PYROLYSIS USING WASTE PALSTIC MATERIAL FOR LOW COST FUEL OIL

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A B S T R A C T
One of the biggest pollutants which effect on the environment is plastics. Plastics are cheap in cost and are easily available for human usage. Plastics are non-degradable and waste that is caused by the use of plastic is tremendous. Therefore, to decrease the waste of plastic several methods have been taken in usage to make usage of waste of plastic waste more efficiently. Pyrolysis is a method which is used to burn the plastic at a particular temperature so that useful fuel oil can be obtained. In this paper we proposed an experiment of pyrolysis domestically. The experimental result showed that at temperature of 400-500 degree Celsius, the oil obtained has excellent burning properties which can be achieved without use of any heavy equipment.

Keywords: Plastic, pollutant, pyrolysis, fuel, non-degradable

1. INTRODUCTION

Plastic pollution is the accumulation of plastic objects (e.g.: plastic bottles and much more) in the Earth's environment that adversely affects wildlife, wildlife habitat, and humans. Plastics that act as pollutants are categorized into micro-, meso-, or macro debris, based on size. Plastics are inexpensive and durable, and as a result levels of plastic production by humans are high. However, the chemical structure of most plastics renders them resistant to many natural processes of degradation and as a result they are slow to degrade. Together, these two factors have led to a high prominence of plastic pollution in the environment.

Figure 1: Pollution due to plastic(Source - https://sambadenglish.com/odisha-to-implement-rule-to-deal-with-solid-waste/)

Plastic pollution can afflict land, waterways and oceans. It is estimated that 1.1 to 8.8 million metric tons (MT) of plastic waste enters the ocean from coastal communities each year.

Living organisms, particularly marine animals, can be harmed either by mechanical effects, such as entanglement in plastic objects or problems related to ingestion of plastic waste, or through exposure to chemicals within plastics that interfere with their physiology. Humans are also affected by plastic pollution, such as through disruption of various hormonal mechanisms.

1. Plastic Recycling:

The problem of plastics wastes has increased tremendously since the use of plastics increased in most industrial, commercial and residential applications. Households and industry produce huge amount of plastic waste. Plastic waste causes severe environmental problem when incinerated or open burn on roadsides or illegal dumpsites. Also plastic bags are a major source of littering the residential areas, parks and even protected areas.

About 50% of the total volume of plastic wastes consists of household plastics refuse, which are mainly in the form of packaging wastes. Once rejected, plastics packages gets contaminated and while reusing them, a more serious problem appear which is the so-called commingled plastics, affecting in return the properties of the new recycled products.

The recycling of thermoplastics, or plastics, can be accomplished easily with high revenue. Each type of plastic must go through a different process before being recycled. Hundreds of different types of plastics exist, but 80%-90% of the plastics used in consumer products are:

- PET (polyethylene terephthalate)
- HDPE (high-density polyethylene)
- V (vinyl)
- LDPE (low-density polyethylene)
- PP (polypropylene)
- PS (polystyrene)

2. Pyrolysis

Pyrolysis is generally defined as the controlled heating of a material in the absence of oxygen. In plastics Pyrolysis, the macromolecular structures of polymers are broken down into smaller molecules and sometimes monomer units. Further degradation of these subsequent molecules depends on a number of different conditions including (and not limited to) temperature, residence time, other process conditions. The Pyrolysis reaction can be carried out with or without the presence of catalyst. Plastic waste is continuously treated in a cylindrical chamber. The plastic is pyrolised at 300^{o}C- 500^{o}C.

3. Advantages of Pyrolysis

The advantages of pyrolysis of waste plastics into liquid fuels includes

- It allows the recycling of waste mixed plastics that cannot be efficiently recycled by alternative means
- It permits the recycling of unwashed and soiled plastics (e.g. agricultural plastics, mulch/silage/greenhouse films and dripper/irrigation tube)
- It enables recycling of plastic laminates, co-extrusions and multilayer packaging films, particularly those with aluminum foil layers that are difficult to recycle using traditional reprocessing technologies.

