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Plastic Wastes to Fuels

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Plastics have become an inevitable waste in any developing economy. In India, the production and consumption of plastics has increased to 20000 tonnes per day (TPD), among which municipal solid waste (MSW) composition is around 1-4 % of plastic by weight. This contributes to severe environmental pollution and health issues. In addition, the disposal of polythene bags and its burning leads to the emission of highly toxic gases (CO, Cl, SO_x, NO_x). Recycling of plastic waste is been a favorable solution to these disposal problems. India is leading in plastics recycling contributing around 26%, followed by South africa (16%), Japan (12%), USA (10%), China (10%) and Europe (7%). Other than recycling, plastics can also be utilized to produce fuels and chemicals by various conversion technologies so that both the energy demand and environmental pollution problems will be solved. This article gives insights about the various types of plastics and the methods and scope of its utilization as a fuel.

Plastic and its types

Plastics is derived from cellulose. Now a days plastics comes mainly from petrochemicals which are synthetic organic materials produced by polymerization with high molecular mass. The polymers can be molded or extruded into desired shapes which are the plastics used in the current world. There are two major classification of plastics viz. thermoplastics which can be repeatedly softened and melted (80% of the plastics are thermoplastics) and thermosets or thermosetting plastics which can melt and take shape only once and not suitable for repeated heat treatments (20% of the plastics are thermosets).

THERMOPLASTICS

- **High density polyethylene (HDPE)** - piping, automotive fuel tanks, bottles, toys
- **Low density polyethylene (LDPE)** -plastic bags, cling film, flexible containers
- **Polyethylene terephthalate (PET)** -bottles, carpets and food packaging
- **Polypropylene (PP)** - food containers, battery cases, bottle crates, automotive parts and fibres.
- **Polystyrene (PS)** - dairy product containers, tape cassettes, cups and plates.
- **Polyvinyl chloride (PVC)** - window frames, flooring, bottles, packaging film, cable insulation, credit cards and medical products

THERMOSETTING PLASTICS

- **Polyurethane (PU)** -coatings, finishes, gears, diaphragms, cushions, mattresses and car seats
- **Epoxy** - adhesives, sports equipment, electrical and automotive equipment
- **Phenolics** - ovens, handles for cutlery, automotive parts and circuit boards

Classification of Plastics

The other types of plastics include

- Film packaging, polythene carry bags, blow moulded containers, and broken and discarded moulded items.
- Discarded PVC chappals/shoes in varied colors and grades of plastics material
- Discarded PVC mineral water bottles/PET mineral water and liquor bottles
- PS ice-cream/cold drink cups/disposable catering plates and grays and expanded PS and PE foam packaging
- PE, PVC, PP films, packages, shopping bags, and medicine foils, used and discarded moulded items like containers and range of household non-durables, combs, ball point pens, tooth brushes etc

Current plastic waste treatment and disposal: Disposal of plastic waste is a serious concern in India. New technologies have been developed to minimize there adverse effect on the environment. Currently, the world wide accepted technology used for the plastic disposal is incineration and landfill. The incinerators release extremely toxic compounds (chlorinated dioxins and furans). Garbage containing plastics, when burnt may cause air pollution by emitting polluting gases. Garbage mixed with plastics interferes in waste processing facilities and may also cause problems in landfill operations. The plastic material when eaten by cattle's and other animals is unsuitable for their health and hygiene. It causes occupational health hazard and contamination of soil and groundwater. In addition, the littered plastics spoils aesthetics of the city and choke drains and make important public places dirty.

Production of fuels from plastic wastes: There are two kinds of fuel production from plastic wastes which include the solid fuel and liquid fuels. The former involves the production of pellets from plastic wastes also called RDF (Refuse derived fuel), the latter involves the production of bio-oil from plastc wastes using conventional pyrolysis, microwave induced pyrolysis and plasma pyrolysis.

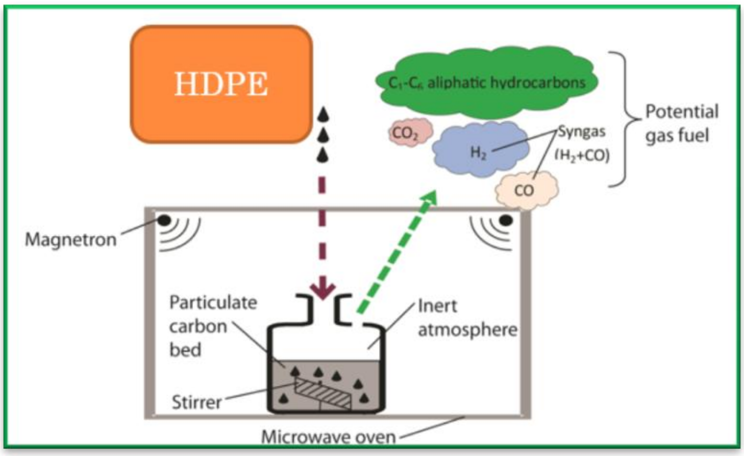
Solid fuel production: The first step in solid fuel production involves the process of pre-treatment wherein coarse shredding and removal of non-combustible materials takes place. The next step is the pellet production comprising the secondary shredding and pelletization process taking place at 200°C to produce RDF. The production process involves the unit operations viz. raw material hand picking, primary magnetic separation, crushing, feeding and extrusion. The produced RDF will be of 30x30x50 mm dimension and has a calorific value of about 6090 kcal/kg which is greater than the calorific value of wood.

