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WASTE PLASTIC SYNTHESIS: ECOLOGICALLY SOUND AND ALTERNATIVE POWER SOURCE

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Abstract:

According to the latest report of the Central Pollution Control Board (CPCB) the plastic waste generated in India in 2017-18 was estimated to be around 660,787.85 tonnes. In India around 43% of manufactured plastics are re-cycle able and enormous quantity of non-recyclable plastic is left behind. Plastic is made from Petroleum or natural gas in a chemical process called Polymerization that combines smaller hydrocarbon molecules into larger hydrocarbon molecules forming chain like structure. The two major universal problems are waste plastic and problem of fuel extraction are being tackled simultaneously, due to continuous increase in industrialization and urbanization that has created measurable rise in the demand of plastic and fuel in the modern world. Pyrolysis is the process which involves thermochemical decomposition of organic matter at high temperature (>370°C) in the absence of oxygen. In this process gasification of granulated plastic is done and also the higher hydrocarbon molecules are converted into smaller hydrocarbon molecules. This hydrocarbon chains are processed to obtain petroleum products like petrol, diesel, kerosene, etc. The plastic used are normally low-density plastic. This process will be able to solve the two major problem wisely with more benefits.

Key words: Plastic, Polymerization, Pyrolysis, Petroleum products, Petrol, Diesel.

1. Introduction:

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Plastics are one of the most commonly used materials in our daily life and offer remarkable contribution to the society. They are widely used in packaging and manufacture of products including electronic, automotive, etc. Plastics are light weight and can be simply formed. They show non-corrosive behavior. They are reusable and conserve natural resources. Resultantly, there has been a quick development in plastic utilization and plastics have been utilized as substitution to wood and metals.

Plastic was invented by Alexander Parkes in 1860 and has high molecular mass. They are synthetic organic materials produced by polymerization. They may contain other substances besides polymers to reduce costs and to improve performance. Desired shape can be given to these polymers by moulding or by extrusion.

While plastic has many valuable uses, we have become addicted to single use or disposable plastic with severe environmental consequences. Around the world, one million plastic drinking bottles are purchased every minute, while up to 5 trillion single use plastic bags are used worldwide every year. In total half of all plastic produced is designed to be recycled only once and then thrown away into the atmosphere. From the 1950-70, only small amount of plastic was produced, so plastic waste was relatively manageable. But today, we produce about 300 million tonnes of plastic waste every year. That's nearly more than the weight of the entire human population. Plastic waste is now so wide ranging in the natural environment. Majority of plastics that are used are non-biodegradable in nature, which takes ages to decompose. Researchers estimate that more than 8.3 billion tonnes of plastic has been produced every year since 1950. About 60% of that plastic has ended up in either a landfill or the natural environment.

Mainly there are two types of plastics: thermoplastics and thermosetting plastic. If enough heat is supplied, thermoplastics can be softened and melted repeatedly. On cooling, they are hardened, so that they can be made into new plastics products. Examples are polyethylene

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terephthalate, polystyrene, polyvinyl chloride, high-density polyethylene, low-density polyethylene, poly propylene etc. They are recyclable. Thermosets or thermosetting plastics can be melted and shaped only once. It is not good to repeatedly heat such plastics; therefore, they remain in solid state after they have been solidified. Examples are epoxy resin, phenol formaldehyde and urea formaldehyde.

There are sub division of plastics are like 1.Polyethylene Terephthalate (PET) [water bottles, dispensing containers, biscuit trays], 2.High Density Polyethylene (HDPE) [shampoo bottles, milk bottles, freezer bags, ice cream containers], 3.Low Density Polyethylene (LDPE) [bags, trays, containers, food packaging film], 4.Polypropylene (PP) [chips bags, microwave dishes, ice-cream tubs, bottle caps], 5. Polystyrene (PS) [cutlery, plates, cups], 6. Expanded Polystyrene (EPS) [protective packaging, hot drink cups], 7.Polyvinyl Chloride (PVC) [plumbing pipes].

