abstract - *The coronavirus (COVID-19) pandemic has led hospitals, quarantine facilities, and home isolation to generate unprecedented volumes of infectious biomedical waste (BMW) globally, largely comprised of personal protective equipment, testing paraphernalia, masks, and gloves. The improper disposal of this distinct category of waste, termed "COVID-waste," poses threats to public health, and ecological sustainability. COVID-waste may propagate disease spread by serving as a vector for live SARS-CoV-2, which can persist for up to 7 days post-discard. Thus, the appropriate handling of COVID-waste is imperative to mitigate pandemic intensification. Pyrolysis offers a promising technical intervention for managing COVID-waste during this crisis. The present study optimized the yields of oil, gas, and char generated via microwave-assisted pyrolysis of COVID-healthcare discards. Characterization of these pyrolysis byproducts revealed appreciable calorific content and additional beneficial attributes, indicating their potential to alleviate pressing global challenges related to resource depletion and pollution. This work provides critical insights to inform management policies for the COVID-waste crisis along with future epidemics of comparable scale and consequence.*

Key Words: **Biomedical Waste, Polyethylene, Pyrolysis, Incineration, Sustainability**

1. INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has inflicted devastating impacts globally, with over 510 million confirmed cases across 215 countries as of November 2022 [1]. Many nations have implemented lockdowns to mitigate viral transmission, leading to both positive, and negative environmental ramifications like reduced pollution alongside burgeoning waste streams. Healthcare waste volumes have surged due to intensified utilization of personal protective equipment (PPE), including masks, gloves, gowns, sanitizers, and medical instruments such as test kits, syringes, and vials. Improper disposal of this hazardous biological material risks occupational and community exposure to infectious pathogens via waste handlers, health workers, patients, and contamination of land and water resources [2].

Pyrolysis represents a promising technique to convert this problematic waste into useful materials via thermochemical decomposition. However, research remains lacking regarding optimizable pyrolysis parameters and the characteristics of by-products from COVID-related waste streams specifically. This study provides an in-depth exploration of microwave-assisted pyrolysis for transforming coronavirus infectious waste into energy-dense oils, combustible gases, and carbonaceous chars. Rigorous experimentation identifies ideal pyrolysis settings for maximized oil yields vital for renewable fuel applications. Additionally, the fuel properties, and composition of generated pyrolysis byproducts are thoroughly examined to unveil viable end-use scenarios amidst energy and pollution crises exacerbated by the ongoing pandemic. This work elucidates pyrolysis as an auspicious waste-to-resource pathway for enhanced resilience against future public health emergencies precipitating hazardous discards.

2. LITERATURE REVIEW

India's Central Pollution Control Board (CPCB) [3] reports 2,907 hospitals, 20,707 quarantine facilities, 1,539 testing centers, and 264 diagnostic laboratories contributing coronavirus-inflected biomedical waste, intensifying pressure on existing medical waste infrastructure. From May 2020 to May 2021 alone, India amassed 45,954 tonnes of COVID-related infectious discards, averaging 126 tonnes per day supplementary to 614 daily tonnes of typical biomedical effluent. This represents a concerning 20% spike in biomedical flows amidst the ongoing health crisis. Although national directives mandate medical waste incineration, studies indicate 70% compliance with 30% mismanaged through illegal dumping or disposed as standard municipal garbage. Despite restrictions, 23 states still rely on deep burial for disposal, risking groundwater contamination from untreated pathological effluents [4].

Incinerators can diminish waste volumes by 85-90% through thermal oxidation, neutralizing materials unsuitable for recycling, including COVID- contaminated personal protective equipment, swabs, and materials unfit for landfilling. However, drawbacks include energy intensiveness, air toxins like dioxins, furans, metals, and incomplete combustion byproducts. Flue gas infrastructure further escalates incineration installation/operational expenses. Alternatively, pyrolysis allows energy-dense oil and gas recovery from decomposed waste using 400–700°C temperatures under oxygen-absent conditions, mitigating contamination risks while providing self-sustained heating valorizing waste as a thermal feedstock [5]. Additional techniques like autoclaving sterilize waste using pressurized steam, although disposal requires further processing and risks pollution from poor segregation [6].

