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Plastics and Circular economy

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Abstract:
Plastic is flexible material obtained from various polymers which can be made into any shape and size therefore, has many uses until today. We use plastic for various purposes in our daily life but the waste ends up in the landfills, rivers and oceans causing adverse effects on the environment. Circular economy which follows make, use, reuse, remake, recycle and repeat principles can be applied for plastic waste. Therefore, plastic waste can be converted to fuel oil by catalytic pyrolysis which follows circular economy.

Keywords: *Circular economy, Linear economy, Multilayer laminated packaging, Landfills, Incineration, Post-industrial waste, Catalytic pyrolysis, Zeolite, Carbon black, Hydrocarbon gas*

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I. Introduction

Plastics are an essential part of the 21st century, mostly everything around us is made up of plastic. Nearly 242 million tons of plastic waste were produced in the year 2016. Plastic is composed of various elements such as carbon, hydrogen, oxygen, nitrogen, chlorine, and sulphur. Plastics, also known as polymers, are produced by the conversion of natural products or by the synthesis from primary chemicals generally coming from oil, natural gas, or coal[1].

Circular & linear economy

Recycling plastic is a better option as the characteristic of plastic is that they do not decompose easily. Here we're using the technique of pyrolysis to recycle the plastic, which is a part of circular economy. Circular economy aims on the economic development of business, society and environment by reusing, remanufacturing and recycling the non- biodegradable waste. Whereas on the other hand linear economy aims on the 'take-make- waste' policy[2]. The different types of plastics are natural plastic like amber, semi synthetic plastic like cellulose acetate and synthetic plastic are obtained from petroleum industry[3].

Types of plastic in waste

Multilayer laminated packaging (MLP) are complex materials made up of different layers of polymers such as polyolefins, polyester, etc. Each layer contributes different property. It mainly consists of three or more layers of polymers bonded with adhesives. These plastics are ubiquitous due to their various properties like improved physical and mechanical properties, acting as an oxygen barrier in food packaging, etc. Multilayer plastic films are made by lamination, coextrusion or various coating technologies. They are also called co-extruded films.[4]

Ethylene vinyl acetate (EVA), ethylene-vinyl alcohol (EVOH), polyethylene (PE), polyethylene terephthalate (PET) and polypropylene (PP) are some of the most common polymers used in the packaging industries. Polyethylene (PE) is easy to process and is often used as a moisture barrier; ethylene-vinyl alcohol (EVOH) is used as an oxygen barrier in food packaging; polyethylene terephthalate (PET) is used as a gas and moisture barrier that is rigid and strong. Linear low-density polyethylene (LLDPE) is a high clarity film used widely in food packaging and blow moulding of bottles. When combined with high density polyethylene (HDPE), it provides superior properties and thinner films can be produced[5].

Due to various useful properties of MLP it is widely used resulting increase in post-consumer waste and post-industrial waste.

II. Current Status & Landfills

Studies show, in the last 65 years 8.3 billion metric tonnes of plastic is produced, of which 60% of it has already ended up in landfills, rivers, and oceans. Plastic waste of 300 million tons/year is dumped in landfills, rivers and, oceans, also burnt causing massive CO2 footprint and less than 9% is mechanically recyclable. By 2050 plastic waste is estimated to be 12 billion tonnes. Plastic waste consists of post-consumer waste as well as post-industrial waste and many impurities.

Post-consumer waste is understood that it's plastic packaging like bottles, plastic bags, etc. used and then thrown away. These are contaminated with food and other impurities and are dumped into landfills, rivers and oceans.

Post-industrial waste (PIW) is the plastic scrap generated in the industry in the manufacturing and packaging process. As post-consumer waste contains different types of plastic, PIW consists of Multilayer laminated packaging. Up to 30 or 40% of the packaging goes unused during the fabrication process like cutting into template shapes, discarding the excess films, etc[6]. Hence, these unused fraction of packaging results in a large number of PIW. This adds the load on landfills.

What are landfills and how are they affecting us?

A Landfill site is a large extended area where all types of waste are dumped in the open air for disposal. This is the oldest method of disposing waste which is also continued today. Landfills have adverse effects on our health and the environment. The toxic gases released in the air cause objectionable odours and air pollution, and it enters the soil too which contaminates the groundwater[7].

Each city has one, two, or more landfills located, for example, Mumbai, India initially had 3 dumping grounds in Mulund, Deonar and Kanjurmarg. In 2018 due to repeated incidents of fire at the Mulund ground the Bombay high court (HC) ordered to shut it down. Where Deonar is the largest dumping ground in Asia, 7 years after HC ordered to shut down the ground the municipal has finalized a contract to build a waste-to-energy plant[8].

Building waste-to-energy plants are not going to help save the environment due to various harmful effects of the incineration process. We can't stop using plastic as it is an essential alternative to many materials, from storage to packaging, plastic is used everywhere. Effective management and correct disposal of plastic waste is the key factor to overcome the issues.