Pyrolysis is a process of decomposing plastics by heating in absence of oxygen generating gaseous and liquids products which can be utilized as fuels. This process can be thermal or catalytic and is an alternative that allows the conversion of polymers into gas and liquid hydrocarbons. In Pyrolysis of plastic the macromolecular structures of polymers are broken down into smaller molecules, and the process is known as De-polymerization. The plastic waste is processed to produce petrochemical compounds. This process converts, or “reverses”, petroleum made plastic solids into liquid form petroleum products, namely petrol, diesel and other fuels. It aims to present an overview of the technology available for converting waste plastics into a resource. The Pyrolysis by direct heating was adopted to produce the paraffin and crude oil from plastic waste in the 1990’s. Although this process is simple and convenient, the converting rate and yield is still low.

The total yield of fuel oil is 50-65%. The process here involves five types of plastics out of seven, namely High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE),

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Polypropylene (PP), Polystyrene (PS), Expanded Polystyrene (EPS), and the other two (PET and PVC) are not used for its oxygen content property, but can be used by using catalyst like Zeolite. The problem for this process is the pyrolysis equipment's corrosion incurred by PET and PVC in mixed plastic wastes. The all type of waste plastic is converting to fuel works like Petrol, diesel, kerosene and LPG. By implementing this concept can be reduced 80-90% of waste plastic and can be provide 60% fuel for vehicles

1.1 Different Types of Plastics:

Plastic is an essential component of many items, including water bottles, combs, and beverage containers. Knowing the difference, as well as the SPI codes, will help you make more informed decisions about recycling.

Polyethylene terephthalate (PET): This plastic is one of the most commonly used on the planet. Interestingly enough, it took another 30 years before it was used for crystal- clear beverage bottles, such as the ones produced by Coca-Cola and Pepsi. PET plastics make up 96% of all plastic bottles and containers in the United States, yet only 25% of these products are recycled. By being mindful and making sure to recycle code 1 plastics, you're helping to ensure a cleaner environment and less landfill pollution!

High Density Polyethylene (HDPE): High-Density Polyethylene products are very safe and are not known to transmit any chemicals into foods or drinks. HDPE products are commonly recycled. Items made from this plastic include containers for milk, motor oil, shampoos and conditioners, soap bottles, detergents, and bleaches. It is NEVER safe to reuse an HDPE bottle as a food or drink container if it didn't originally contain food or drink. HDPE is a long linear polymer chain having high strength properties. The features contributing to the strength are high degree of crystallinity and low branching. There are wide range of applications for HDPE. It is typically used for the production of milk bottles, detergent bottles, oil containers, toys and many more. It is the third largest plastic type found in MSW

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(Municipal Solid Waste). HDPE is well-defined by a density of larger or equal to 0.941 g/cm3

Polyvinyl Chloride (PVC): PVC is one of the oldest synthetic materials in industrial production. PVC is one of the least recycled materials; generally less than 1% of PVC plastic is recycled each year. It has been called the "poison plastic" because it contains numerous toxins and is harmful to our health and the environment.

Low density Polyethylene (LDPE): Low-Density Polyethylene is sometimes recycled. It is a very healthy plastic that tends to be both durable and flexible. Items such as cling-film, sandwich bags, squeezable bottles, and plastic grocery bags are made from LDPE. LDPE has lower tensile strength and hardness. This is because of the weaker intermolecular force of LDPE. In comparison with HDPE, LDPE has more branching. LDPE waste is the second largest plastic waste in MSW after PP. LDPE is well-defined by a density range of 0.91–0.94g/cm3.

Polypropylene (PP): PP have Polypropylene is occasionally recycled. PP is strong and can usually withstand higher temperatures. It is used to make lunch boxes, margarine containers, yogurt pots, syrup bottles, prescription bottles. Plastic bottle caps are often made from PP. high chemical as well as heat resistance properties. It is a saturated polymer having linear hydrocarbon chain. It does not melt below than 160°C. PP has high hardness and rigidity which makes it preferable for plastic industry. Unlike HDPE, PP has a lower density. It is the largest contributor of plastics in MSW.