In summary, current COVID-waste (CMW) management remains insufficient with prevalent dumping, subpar incineration, and reliance on controversial burial pits, demanding introduction of cleaner waste-to-energy techniques like pyrolysis to alleviate pressure on conventional protocols.

3. METHODOLOGY

3.1 Materials

- Raw materials for sample: Face masks, surgical gloves, gown, Yellow hazardous bag, PP goggles.
- Silicon Carbide susceptor was used because of its high thermal conductivity.
- Dichloromethane was used as a solvent.
- Nitrogen gas was used to create inert atmosphere in the pyrolysis chamber.
- Constant supply of cold water to condense vapors.

3.2 Instruments

The experimental setup for pyrolysis is shown in Figure-1. It comprises an insulated 12 cm diameter and 14 cm height quartz can reactor, and a water-jacketed pipe is connected with a receiving flask. The reactor vessel is connected with Nitrogen gas cylinder through flexible pipe.

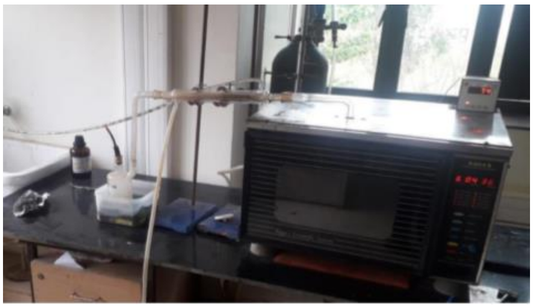


Fig-1: Bench Top-Microwave Pyrolysis Setup

3.3 Experimentation

The experiment required raw materials (face masks, surgical gloves, gown, Yellow hazardous bag, PP goggles), which were obtained from local drugstores & chopped into pieces (Figure-2).

Fig-2: Chopped Raw Materials

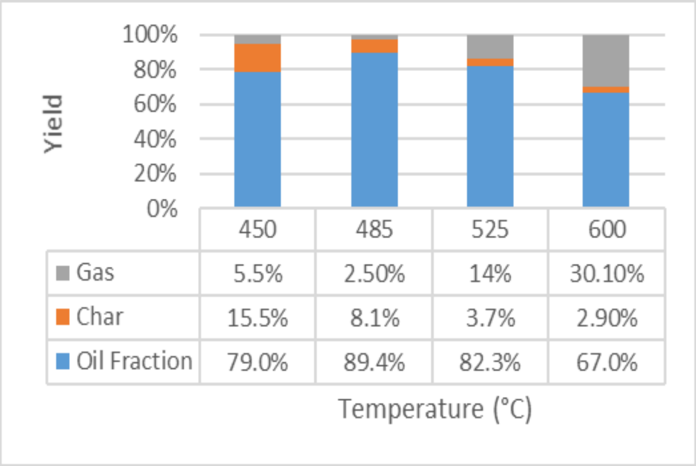
Then, 300 gm of PPE kit sample was taken, consisting of 40% (120 g) Gown, 20% (45 g) yellow hazardous bag, 20% (60 g) surgical gloves, 20% (45 g) face mask, 10% (30 g) PP goggles. The waste materials were placed in a sealed reactor and heated in a closed system with nitrogen gas flow. Thermal treatment was applied to induce depolymerization, cracking, and pyrolysis to produce pyrolyzed oil. The process released light hydrocarbon gases that were continuously removed from the reactor. A water-jacketed cold trap condensed the pyrolysis vapors to around room temperature (30–35 °C). The experiment was limited to one hour of heating due to gas seal leaks in the small experimental setup. After the reaction, the reactor and trap contents were analyzed to determine yields of recovered pyrolysis oil and char residue from the processed waste sample.