Refuse derived fuel from plastic wastes

Liquid fuel production: Plastic wastes can be converted to liquid fuels by pyrolysis. Pyrolysis is the process of thermo chemical decomposition of organic material at elevated temperatures (> 430˚C) in the absence of oxygen. The raw materials that can be used are high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylenestyrene, polyvinyl alcohol, polyoxymethylenamide, polyurethane, polyphenylene, polyvinride etc. The ultimate composition range of these plastics will be of 85% C, 13% H, 0.8% N and 1.2% S. These materials are commonly found littered around our environment which are excellent source of hydrocarbon products. They are highly resistant to thermal degradation, requiring a temperature of 400 to 550 ˚C in order to exhibit sufficiently high degradation rates. This high temperature causes the loss of selectivity, increased secondary reactions, coke formations and reduced catalyst life. The comonly used catalysts to enhance the production of fuel are nickel-loaded silica-alumina (ni/si-al) with a molar ratio of 1:4.

Pyrolysis: In conventional pyrolysis, the thermal decomposition of plastic waste starts at around 270˚C. As the temperature rises from 270˚C, the yield of liquid obviously increased. The maximum liquid yield was obtained at 500 - 600˚C. If the temperature was increased continuously, the increase of yield was slow. The chemistry involves the heating the waste plastic to form a liquid slurry (400℃ to 550℃) folowed by distilling the slurry in the presence of cracking catalyst to recover the liquid hydrocarbon fuel materials.

Microwave-induced pyrolysis of plastic wastes: The process involves the thermal treatment in a microwave-heated bed of particulate-carbon which will be an effective method of recovering and recycling chemicals present in troublesome wastes such as plastic waste, sewage sludge, and coffee hulls. The waste material is mixed with a highly microwave absorbent material carbon, which absorbs microwave energy to generate sufficient thermal energy to achieve the temperatures required for extensive pyrolysis to occur. The waste material is thermally cracked in the absence of oxygen into smaller molecules. The resulting volatile products are either recondensed into an oil product (“pyrolysis-oil”) or collected as incondensable gaseous products (“pyrolysis-gases”) of different compositions depending on the reaction conditions.



Microwave pyrolysis of plastics

Plasma pyrolysis: Plasma is the fourth state of matter. It is an ionized gas that exists in nature. Plasma creates extremely high temperatures equivalent to nuclear fusion/fission. It provides the most effective medium to completely separate all components (organic and inorganic) into their elemental compounds for recovery and recycling. Plasma Gasification also called "Plasma pyrolysis" is the thermal disintegration of carbonaceous material into fragments of compounds in an oxygen-starved environment. It exploits the plasma’s ability to rapidly initiate a variety of chemical reactions including decomposition, evaporation, pyrolysis and oxidation. Inorganic materials can be heated to high temperatures where they melt and are transformed into molten slag and metal phases. Most waste streams, including medical/ hospital waste, chemical waste, hazardous waste, and low level radioactive waste are destructed completely safe and inert. Materials, such as dioxins, furans, halogenated hydrocarbons pose serious problems to the environment and to the public when burnt in conventional methods. However, facilities employing plasma process for the destruction of such materials has resulted in safe disposals with emissions below regulatory requirements. Plasma gasification of typical hazardous waste generates almost eight to ten times as much energy per unit of waste than the energy required to destroy the waste. The advantages include the eliminaton of toxic dioxins formation and furans molecules (in case of chlorinated waste), 99% conversion of organic waste into non toxic gases (CO_2, H_2O), not necessary to segregate the waste since the very high temperatures ensure treatment of all types of waste without discrimination and potential for significant reductions in cost and time required for treatment of municipal and industrial wastes.

Conclusion

The conversion of waste plastics to fuels like solid pellet and liquid bio-oil are promising routes that can be carried out for effective utilization and treatment of plastics. The pyrolysis process of plastic wastes will show better yield of fuel oil with increasing temperature, above 300˚C. However the reactors used in the pyrolysis process must be properly lagged before usage to prevent heat loss during the reaction for increased product yield. In general, a 100g of waste plastic has potential to yield 85-95g (100-120ml) of fuel oil and many of the thermoplastics are potentially used as a binder to solid fuel to increase calorific value of the produced solid fuel. Thus the waste to energy conversion of plastics not only yields energy rich products but also saves the environment from pollution.