Polystyrene (PS): Polystyrene is commonly recycled, but is difficult to do. Items such as disposable coffee cups, plastic food boxes, plastic cutlery and packing foam are made from PS.PS is synthesized from the liquid petrochemical and is the polymer of styrene monomers. It has compounds of long hydrocarbon chain with phenyl group attached to every carbon atom. It is a colorless compound, but can be colored with suitable colorants. Due to its

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reasonable durability, strength and lightness, PS is used in variety of applications including in food packaging, electronics, construction, medical, appliances, toys and many more. As the range of applications is higher, large waste accumulation is there. PS cannot be included in the roadside recycling program as the recycling bins only include glasses, papers, cans, and other light plastics. People won't throw the foam food packaging into plastics recycle bin but will be put into the general bin. So recycling is challenging in the case of PS. The only way for the recovery of PS waste is pyrolysis process which converted it into high quality liquid oil.

Others: The remaining plastics include: polycarbonate, polylactide, acrylic, acrylonitrile butadiene, styrene, fiberglass, and nylon. Of course, there are many differences in the plastics classified as miscellaneous by recycling programs. Many BPA products fall into this category, which means it's best to avoid them, especially for food products. It is not very easy to break down these plastics once they are created, unless they are exposed to high temperatures. This means they are nearly impossible to recycle.

2. Objectives and Justification:

Environmental Benefits: The production of plastic in India itself is too much, of which nearly all are not recycled and dumped into environment. It take's years to decompose, which leads to instability of soil and correspondingly environment. Use of this plastic for alternative purpose not only useful for the user but also for the environment.

Waste Management: The waste produced can neither be burnt in open air nor it can be buried into the soil. And also the ratio of plastic waste is increasing tremendously and needs ages to degrade and decompose. By the pyrolysis process the plastic waste taken to recycle is 100% eliminated.

Alternative Conventional Fuel: The Percentage of Fossil Fuel consumption has increased over the years due to urbanization and industrialization. Due to this, there is shortage of

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naturally available fossil fuel. The fuel imported is of high cost, which may not be available at affordable cost for common citizen. The fuel produced by plastic waste pyrolysis can overcome this issue as an alternate fuel source.

Employment and Business Opportunities: The extraction of fuel from plastic waste can lead to a startup at low initial investments. The abundant availability of Plastic waste especially in India helps in the cause of raw material collection at lowest investment thus to produce fuel at low cost. This not only provide business opportunity for entrepreneurs but also employment opportunities for needy.

Health and Safety: Dumping of plastic waste into soil and water bodies results adversely on environment and ecosystem. Aquatic life is suffering huge loss of life by in-taking the plastic unknowingly. The use of plastic waste for this process may reduce the quantity of plastic waste dumping into water bodies, which can clean them and save the life in it.

3. Materials and Methodology:

3.1 Materials:

Stainless Steel 201 Sheets and Pipes: 201 stainless steel is an alloy that contains half the nickel and increased manganese and nitrogen of more popular steels. While it is less expensive than some other alloys (because of its low nickel content), it is not as easy to work or form. Type 201 is an austenitic metal because it is a non-magnetic stainless steel that contains high levels of chromium and nickel and low levels of carbon.

Facts about Type 201 Stainless Steel: Type 201 stainless steel is a mid-range product with a variety of useful qualities. While it is ideal for certain uses, it is not a good choice for structures that may be prone to corrosive forces such as salt water.

- Type 201 is part of the 200 series of austenitic stainless steels. Originally developed to conserve nickel, this family of stainless steels is characterized by low-nickel content.

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- Type 201 can substitute for type 301 in many applications, but is less corrosion resistant than its counterpart, particularly in chemical environments.
- Annealed, it is non-magnetic but can become magnetic by cold working. A greater nitrogen content in type 201 provides higher yield strength and toughness than type 301 steel, especially at low temperatures.
- Type 201 is not hardened by heat treatment and is annealed at 1850-1950°F (1010-1066°C), followed by water quenching or rapid air cooling.
- Type 201 is used to produce a range of household appliances, including sinks, cooking utensils, washing machines, windows, and doors. It is also used in automotive trim, decorative architecture, railway cars, trailers, and clamps. It is not recommended for structural outdoor applications because of its susceptibility to pitting and crevice corrosion.