2. LITERATURE SURVEY

(Thahir et al., 2019): liquid product of pyrolysis from as much as 500 g of polypropylene (PP) plastic waste, using a fixed bed type reactor in a vacuum condition (−3 mm H2O), to minimize the oxygen entering the reactor. The vapour flows through the 4-tray distillation bubble cap plate column for fractionation by utilizing heat from the reactor. Process conditions at 500–650oC and of 580oC optimum liquid oil yield is 88 wt.%, comprising of kerosene in tray I with a volume of 350 ml, gasoline in tray II and III with a volume of 228 ml, and tray IV had no condensate. Gas yield is 5 wt. % and the rest is char. At the conditions between 500oC and 560oC, gasoline yield in 6–67 wt.% comprises of kerosene and gasoline. However, at process conditions between 600oC and 650oC yields of 64–83 wt. % comprising of diesel oil was obtained at tray I and II, while kerosene and gasoline were obtained in the next tray. The characteristics of fuel obtained from plastic such as density, viscosity, octane–cetane number, ash content and calorific value have similar properties with those of fossil fuels.

(Al-Salem, 2019): pyrolysis is a promising thermolysis technique to recover valuable oils and light hydrocarbons (HC) with high yields from plastic solid waste (PSW). In this work, thermal pyrolysis of high-density polyethylene

(HDPE) with the aim of producing gasoline range hydrocarbon oils, has been carried out in a novel fixed bed (batch) reactor. The pyrolysis of HDPE has been conducted between 500 to 800oC in the presence of nitrogen as an inert carrier gas media to produce liquid fuel oil, gaseous products and solid char. The optimum temperature of obtaining maximum oil product yield (70%) was 550oC. A comprehensive gas chromatography (GC) analysis of the liquid and gaseous products was conducted to quantify high molecular weight individual Components. Moreover, light molecular weight HC constituting the gaseous fraction was identified. A chemical kinetic analysis of the cracking reactions was performed to investigate the reaction mechanism of yielding the maximum oil product. The oil product recovered had high proportion of aliphatic HC especially in the range of C8 to C12, whilst aromatic HC were of lower proportion. The carbon number of the pyrolysis oil was noted to increase proportionally with the increasing operating temperature. The gaseous product had a high percentage (> 70%)of C2 to C4 HC, which was attributed to the high activity of carbon/carbon (C-C) chain scission reaction.

(Miandad et al., 2019): pyrolysis based bio-refineries have great potential to convert waste such as plastic and biomass waste into energy and other valuable products, to achieve maximum economic and environmental benefits. In this study, the catalytic pyrolysis of different types of plastics wastes (PS, PE, PP, and PET) as single or mixed in different ratios, in the presence of modified natural zeolite (NZ) catalysts, in a small pilot scale pyrolysis reactor was carried out. The NZ was modified by thermal activation (TA-NZ) at 550oC and acid activation (AA-NZ) with HNO3, to enhance its catalytic properties. The catalytic pyrolysis of PS produced a higher liquid oil (70% and 60%) than PP (40% and 54%) and PE (40% and 42%), using TA-NZ and AA-NZ catalysts, respectively. The gas chromatography-mass spectrometry (GC-MS) analysis of oil showed a mixture of aromatics, aliphatic and other hydrocarbon compounds. The TA-NZ and AA-NZ catalysts showed a different effect on the wt. % of catalytic pyrolysis products and liquid oil chemical compositions, with AA-NZ showing higher catalytic activity than TA-NZ. FT-IR results showed clear peaks of aromatic compounds in all liquid oil samples with some peaks of alkanes that further confirmed the GC-MS results. The liquid oil has a high heating value (HHV) range of 41.7–44.2 MJ/kg, close to conventional diesel. Therefore, it has the potential to be used as an alternative source of energy and as transportation fuel after refining/blending with conventional fuels.