3.4 Analytical Techniques

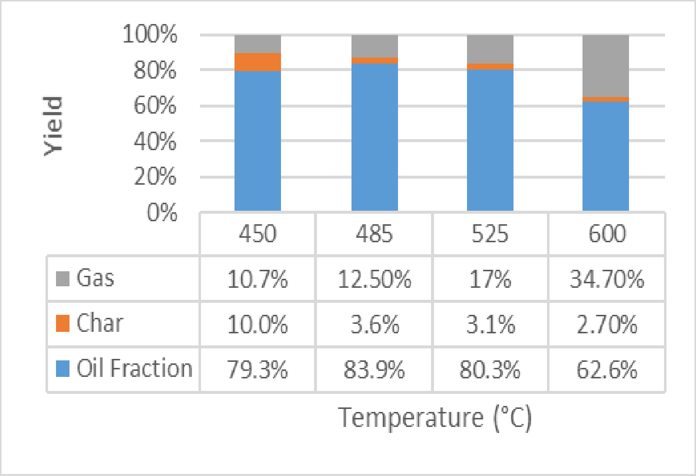
Heating values of the input plastic as well as the pyrolyzed oil and char samples were determined using a Bomb calorimeter. For each test, 1 g of sample was taken. The moisture content was analyzed using a water analyzer, with 1 g of each sample. The ash content was calculated by placing 2 g of each sample in a Muffle furnace.

4. RESULTS & DISCUSSION

Data in Figure-3 indicates slower pyrolysis heating rates (20°C/min) optimize char yield over extended residence periods, whereas fast pyrolysis with rapid heating (160°C/min) minimizes char. The slow pyrolysis also produces more oil than fast pyrolysis under similar conditions. The gradual temperature increase in slow pyrolysis enables secondary reactions of primary pyrolysate over time, maximizing yields of coke, tar, char, and oil. The extended duration facilitates advantageous secondary transformations.



(a) Slow Heating Rate (20°C/min)



(b) High Heating Rate (160°C/min)

Fig-3(a), (b): Effects of Temperature and Heating Rate on Liquid, Gases and Char Yields

Thermal decomposition at lower temperatures favor increased production of char and liquid oil, while higher temperatures promote higher yields of gases. This observation of progressively lower char outputs accompanying rises in temperature aligns with findings documented by Abbas et al. [7] and Demirbas et al. [8].

4.1 Properties of Pyro-Products

Oil: Pyrolysis of CMW yields an oil with a high heating value (HHV) of 42–44.5 MJ/kg – which is equivalent to conventional diesel fuel. Pyrolytic processing of plastic polymers including polystyrene, polyethylene, polypropylene, and polyethylene terephthalate yields an oil with considerable aromatic content analogous to petroleum fuels [9]. Empirical analysis indicates comparable engine performance utilizing a 20/80 blend by volume of pyrolytic oil and diesel fuel versus 100% diesel fuel [10].

Char: Pyrolysis solid residue (char) has a high heating value (HHV) of 28.7–29.5 MJ/kg and moisture content of 1.6–2.3 and ash content of 11%. The adsorption capacity of 26 mg/g in aqueous medium highlights the potential of this char product as a lead adsorbent. Its high surface area and porosity substantiate its applicability as an effective adsorbent material. The char also has carbon sequestration properties (trapping of CO2) and can be utilized for the production of activated carbon.

Gases: The conversion of PP plastic into gaseous products by pyrolysis has been assessed by recent studies as an alternative to natural gas. The gas from plastic pyrolysis differs from natural gas in that it contains a mixture of alkanes, alkenes, dienes, and alkynes [11]. Therefore, the gas from plastic pyrolysis can be used for various purposes, such as sustainable gaseous fuels or feedstock for chemical synthesis (for example, for producing hydrogen and carbon nanotubes [12]).

4.2 Pyrolytic Parameters

Pyrolysis parameters determine product yields; optimizing operating conditions thus maximizes oil, char, and gas production.

Temperature: The temperature has a direct impact on the types of products formed during pyrolysis. Specifically, temperatures exceeding 600°C facilitate the generation of lighter hydrocarbons, while the 400-600°C range promotes wax and liquid oil production. Meanwhile, carrying out pyrolysis below 400°C results in higher yields of viscous liquid products and secondary products.

Residence Time: By altering the rates of feed or product discharge, the duration of residence can be controlled. Longer residence times of solid lead to more side reactions that produce char and other stable products. For temperatures below 600°C, longer residence period (40-200 min) results in higher oil yield. Above 600°C, there is not much effect of residence time on gas and oil yields.

Heating Rate: Utilizing a higher heating rate during pyrolysis leads to increased volatile yields and facilitates secondary reactions that boost gas fraction outputs. In contrast, low heating rates produce higher oil and solid product yields. Consequently, conducting pyrolysis with a slow temperature ramp optimizes the production of carbonaceous char.