Copper Spiral Coil: The word copper comes from the Latin word 'cuprum', which means 'ore of cyprus'. This is why the chemical symbol for copper is Cu. Copper has many extremely useful properties, including:

- Good electrical conductivity
- Good thermal conductivity
- Corrosion resistance and is also
- Easy to alloy
- Easily joined
- Ductile and tough
- Attractive and non-magnetic
- Catalytic.

Copper is a good conductor of heat. This means that if you heat one end of a piece of copper, the other end will quickly reach the same temperature. Most metals are pretty good

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conductors; however, apart from silver with relative conductivity of 418 copper is best with relative conductive 394. Cooper is used in many heating applications because it doesn't corrode and has high melting point. The only other material that has similar resistance to corrosion is stainless steel. However, its thermal conductivity is 30 times worse than that of copper.

Zeolite as Catalyst:

Zeolites are crystalline solids structures made of silicon, aluminum and oxygen that form a framework with cavities and channels inside where cations, water and/or small molecules may reside. They are often also referred to as molecular sieves.

Zeolites were introduced in 1954 as adsorbents for industrial separations and purifications. Because of their unique porous properties, zeolites are used now in a variety of applications with world production estimated to be in the range of 2.5 million to 3 million metric tons (Mt) in 2008 year. They are used in petrochemical cracking, water softening and purification, in the separation and removal of gases and solvents, agriculture, animal husbandry and construction.

Characteristics of Zeolite:

1. Tectosilicate i.e. Three dimensional structure built from tetrahedral. Some silicon atoms have been replaced by aluminum, i.e. the(Si+Al)/0=1/2. (Tetrahedra usually denoted T atoms).
2. Open framework structure built from To4-Tetrahedra, containing pores and voids the structure and porosity is periodic (i.e. Crystalline materials). The pores have molecular dimensions.

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3. High degree of hydration.
4. Low density and large void vole when hydrated.
5. Stability of the crystal structure when dehydrated.
6. Cation exchange properties.
7. Uniform molecular sized channel in dehydrated crystal.
8. Ability to absorb gasses and vapors.
9. Catalytic properties.

Plastics to be used:

Five types of plastics to be used excluding PET and PVC which are containing high oxygen molecules which may hinder the accuracy of the results and also may need to introduce nitrogen in the reactor to eliminate oxygen. The plastics to be used are:

- High Density Polyethylene (HDPE)
- Low density Polyethylene (LDPE
- Polypropylene (PP
- Polystyrene (PS)
- Others

3.2 Methodology:

This discusses experimental methodology of the research. The literature study was carried out in the early stage of the study to enhance the understanding of the process. Technical papers from the international proceedings, journals and published reports were reviewed to keep up to date.

3.2.1 Pyrolysis Process:

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Pyro = heat.

lysis = break down.

Pyrolysis is the thermal decomposition of materials at elevated temperatures in the absence of oxygen. It involves a change of chemical composition. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating". Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, cloth, like wood, and paper, and also of some kinds of plastic. This reaction involves the molecular breakdown of larger molecules into smaller molecules in the presence of heat. Pyrolysis is also known as thermal cracking, cracking, thermolysis, depolymerization, etc.

Pyrolysis process can also be used to produce liquid fuel similar to diesel from plastic waste. Pyrolysis technology is thermal degradation process in the absence of oxygen. Pyrolysis technology is thermal degradation process in the absence of oxygen. The most common application of pyrolysis is applied to the treatment of organic materials. It is one of the processes involved in charring wood, starting at temperature of 350°C. During pyrolysis of organic substances, it produces volatile products and leaves a solid residue which is rich in carbon, char. Extreme pyrolysis leaves mostly carbon as the residue which is called carbonization.