(Budsaereechai, Hunt and Ngernyen, 2019): catalytic pyrolysis of waste plastics using low cost binder-free pelletized bentonite clay has been investigated to yield pyrolysis oils as drop-in replacements for commercial liquid fuels such as diesel and gasohol 91. Pyrolysis of four waste plastics, polystyrene, polypropylene, low density polyethylene and high density polyethylene, was achieved at a bench scale (1 kg per batch) to produce useful fuel products. Importantly, the addition of binder-free bentonite clay pellets successfully yielded liquid based fuels with increased calorific values and lower viscosity for all plastic wastes. This larger scale pyrolysis study demonstrated that use of a catalyst in powder form can lead to significant pressure drops in the catalyst column, thus slowing the process (more than 1 hour). Importantly, the use of catalyst pellets eliminated the pressure drop and reduced pyrolysis processing time to only 10 minutes for 1 kg of plastic waste. The pyrolysis oil composition from polystyrene consists of 95% aromatic hydrocarbons, while in contrast, those from polypropylene, low density polyethylene and high density polyethylene, were dominated by aliphatic hydrocarbons, as confirmed by GC-MS. FTIR analysis demonstrated that low density polyethylene and high density polyethylene oils had functional groups that were consistent with those of commercial diesel (96% similarity match). In contrast, pyrolysis-oils from polystyrene demonstrated chemical and physical properties similar to those of gasohol 91. In both cases no wax formation was observed when using the bentonite clay pellets as a catalyst in the pyrolysis process, which was attributed to the high acidity of the bentonite catalyst (low SiO2 :Al2O3 ratio), thus making it more active in cracking waxes compared to the less acidic heterogeneous catalysts reported in the literature. Pyrolysis-oil from the catalytic treatment of polystyrene resulted in greater engine power, comparable engine temperature, and lower carbon monoxide (CO) and carbon dioxide (CO2) emissions, as compared to those of uncatalyzed oils and commercial fuel in a gasoline engine. Pyrolysis-oils from all other polymers demonstrated comparable performance to diesel in engine power tests. The application of inexpensive and widely available bentonite clay in pyrolysis could significantly aid in repurposing plastic wastes.

(Nursyamsi, Indrawan and Ramadhan, 2019): it has been a long time that red bricks become the raw material for wall compilers. As the era develops, the bricks that are light, easy to compile and not time-consuming in manufacturing are invented. The composition materials for the building blocks are cement, sand and water. In this study, the use of sand in the bricks is reduced with LDPE plastic pellets. The reason for the use of LDPE plastic pellets as substitution of plastic materials is that LDPE plastic pellets have smaller density than sand does, so that it is expected that the brick becomes lighter although consists of the same composition and it can also reduce environmental problems as LDPE plastic waste is difficult to be decomposed by nature but gradually produced by humans that results in excessive waste The LDPE plastic pellets utilized are used LDPE plastics that are recycled into plastic pellets. The sample in this study consists of cylinder with diameter of 15 cm and height of 30 cm as sample of trial mixes test, concrete bricks with size of 40 cm x 20 cm x 10 cm, cube with size of 5 cm x 5 cm x 5 cm and briquette. The trial mixes samples will be treated for 7 days and the brick, cube and briquette samples will be treated for 28 days prior to testing. Furthermore, the sample will be tested with visual, content weight, absorption, compressive strength and drag strength tests. The data analysis uses SNI 03-0349-1989 reference on Concrete Bricks as The Matching Composition for Walls. This study used a mixture of cement, sand and water with ratio of 1: 6: 0.24, this composition was obtained from experiments on several specified compositions. The composition of substitute of plastic pellets used is 20% to the sand, the composition of this substitution is obtained from the experiments on several specified compositions. From the visual appearance, the content weight and absorption, both of normal brick and 20% LDPE pellets are included in the quality I, while the compressive strength test against the sample of normal brick results in quality I and 20% LDPE pellets brick results in quality III.

(Nursyamsi, Indrawan and Ramadhan, 2019): mechanical properties of blend of high density polyethylene (HDPE) and low density polyethylene (LDPE) have been investigated. Four different HDPE/LDPE blends with various ratio (80/20,60/40,40/60, and 20/80) were prepared by melt-mixing technique using mini-twin-extruder at 200oC and 90rpm. Characterization tests including tensile and impact strength tests as well as hardness have been performed in order to better understand the behaviour of these blends. Information on ductility and toughness were obtained from the stress-strain curves of HDPE/LDPE blends. Mechanical properties were varied according to LDPE content. Blends-rich with LDPE showed to have lower strength and hardness and higher elongation, impact strength, ductility and toughness than blends-rich with HDPE. Blend with the composition (HDPE (40)/LDPE (60)) showed comparatively better overall mechanical properties.

