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Review JoPC

Review of Post-consumer Plastics and Pyrolysis Technology

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Abstract

In both industrial and residential products, synthetic polymers are widely used. Since synthetic polymers are made from fossil fuels, they cannot decompose. disposal of plastic solid waste (PSW) has threatened the ecosystem seriously. In this article, we examine the various post-consumer PSW thermo-chemical recycling techniques. A method that has shown promise for converting PSW into valuable hydrocarbon compounds is pyrolysis. PSW has been broken down through thermal decomposition, however, value-added products have not been produced as a result. The results of catalytic pyrolysis are not ecologically benign, although the catalytic thermal decomposition of PSW has produced hydrocarbon fuel at lower temperatures and with better reaction selectivity than thermal decomposition. Producing value-added goods from the decomposition of PSW is the answer to the problem of sustainable disposal of PSW. The direct combustion of pyrolysis byproducts can lead to both atmospheric pollution and the production of harmful foods for humans. In this study, we examine alternative technologies for creating value-added, environmentally responsible goods that go beyond pyrolysis. The hydrotreatment of PSW pyrolysis oil employing monumental or bimetal catalysts has produced valuable products from PSW with encouraging results. Hydrotreatment of pyrolysis products includes hydrocracking, hydrogenation, and aromatization. Metal supported on zeolite supports has generated good outcomes, according to prior investigations. PSW disposal techniques should be both economically feasible and environmentally friendly.

Keywords: Synthetic plastic, catalyst, pyrolysis, incineration, and hydro treatment.

INTRODUCTION

Hydrocarbon-derived polymers are the source of synthetic plastics. As of 2022, it is anticipated that there would be 300 million tonnes of plastic "consumption" worldwide. "Figure 1" illustrates the various technologies used to dispose of PSW. Landfills still provide a threat to the environment due to direct incineration. Previous research on recycling has revealed the degradation of a plastic's characteristics with time. Recycled goods lack the strength and durability of virgin polymers. Degradation will not, therefore, contribute to the full recycling of plastic products [1]. There is a chance that harmful gaseous products will be discharged into the environment during direct incineration. A fix must be found to stop harmful compounds from being produced during incineration [2]. Since 1950, more than three-fourths of all PSW has been disposed of in landfills, which is the worst method [3]. Roof tiles have been made from waste plastic [4]. A possible approach for converting PSW into synthetic gas is plasma pyrolysis. The synthetic gas created can be utilized to power a turbine that produces electricity [5]. Concrete was made using waste HDPE plastic as a filler, and the filler's presence had no effect on the concrete's compression strength [6].

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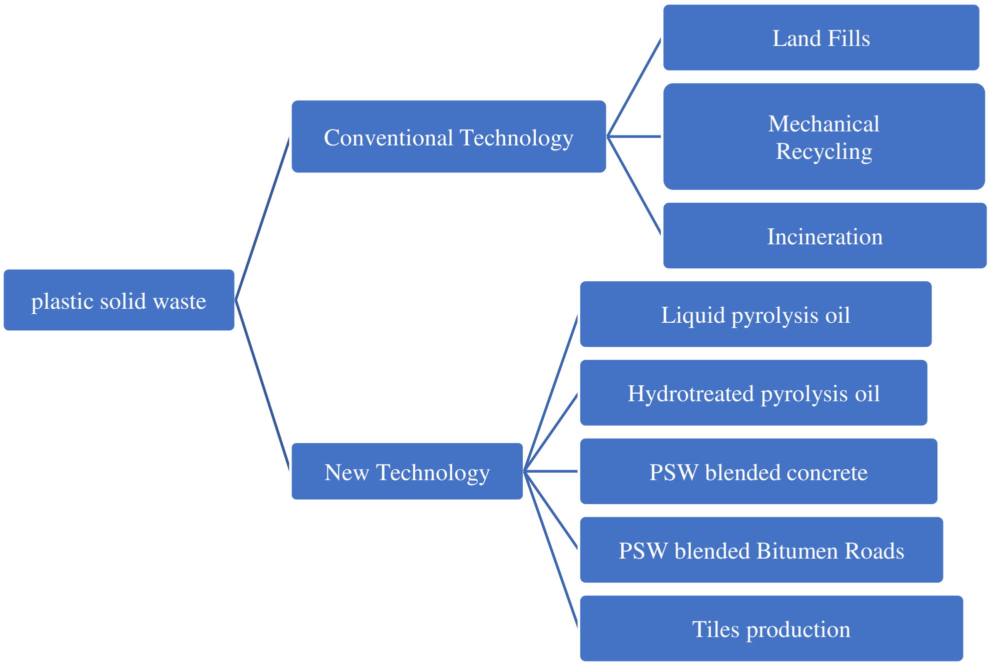

Figure 1. Technology to eliminate PSW.