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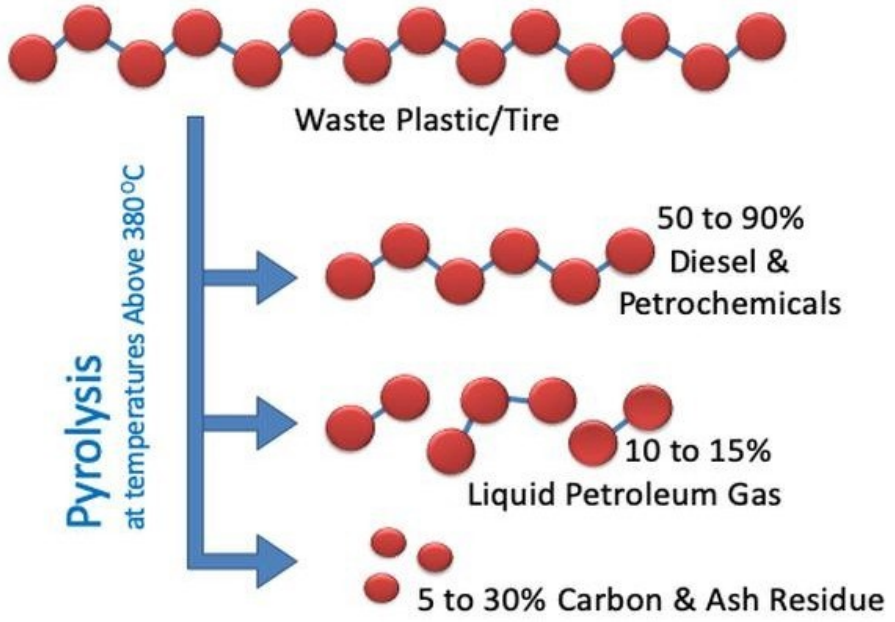

Fig. 3.2.1 breaking of hydrocarbon chain in pyrolysis process

3.2.2 Pyrolysis of Plastic:

Production of fuel from waste plastic involves pyrolysis process. In this process, plastic is heated to a temperature starting from 350°C to 700°C in a reactor in the absence of oxygen. The temperature required depends on the types of plastics used. Once the melting point is reached, the plastics melts and the gaseous vapours rise up and flows through the pipe connections to the condensing units. The condensed vapour is collected in the form of liquid which is pyrolysis oil. The pyrolysis of plastic gives out the mixture of fuel, gases and solid char. Variation of the pyrolysis process, type of plastic used and the temperature will produce the varying percentage of these three products.

Various technologies and methodologies can be used for the pyrolysis process such as batch reactor, semi batch reactor, fluidized bed reactor, fixed bed reactor etc. The process can be

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Performed with or without the use of catalyst. The different types of catalyst that can be used for plastic pyrolysis are zeolite, alumina (Al2O3), silica (SiO2), and many more.

4. Results:

Table 4. Results of Tests Conducted

Sl. No.	Test Name	Conventional oil (Range)	Pyrolysis Oil
1.	Viscosity	1.32-2.4	1.980
2.	Density (g/cc)	0.71-0.77	0.7477
3.	Carbon Residual Weight (%)	0.5-0.9	0.5
4.	Ash Content (%)	0.03-0.07	0.036
5.	Sulphur Content (%)	0.05-0.25	0.246
6.	Flash Point (%)	40-62	50
7.	Fire Content °C	>52	56
8.	Calorific Value (kCal/kg)	10800-11800	10989
9.	Colour	Petrol: Blueish Green Diesel: Yellowish Green	Petrol: Dark brown to Blueish Green Diesel: Yellowish Green
10.	Water Content	1.0	Nil

- The color of crude oil extracted is dark brown and when further processed it bluish green and yellowish red.

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- The bifurcated petrol oil is highly combustible at room temperature resembling the properties of conventional petrol.
- The cloud point and pour point is low which means this fuel can be used in extreme cold conditions when needed.
- As per gross calorific value petrol and diesel can be used for heavy diesel engines.
- The conventional oil is not renewable and need excavation to very large depth which results in high investment, but in case of pyrolysis oil easily available materials are used which comparatively reduce the investment and time.
- A successive pyrolysis experiment can overcome the dependency over fossil fuels.

5. Conclusion:

Catalytic pyrolysis is a promising technique to convert plastic waste into liquid oil and other value-added products, using a modified natural zeolite (NZ) catalyst. The catalytic pyrolysis of PS produced the highest liquid oil (70 and 60%) compared to PP (40 and 54%) and PE (40 and 42%), Bio refineries have a great potential to convert waste into energy and other valuable products and could help to achieve circular economies. This provide win and win situation when all safety and working measures are considered. This process not only help to increase economy but also to reduce the amount if plastic present using that as a feedstock.

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