5. CONCLUSIONS

Although incumbent techniques like incineration and landfilling can effectively process large volumes of medical waste, their association with toxic emissions and ground contamination conflicts with sustainability. Policies emphasizing reduction, reuse, recycling and biodegradable protective equipment offer more eco-friendly waste management pathways.

Transitioning from conventional disposal methods, pyrolysis technology could prove transformative, enabling efficient, economical, and low-emission conversion of biowastes into usable oils, gases, and chars without segregation. Experiments reveal slow heating around 400–500°C, over 1-2 hours optimizes char and oil yields. The char byproduct also harbors applications including super capacitors, wastewater treatment, and construction fillers. With high calorific values near 44MJ/kg, pyrolysis oil can replace fossil fuels.

In conclusion, this study demonstrated the feasibility and advantages of pyrolysis as a waste treatment method for COVID healthcare waste. However, further research is needed to understand the properties and applications of pyro-oil and char. It is also imperative for scholars to develop new and efficient waste treatment methods that can address the current and future challenges of healthcare waste management.

REFERENCES

[1] United Nations Environment Programme (UNEP). How to choose your waste management technology to treat COVID-19 waste. Published 2022. Accessed November 30, 2022. https://wedocs.unep.org/bitstream/handle/20.500.11822/32778/FS3.pdf

[2] Datta P, Mohi GK, Chander J. Biomedical waste management in India: critical appraisal. J Lab Physicians. 2018;10:6-14. doi:10.4103/JLP.JLP_89_17

[3] Central Pollution Control Board website. Accessed November 10, 2020. https://cpcb.nic.in/

[4] Ramteke S, Sahu B. Novel coronavirus disease 2019 (COVID-19) pandemic: considerations for the biomedical waste sector in India. Case Studies in Chemical and Environmental Engineering. 2020;2:100029.

[5] Manupati VK, Ramkumar M, Baba V, Agarwal A. Selection of the best healthcare waste disposal techniques during and post COVID-19 pandemic era. J Clean Prod. 2021;281.

[6] BMW China chooses the Sterilwave solution for on-site treatment of waste contaminated by the coronavirus. Published 2020. Accessed November 30, 2022. https://www.bertin-medical-waste.com/china-chooses-the-sterilwave-solution-for-on-site-treatment-of-waste-contaminated-by-the-coronavirus/

[7] Abbas-Abadi MS, Haghighi MN, Yeganeh H. Evaluation of pyrolysis product of virgin high density polyethylene degradation using different process parameters in a stirred reactor. Fuel Process Technol. 2013;109:90-95.

[8] Demirbas A, Arin G. An overview of biomass pyrolysis. Energy Sources. 2002;24(5):471-482.

[9] Boopathi R, Gopinath E. Performance analysis of plastic oil blend by changing the fuel injection timing in diesel engine. Mater Today Proc. 2021;46:4613-4618.

[10] Jaafar Y, Muhamad N, Ku Hamid KH, et al. Pyrolysis of common plastics and their mixtures to produce valuable petroleum-like products. Polym Degrad Stab. 2022;195:109770.

[11] Harussani MM, Sapuan SM, Rashid U, Khalina A, Ilyas RA. Pyrolysis of polypropylene plastic waste into carbonaceous char: Priority of plastic waste management amidst COVID-19 pandemic. Sci Total Environ. 2022;803:149911.

[12] Zhang S, Horttanainen M, Li X, et al. Sustainable production of value-added carbon nanomaterials from biomass pyrolysis. Nat Sustain. 2020;3(9):753-760.

[13] Hantoko D, Li X, Pariatamby A, et al. Challenges and practices on waste management and disposal during COVID-19 pandemic. J Environ Manag. 2021;286:112140.

[14] Harussani MM, Sapuan SM, Rashid U, Khalina A. Development and characterization of polypropylene waste from personal protective equipment (PPE)-derived charfilled sugar palm starch biocomposite briquettes. Polymers (Basel). 2021;13(11):1707.

[15] Hong J, Zhan S, Yu Z, Hong J, Qi C. Life-cycle environmental and economic assessment of medical waste treatment. J Clean Prod. 2018;174:65-73.

[16] Leal Filho W, Voronova V, Kloga M, et al. COVID-19 and waste production in households: a trend analysis. Sci Total Environ. 2021;777:145997.