The pyrolysis technique is used in the manufacturing of liquid fuel from PSW to transform the solid waste into liquid carbon products. The process of melting and evaporating solid waste in the absence of oxygen is known as pyrolysis. The pyrolysis technique is used in the manufacturing of liquid fuel from PSW to transform solid waste into liquid carbon products. The process of melting and evaporating solid waste in the absence of oxygen is known as pyrolysis. There are two ways to do pyrolysis: thermal pyrolysis or catalytic pyrolysis. Waste plastics have been effectively transformed into liquid gasoline by thermal pyrolysis [7]. Under an inert atmosphere, thermal pyrolysis uses the application of heat to the PSW products. The reaction temperature was previously noted to range from 500 to 600°C. Alkanes, alkenes, and aromatics are present in the liquid fuel produced, and efforts have been made to use it as diesel engine fuel.

Similar steps are taken in catalytic pyrolysis, however the PSW is also given a catalyst in this case [8–9]. The catalyst enhances the selectivity of chemicals produced in the resultant fuel oil and speeds up the depolymerization process. The catalytic process involves reactions that occur at temperatures between 300 and 450°C. Fuel oil produced by a thermal or catalytic process has characteristics that are different from those of diesel. These fuels are currently largely used in boiler burners or incinerators.

In this paper, we examine the earlier research on PSW pyrolysis oil conversion to alternative diesel fuel.

RESULTS AND DISCUSSIONS

Polymers in PSW have different latent heats of evaporation and melting temperatures. "Figure 2" depicts the thermal pyrolysis procedure. A reactor is loaded with the PSW component parts and heated to a temperature between 500 and 650°C. To prevent interaction with oxygen, the reactor's contents are heated in an inert environment. A hoover can also be used to maintain the inert environment. The many types of polymers that are present in PSW to varying degrees affect the reaction time and temperature.

The activation energy of each PSW component affects the reaction temperature of the PSW. High carbon number compounds are found in PSW polymers, which when pyrolyzed change into liquids before finally gelling to create wax. Thermal pyrolysis has the drawback of not being able to break down higher carbon molecules into lower ones. In addition, because thermal pyrolysis reaction temperatures are higher than those of catalytic pyrolysis, it uses more electricity.

Liquid/wax fuel, noncondensable hydrocarbon gases, and carbonaceous char are the byproducts of thermal pyrolysis.

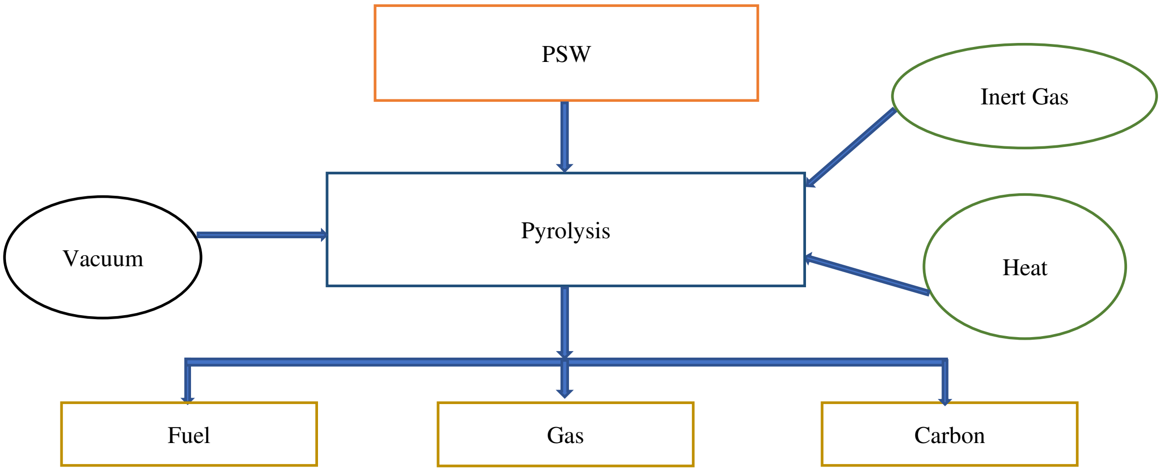

Figure 2. Layout for PSW's thermal pyrolysis of PSW.