III. Pyrolysis

Pyrolysis is one such method which follows the principles of circular economy. Where the plastic generated from the crude oil or fuels is recycled to give back the fuel itself in form of pyrolysis oil. Following are the two pyrolysis process:

Catalytic pyrolysis

Sometimes low pyrolysis temperature doesn't degrade completely leaving behind solid residues. Such problems are solved by using catalysts. Different kinds of catalyst are used in the process of pyrolysis of plastic waste to improve efficiency of the process. Catalysts have an important role in increasing process efficiency and reducing process temperature and time. Most commonly used catalysts are ZSM-5 (Zeolite Socony Mobil–**5**), zeolite, Y-zeolite, and MCM-41[9].

Non-catalytic pyrolysis

Pyrolysis is a process in which an organic compound is decomposed in the absence of oxygen at elevated temperatures. Since oxygen is not present, the compound decomposes into combustible gases and liquid. Most of these gases can be condensed into a combustible liquid, which is called pyrolysis oil. Therefore, pyrolysis produces three products, solid (biochar or charcoal), liquid (bio-oil) and gas (syngas). The proportion of these products depends on process parameters. Fast pyrolysis, where the heating rate is high, yields 60-70 wt.% bio-oil, 15-25 wt.% biochar and the remaining 10-15 wt.% syngas. Slow pyrolysis where heating rate is low the major product is bio-char[10].

IV. Mass Balance.

Considering catalytic pyrolysis and assuming 1000 kg/day of plastic as feed for material balance it was reported that 5% (w/w) of carbon black, 45% (w/w) of hydrocarbon gas, 45% (w/w) pyrolysis oil, 0.1% (w/w) oily wastewater, 4.9% (w/w) pyrolysis wax was obtained[11]. Mass flow rates for respective components are given below in table 1.

Basis: 1000 kg/day of plastic feed.

Table no. 1 Mass Balance

Components	Composition (% w/w)	Mass flowrate (in Kg/day)
Carbon Black	5	50
Hydrocarbon Gas	45	450
Pyrolysis Oil	45	450
Oily Wastewater	0.1	1
Pyrolysis wax	4.9	49
Total	100	1000

V. Block Diagram

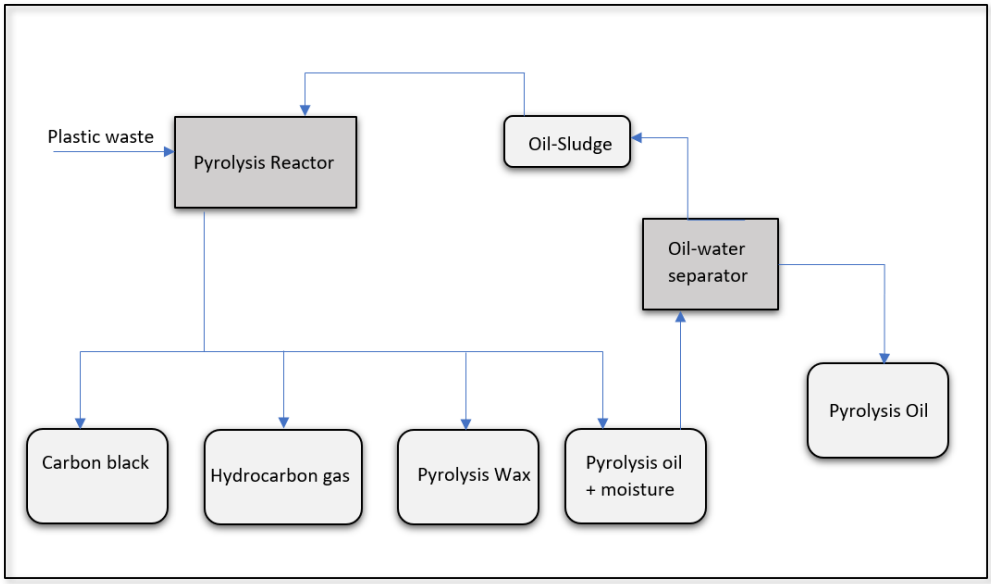

Fig. 1 Pyrolysis by catalytic route

Initially plastic waste is shredded into fine pieces and fed to the pyrolysis reactor which gives two main products namely, carbon black and oil vapour-gas mixture. The oil vapour is fractionally condensed to give hydrocarbon gas, pyrolysis wax and pyrolysis oil + moisture. The oil + moisture content is passed through an oil water separator which yields pyrolysis oil and the remaining oil sludge is recycled to the pyrolysis reactor. The black carbon can be packed and sold as an alternative for coal, the hydrocarbon gas can be treated and then passed through the exhaust pipes. Lubricating grease or oil can be obtained from the wax. Pyrolysis oil can be used in many ways like a fuel oil or can be refined into petroleum products[12].

VI. Conclusion

Thus, in this paper we have studied useful conversion of plastic waste. Bothe catalytic and non-catalytic process were mentioned. The catalytic process was studied in detail. Pyrolysis oil which is a product may be used as fuel oil or converted to other useful products.

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