(Sharuddin et al., 2018): the worldwide plastic generation expanded over years because of the variety applications of plastics in numerous sectors that caused the accumulation of plastic waste in the landfill. The growing of plastics demand definitely affected the petroleum resources availability as non-renewable fossil fuel since plastics were the petroleum-based material. A few options that have been considered for plastic waste management were recycling and energy recovery technique. Nevertheless, several obstacles of recycling technique such as the needs of sorting process that was labour intensive and water pollution that lessened the process sustainability. As a result, the plastic waste conversion into energy was developed through innovation advancement and extensive research. Since plastics were part of petroleum, the oil produced through the pyrolysis process was said to have high calorific value that could be used as an alternative fuel. This paper reviewed the thermal and catalytic degradation of plastics through pyrolysis process and the key factors that affected the final end product, for instance, oil, gaseous and char. Additionally, the liquid fuel properties and a discussion on several perspectives regarding the optimization of the liquid oil yield for every plastic were also included in this paper.

3. METHODOLOGY

1. PYROLYSIS

Pyrolysis is the thermal degradation of plastic waste at different temperatures (300–900°C), in the absence of oxygen, to produced liquid oil. Plastics are made of petrochemical hydrocarbons with additives such as flame-retardants, stabilizer, and oxidants that make it difficult to bio-degrade. Pyrolysis is a common technique used to convert plastic waste into energy, in the form of solid, liquid and gaseous fuels.The liquid oil produced can be used in multiple applications such as furnaces, boilers, turbines and diesel engines without the needs of upgrading or treatment.

2. MATERIALS AND EQUIPMENTS:

2.1.Plastic:

The production and use of plastic products have grown enormously over the last couple of decades due to their wide range of properties. Plastics are long chains of monomers that are mainly derived from fossil fuels but can also be derived from chemical processes. Plastics are categorised into the following groups: Poly-Propylene (PP), Polyethylene terephthalate (PET), Low-density polyethylene (LDPE), High-density polyethylene (HDPE) and Polyvinyl chloride (PVC) [77,78]. Due to the fact that there is not a proper way to recycle all types of plastics, most of it is dumped in landfills. Pyrolysis of plastic may be an interesting alternative as it provides an opportunity to turn waste into valuable biogas and biofuel [79].

2.2.Low density polyethylene:

Low-density polyethylene has a good balance of flexibility, strength, barrier properties, and cost and can have a wide combination of properties. Low-density polyethylene has high clarity, is chemically inert, and has good impact strength and excellent tear and stress crack resistance. Low-density polyethylene (LDPE) has applications in sterile blister packs for drug packaging. Linear low-density polyethylene (LLDPE) is used in films and packaging due to its flexibility and toughness.

2.3.High density polyethylene:

HDPE has a large area of usage. 40% of produced HDPEs are used in production of many plastic belongings such as bottles for drink, food, cleaning products, etc. 30% of it are used in packaging, thin film coating, productions of pipe, tube and cable (Kurbanova et al., 1997). High-density polyethylene (HDPE) is typically translucent and less flexible than LDPE. Due to its higher crystallinity, it has better chemical resistance, stiffness, and strength than LDPE. Surgical and medical instruments use the vast majority of HDPEs. Like LDPE, HDPE exhibits good chemical and stress crack resistance, radiation resistance, and impact strength. High-density polyethylene (HDPE) is widely used in medical tubing, where its low cost, low friction, chemical resistance, and easy moldability make it a strong competitor to PVC. Another HDPE market is pharmaceutical closures.

2.4.Steel cane:

The material used for the fabrication of major components is mild steel. Mild steel has a carbon content ranging from 0.15% to 0.30%. It has properties suitable for fabrication and is available easily.Some typical values for physical properties of steel are:

- density ρ = 7.7 - 8.1 [kg/dm3]
- elastic modulus E=190-210 [GPa]
- Poisson's ratio ν = 0.27 - 0.30
- Thermal conductivity κ = 11.2 - 48.3 [W/mK]
- Thermal expansion α = 9 - 27 [10-6 / K]

2.5.Copper tube:

Copper has a melting point of 1083.4 +/- 0.2°C, boiling point of 2567°C, specific gravity of 8.96 (20°C), with a valence of 1 or 2. Copper is reddish colored and takes a bright metallic luster. It is malleable, ductile, and a good conductor of electricity and heat. It is second only to silver as an electrical conductor.

2.6.Glass beaker:

Glass beaker has been used to collect the fluid from copper tube which was connected to the steel cane.

3. EXPERIMENTAL SETUP:

Experiment has been carried out as per the following steps:

[1]. Initial an air tight steel container was taken in usage. In which 250 gms of plastic has been filled.

Figure 2: steel can filled with plastic

[2]. After filling plastic in the steel container. Copper tube has been connected to the top of steel cane with Teflon tape for condensing the gases.