"Figure 3" depicts the catalytic pyrolysis procedure. Adding a catalyst to the thermal pyrolysis process results in catalytic pyrolysis. The catalyst makes it possible. Fuel can be produced using the pyrolysis method at lower reaction temperatures and times. Effective depolymerization and cracking are made possible by the carbonium ion process [10–11]. Catalytic cracking yields gaseous hydrocarbons, liquid fuel, and carbonaceous char. The technique has produced more oil than thermal pyrolysis, and the catalyst employed is primarily made of zeolites. The reaction time is faster with catalytic pyrolysis than with thermal pyrolysis. ZSM-5, SBA-15, H-Beta, and mordenite are a few of the catalysts that are frequently utilized. Alkanes, alkenes, and aromatics can be found in the byproducts of catalytic pyrolysis.

The performance of the catalytic pyrolysis-produced fuel has been thoroughly tested in diesel engines, although it falls short of that of commercial diesel fuel [12]. Alkenes in the pyrolysis fuel are the primary cause of this. Alkenes cause high heat release rate (HRR) during combustion in engines because of the nature of their double bonds. Delay in combustion is caused by the double bond's high heat energy need for evaporation.

Low thermal efficiency, increased fuel consumption, and higher exhaust gas temperatures are the results of delayed combustion and high HRR. greater NOx levels are the result of greater exhaust gas temperatures [13–14]. The pyrolysis fuel's chemical makeup holds the key to turning it into diesel fuel. The pyrolysis fuel's alkenes compounds must be changed into alkanes [15]. Aromatic and alkane compounds are found in commercial diesel. It is necessary to modify the pyrolysis fuel to make it compatible with diesel.

"Figure 4" depicts the hydrotreatment mechanism. The pyrolysis fuel for PSW contains both saturated and unsaturated heavy carbon components. Heavy carbon elements can be cracked by hydrotreatment of PSW pyrolysis oil, and hydrogenation can be used to change unsaturated molecules into saturated ones [16–19].

The PSW pyrolysis oil was maintained at a temperature of 300 to 400°C during the hydrotreatment process, which was carried out inside a reactor with hydrogen gas present at 50 to 80 bar. Inside the reactor, a metal impregnated on an acidic base support catalyst is in contact with PSW pyrolysis oil [20–23]. The physicochemical qualities of the fuel are improved through hydrotreatment to diesel standards, and the hydrotreated fuel exhibits diesel-like performance in diesel engines [24–27].