Figure 3: copper tube connected with cap of steel cane

[3]. Steel cane has been tightly packed with the help of Teflon tape.

Figure 4: Tightly packed container

[4]. The other end of the copper tube is connected with a glass beaker for collecting the fuel.

Figure 5: copper tube connected with glass beaker

[5]. After the whole setup is completed, steel cane is burned at 400-500ºC. Where copper tube is supported with the help of stick.

Figure 6: Setup of experiment

[6]. 150 ml of Fuel has been obtained from experiment.

Figure 7: Fuel obtained

[7]. Remaining residues left in steel can after experiment

Figure 8: Remaining Residues

4. RESULTS AND DISCUSSIONS

1. GENERAL: The current experiment has been carried out on the process of pyrolysis. This process is used to obtain the fluids from the waste of plastic. Initially a cane of steel was filled with 250gms of plastic and burned at 400 to 500ºC. The oil obtained after the melting of plastic materials is collected by the means of copper tube connected from the steel cane to a glass beaker. The amount of fuel obtained after the pyrolysis in this experiment is 150ml.

2. PYROLYSIS CARRIED OUT AT SEVERAL TEMPERATURES:

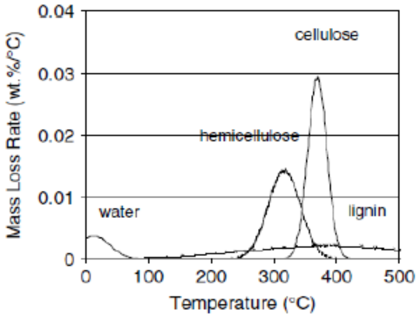

Figure 10: Decomposition rate of individual biomass components with pyrolysis temperature

The major components of plastic are cellulose, hemicellulose and lignin, each of which is different in their decomposition behaviour. Moreover, decomposition of each component depends on heating rate, temperature and the presence of contaminants due to different molecular structures. In the pyrolysis process, the three components are not decomposed at the same time. Hemicellulose would be the easiest one to be pyrolysised, next would be cellulose, while lignin would be the most difficult one. Interestingly, both lignin and hemicellulose could affect the pyrolysis characteristics of cellulose while they could not affect each other obviously in the pyrolysis process.

Results obtained at different temperature in pyrolysis

Table 1: Pyrolysis reactions at different temperatures

TEMPRATURE	PROCESS	PRODUCT OBTAINED
Below 300ºC	Slow Pyrolysis, Reacted with fixed bed, and Furnace or kilns heating method	Bio-char, Bio-oil, and syngas
Below 350ºC	Free radical formation, water elimination and de-polymerization	Formation of carbonyl and carboxyl, evolution of CO and CO_2, and mainly a charred residue
Below 350ºC and 450ºC	Breaking of glycosidic linkages of polysaccharide by substitution	Mixture of levoglucosan, anhydrides and oligosaccharides in the form of a tar fraction
Above 450ºC	Dehydration, rearrangement and fission of sugar units	Formation of carbonyl compounds such as acetaldehyde, glyoxal and acrolein
Above 500ºC	A mixture of all above processes	A mixture of all above products
Condensation	Unsaturated products condense and cleave to the char	A highly reactive char residue containing trapped free radicals

Below 300 °C, the products of pyrolysis are generally expected largely to contain biochar, bio-oil and syngas. However, the phase distribution and chemical composition of the products is highly dependent on the feedstock used as well as the operating parameters of the process. Plant based feedstock produces more biochar while plastic based feedstock produces more bio-oil. The composition of products can be analysed using gas chromatography/mass spectrometry. Current applications of pyrolysis are focused on high temperatures due to the increased yields of gases and bio-oils, which are more valuable. Biochar, however, is becoming increasingly popular due to its various applications such as a filter material for water purification. Low temperature pyrolysis is an area where further research is required in order to produce economically viable processes.(Jouhara *et al.*, 2018)

The three primary products obtained from pyrolysis of biomass are char, permanent gases, and vapours that at ambient temperature condense to a dark brown viscous liquid. Maximum liquid production occurs at temperatures between 350 and 500 °C. This is because different reactions occur at different temperatures in pyrolysis processes. Consequently, at higher temperatures, molecules present in the liquid and residual solid are broken down to produce smaller molecules which enrich the gaseous fraction. Yield of products resulting from biomass pyrolysis can be maximized as follows:

1. Charcoal—a low temperature, low heating rate process,
2. Liquid products—a low temperature, high heating rate, short gas residence time process,
3. Fuel gas—a high temperature, low heating rate, long gas residence time process.