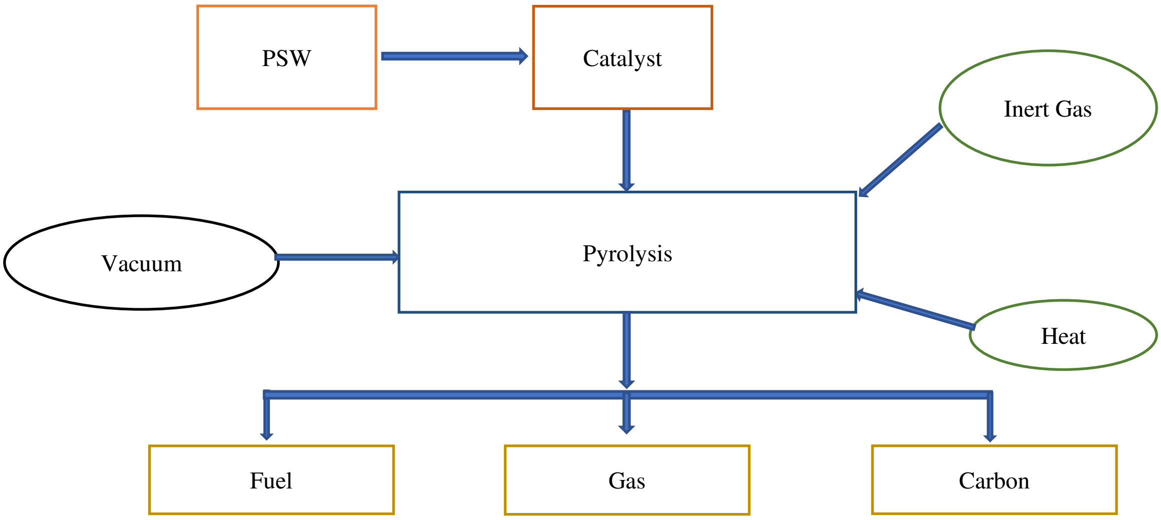

Figure 3. Layout of catalytic Catalytic pyrolysis of PSW layout.

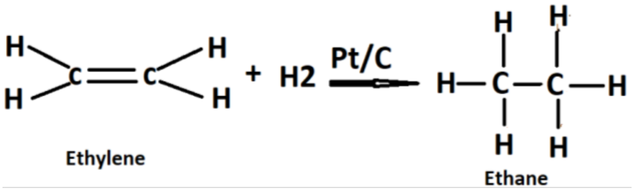

Figure 4. Hydrogenation Alkenes' mechanism of alkene.

CONCLUSIONS

Incineration and landfills have been traditional PSW disposal methods. Both had negative environmental effects. The disposal of PSW is now possible through alternative recycling methods thanks to new technologies. PSW has been used to make tiles, asphalt layers for roads, concrete, and liquid gasoline by pyrolysis. In the past, diesel engines have undergone thorough testing with PSW pyrolysis fuel.

Increased combustion peak pressures and HRR were produced as a result of the increased carbon components and unsaturated chemicals present. Compared to commercial diesel, PSW pyrolysis fuel had substantially greater emissions. Previous research demonstrates that diesel engine testing and the production of hydrotreated pyrolysis fuel were both successful. A viable solution for energy recovery and environmentally safe disposal is hydrotreated PSW pyrolysis oil.

REFERENCES

1. Waste Management, 33, 1898–1905 (2013) Saeed Kazemi Najafi, "Use of recycled plastics in wood plastic composites: A review."
2. Plastics recycling: Challenges and prospects, Phil. Trans. R. Soc. B, 364, 2115–2126 (2009) by Jefferson Hopewell, Robert Dvorak, and Edward Kosior
3. Plastic trash inputs from land into the ocean, by Jambeck Jenna R., Geyer Roland, Wilcox Chris, Theodore Siegler R., Miriam Perryman, Anthony Andrady, Ramani Narayan, and Kara Lavender Law (2015).
4. Ecological Roofing Tiles Made with Rubber and Plastic Wastes by Gaggino, Positieri, Irico, Kreiker, Arguello, and Sánchez (2013), Advanced Materials Research, 844, 458–461.