Table 1 summaries the products created at different pyrolysis conditions. Products from pyrolysis processes also strongly depend on the water content in the biomass which produces large quantities of condensate water in the liquid phase. This contributes to the extraction of water-soluble compounds from the gaseous and tar phases, and thus a greater decrease in gaseous and solid products.

Comparison of Results:

From all the Pyrolysis reactions at different temperatures, it has been found that the experiment performed at 400°C in the proposed work provide fuel of much better quality as compared to the other fuels obtained below 400°C. The residuals obtained at 400°C were minimum because of that the quality of obtained fuel is improved as compared to the residual obtained below the temperature of 400°C were higher because of that the quality of obtained fuel was not so much improved.

5. CONCLUSIONS

From the result concluded it has been found that at the temperature of 400°C to 500°C, fuel obtained is of much better quality. It is achieved domestically with low cost of equipment and external large equipment is not required in this experiment. Thus, the experiment proposed has been achieved successfully.

If further experiment is performed at higher temperature than 400°C, it is expected that much better quality fuel might be obtained but for higher temperature experiment, large laboratory equipment and huge amount of space would be required which might eventually increase the overall cost of the experiment as temperatures above 500 degrees can be achieved by use of external furnaces and not domestically. Therefore, this experiment is cost effective at domestic levels with better quality of fuel. The results also discusses that fuel quality obtained below 400 degrees considerably have lower burning properties and they form more residues after the pyrolysis.

REFERENCES

1. Bridgwater, A. V. and Peacocke, G. V. C. (2000) ‘Fast pyrolysis processes for biomass’, Renewable and sustainable energy reviews, 4(1), pp. 1–73. doi: 10.1016/S1364-0321(99)00007-6.

2. Jahirul, M. I. et al. (2012) ‘Biofuels production through biomass pyrolysis- A technological review’, Energies, 5(12), pp. 4952–5001. doi: 10.3390/en5124952.

3. Jouhara, H. et al. (2018) ‘Pyrolysis of domestic based feedstock at temperatures up to 300 °C’, Thermal Science and Engineering Progress. Elsevier, 5(October 2017), pp. 117–143. doi: 10.1016/j.tsep.2017.11.007.

4. Mathur, K. et al. (2016) 'Extraction of pyrolysis oil from waste plastics', International Research Journal of Engineering and Technology (IRJET), 03(04), pp. 4–7. Available at: //www.irjet.net/archives/V3/i4/IRJET-V3I4325.pdf.

5. Miandad, R. et al. (2019) 'Catalytic pyrolysis of plastic waste: Moving toward pyrolysis based biorefineries', Frontiers in Energy Research, 7(MAR), pp. 1–17. doi: 10.3389/fenrg.2019.00027.

6. Sastri, V. R. (2014) Commodity Thermoplastics, Plastics in Medical Devices. doi: 10.1016/b978-1-4557-3201-2.00006-9.
7. Schubert, T. et al. (2019) 'Influence of reaction pressure on co-pyrolysis of LDPE and a heavy petroleum fraction', Fuel Processing Technology. Elsevier, 193(December 2018), pp. 204–211. doi: 10.1016/j.fuproc.2019.05.016.

8. Sharuddin, S. D. A. et al. (2018) 'Pyrolysis of plastic waste for liquid fuel production as prospective energy resource', IOP Conference Series: Materials Science and Engineering, 334(1). doi: 10.1088/1757-899X/334/1/012001.

9. Sogancioglu, M., Yel, E. and Ahmetli, G. (2017) 'Pyrolysis of waste high density polyethylene (HDPE) and low density polyethylene (LDPE) plastics and production of epoxy composites with their pyrolysis chars', Journal of Cleaner Production. Elsevier Ltd, 165, pp. 369–381. doi: 10.1016/j.jclepro.2017.07.157.

10. Vijayakumar, A. and Sebastian, J. (2018) 'Pyrolysis process to produce fuel from different types of plastic - A review', IOP Conference Series: Materials Science and Engineering, 396(1). doi: 10.1088/1757-899X/396/1/012062.