5. Development of a method for disposing of plastic trash utilising plasma pyrolysis technology and a potential for energy recovery, Punochá M., Rujb B., and Chatterjeeb P.K., Procedia Engineering, 42, 420–430 (2012)
6. Use of post-consumer waste plastics in cement-based composites by Naik T.R., Singh S.S., Huber C.O., and Brodersen B.S. Cement and Concrete Research, 26, 1489–1492 (1996)
7. Polymer Degradation and Stability, 2, 113–127 (1980) iang J.K.Y., Uden P.C., and Chien J.C.W., Polymer reactionsPart VII: Thermal pyrolysis of polypropylene
8. An overview of catalysts in biomass pyrolysis for the production of biofuels, Imran A., Bramer E.A., Seshan K., and Brem G., Biofuel Research Journal, 20, 872–885 (2018)
9. Ecology Environment & Conservation, 24, S115–S121 (2018) Sivakandhan, C., Murali, G., & Prabhu, P. S. “An experimental study of updraft biomass Gasifier using biofuels”
10. Korean Journal of Chemical Engineering, 20, 89–92 (2003) Lee K.H. and Shin D.H., "Catalytic Degradation of Waste Polyolefinic Polymers Using Spent FCC Catalyst with Various Experimental Variables"
11. Ind. Eng. Chem. Res., 38(2), 385–390 (1999); Yoshio Uemichi, Junko Nakamura, Toshihiro Itoh, and Masatoshi Sugioka, "Conversion of Polyethylene into Gasoline-range Fuels by Two-Stage Catalytic Degradation Using SilicaAlumina and HZSM-5 Zeolite."
12. Catalytic pyrolysis of polyethylene by Bagri and Williams, Journal of Analytical and Applied Pyrolysis, 63, 29–41 (2002)
13. Applied Thermal Engineering, 29, 2738–2744 (2009) Mani M. Emission and Combustion Characteristics of a DI Diesel Engine Using Waste Plastic Oil
14. Renewable Energy, 131, 737–744 (2019) Arunkumar, M., Kannan, M., & Murali, G. “Experimental studies on engine performance and emission characteristics using castor biodiesel as fuel in CI engine.”
15. Energy, 131, 179–185 (2017); loannis Kalargaris, Guohong Tian, and Sai Gu. "The Utilisation of Oils Produced From Waste Plastic at Different Pyrolysis Temperatures in a DI Diesel Engine."
16. Prospects of pyrolysis oil from plastic waste as fuel for diesel engines: A Review, IOP. Conf. Ser.: Mater. Sci. Eng., 197 (2017). Mangesh V.L., Padmanabhan S., Ganesan S., Prabhudev Rahul D., and Dinesh Kumar Rahul T.
17. International Journal of Ambient Energy, 43(1), 3365–3376 (2022) Rami Reddy, S., Murali, G., & Dhana Raju, V “Assessment of diethyl ether as a fuel additive on the diverse characteristics of diesel engine powered with waste mango seed biodiesel blend.”
18. Journal of Material Cycles and Waste Management, 6, 20–26 (2004) Ihsan Cakici A., Yanik Jale, Suat Ucar Tamer Karayildirim, and Huseyin Anil, "Utilisation of Red Mud as Catalyst in Conversion of Waste Oil and Waste Plastics to Fuel."
19. Applied Catalysis B: Environmental, 117–118, 105–117 (2012); Ardiyanti A.R., Kromova S.A., Venderbosch R., Yakolev V.A., and Heeres H.J. Catalytic hydrotreatment of fast-pyrolysis oil utilising non-sulfided bimetallic Ni-Cu catalysts on a -Al2O3 substrate.
20. Continuous flow cracking of waste polymers by Jerzy Walendziewski, Fuel Processing Technology, 86(12–13), 1265–1278 (2005)
21. Sang-Chul Jung, Jungho Jae, Hoda Shafaghat, In-Gu Lee, and Young-Kwon Park, Pd/C Chemical Engineering Journal, 377, 119986 (2018) Catalysed transfer hydrogenation of pyrolysis oil utilising 2-propanol as hydrogen source
22. High-Density Polyethylene and Waste Plastic Hydrocracking and Hydroisomerization over Zeolite and Silica-Alumina by Weibing Ding, Jing Liang, and Anderson Larry L.Energy & Fuels, 11, 1219–1224 (1997): Supported Ni and Ni–Mo Sulphides
23. Materials Today: Proceedings, 21, 206–211 (2020) Murali, G., Anusha, M., & Arunkumar, M. “Performance study of a single cylinder diesel engine using diesel with Pongamia pinnata and Camelina sativa seed oil blends.”
24. Continuous upgrading of a plastics pyrolysis liquid to an environmentally friendly petrol range product, Fuel Process Technol., 57, 25–40 (1998), by Joo H.S. and Guin J.A.

25. Journal of Cleaner Production, 246, 119066 (2020), Mangesh V.L. et al. "Experimental investigation to identify the type of waste plastic pyrolysis oil suitable for conversion to diesel engine fuel."
26. Combustion and emission studies of hydrogenated waste polypropylene pyrolysis oil combined with diesel, Mangesh V.L., Padmanabhan S., Tamizhdurai P., Narayanan S., and Ramesh A., Journal of Hazardous Materials, 386, 121453 (2020).
27. International Journal of Engineering and Advanced Technology, 8(6), 3732–3735 (2019) Arunkumar, M., & Murali, G. “Research on Performance And Emission on Compression Ignition Engine Fuelled With Blends of Neem Bio-Diesel”