PRODUCTION OF BIO FUEL FROM PLASTIC WASTE, USED PPE KITS AND MASKS

ABSRTACT

Plastics have woven their way into our daily lives and now pose a tremendous threat to the environment. Over 100 million tons of plastics are produced annually worldwide, and the used products have become a common feature at over flowing bins and landfills. Though work has been done to make futuristic biodegradable plastics, there have not been many conclusive steps towards cleaning up the existing problem. Here, the process of converting waste plastic into value biofuel is explained as a viable solution for recycling of plastics. The demand for plastic is increasing day by day especially PPE kits and masks which now pose a tremendous threat to the environment. Converting waste plastics and used PPE kits and masks into fuel hold great promise for both the environmental and economic scenarios. It is an alternative solution to increasing problem of waste disposal

Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. The advantage of the pyrolysis process is its ability to handle unsort and dirty plastic. Plasma pyrolysis is another method which can be used to treat medical waste which is the current need of the hour. PPE kits is being designed for single use needs decades to decompose. So to tackle this problem, Conversion of PPE kits and masks into biofuel can be used as an alternative method through the process of pyrolysis.

This Project Report gives insight about the Pyrolysis process as an effective method to convert waste plastics, used PPE kits and masks into biofuel.

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CHAPTER 1.

INTRODUCTION

1.1 – INTRODUCTION

Plastic is the term commonly used to describe a wide range of synthetic or semi-synthetic materials that are used in a huge and growing range of applications. Everywhere you look, you will find plastics. Plastic were invented in 1860, but have only been widely used in the last 30 years. Plastic are light, durable, modifiable and hygienic. Plastic are made of long chain of molecule called Polymers. Polymers are made when naturally occurring substance such as crude oil or petroleum are transformed into other substance with completely different properties. These polymers can then be made into granules, powders and liquids, becoming raw materials for plastic products. Plastics are non-biodegradable polymers mostly containing carbon, hydrogen, and few other elements like nitrogen. Due to its non-biodegradable nature, the plastic waste contributes significantly to the problem of waste management.

Globally, 5 to 13 million tons of plastic end up in oceans every year. There is little that can be done about the vast amounts of plastic already in the oceans, but we can still do a whole lot to ensure we won't be adding much more plastic waste to that already out there. Encouragingly, several promising initiatives are under way. One such is producing biofuel from waste plastics. Plastic waste also has a detrimental impact on wild life, plastic waste in the oceans is estimated to cause the death of more than a million seabirds and more than 100,000 marine mammals every year (US Environmental Program Estimate). Along with thishundreds of thousands of sea turtles, whales and other marine mammals die every year eatingdiscarded waste plastic bags mistaken for food. Setting up intermediate treatment plants for waste plastic, such as, plastic incineration, recycle, or obtaining the landfill for reclamation is difficult. Therefore it is necessary to reuse waste plastic to avoid such problems and convert into useful bio diesel compounds by different methods.

Though COVID-19 has actually had some positive short-term effects for the environment, personal protective equipment (PPE), which is currently being used and disposed of at an unprecedented rate, poses a serious problem for the environment. Now a new study published claims that plastic from used PPE and masks can, and should be, turned into biofuel. Plastic Pollution has reached pandemic levels worldwide, with the colossal amounts of plastic waste posing grave risks to the health of ecosystems both on land and in the oceans. It’s also a threat to human health with micro plastics having permeated our food and water, and even our table salt. Now a new study published claims that plastic from used PPE and masks can, and should be, turned into biofuel.

As the world is growing faster, transportation is increasing rapidly leading to depletion of fuels. Therefore this is the time to look at an alternative fuel for diesel engines and industries. Biodiesel is an alternative fuel for diesel engine. Drop-in biofuels are functionally equivalent to petroleum fuels and fully compatible with the existing petroleum infrastructure. They require no engine modification of the vehicle. Since plastics were the petroleum-based material the rising in plastic demand led to depletion of petroleum as a part of non-renewable fossil fuel. Recycling and energy recovery method were some alternatives that have been developed to manage plastic waste. However, the recycling method required high labor cost for the separation process and caused water contamination that reduced the process sustainability. Due to these drawbacks, the researchers have diverted their attentions to the energy recovery method to compensate the high energy demand. The plastic waste conversion to energy was developed through extensive research and technology development. The recovery of plastic to liquid oil through pyrolysis process had a great potential since petroleum was the main source of plastic manufacturing.

The conversion methods of waste plastics into fuel depend on the types of plastics to be targeted and the properties of other wastes that might be used in the process. Additionally the effective conversion requires technologies to be selected according to local economic, environmental, social and technical characteristics. Plastic wastes can also be classified as industrial, municipal and medical plastic wastes according to their origins, these groups have different qualities and properties and are subjected to different management strategies

a. Municipal Plastic Wastes

Municipal plastic wastes (MPW) normally remain a part of municipal solid wastes as they are discarded and collected as household wastes. The various sources of MPW plastics includes domestic items (food containers, milk covers, water bottles, packaging foam, disposable cups, plates, cutlery, CD and cassette boxes. fridge liners, vending cups, electronic equipment cases, drainage pipe, carbonated drinks bottles, plumbing pipes and guttering, etc.), agricultural (feed bags, fertilizer bags, and in temporary tarpaulin-like uses such as covers for hay, etc.), wire and cable, automobile wrecking, etc. Thus, the MPW collected plastics waste is mixed one with major components of polyethylene, polypropylene, polystyrene, polyvinyl chloride, polyethylene terephthalate, etc. The percentage of plastics in MPW has increased significantly.

b. Industrial Plastic Wastes

Industrial plastic wastes are those arising from the large plastics manufacturing, processing and packaging industry. The industrial waste plastic mainly constitute plastics from construction and demolition companies (e.g. polyvinylchloride pipes and fittings, tiles and sheets) electrical and electronics industries (e.g. switch boxes, cable sheaths, cassette boxes, TV screens, etc.) and the automotive industries spare-parts for cars, such as fan blades, seat coverings, battery containers and front grills). Most of the industrial plastic waste has relatively well physical characteristics i.e. they are sufficiently clean and free of contamination and are available in fairly large quantities.

c. Medical Plastic Wastes

Medical plastic wastes are those arising from the hospitals. Laboratories, operating rooms, facilities, ambulance service and cafeterias are identified as major sources of plastic waste generated by hospitals. This include syringes, PPE kits, masks, surgical gloves, IV tubes , Trays, insulin pens, saline bottles, packaging and storage containers etc. Polypropylene is largely used in making masks and PPE. Some of the most common thermoplastics used in medical device injection molding is polyethylene, polypropylene, polyamide, polycarbonate etc.

1.2 DIFFERENT TYPES OF PLASTIC

1.2.1. Polyethylene terephthalate (PET)

PET has become the great choice for plastic packaging for various food products, mainly beverages such as mineral water, soft drink bottle and fruit juice containers. This is due to its intrinsic properties that are very suitable for large-capacity, lightweight and pressure-resistant containers. Different utilizations of PET incorporate electrical protection, printing sheets, attractive tapes, X-ray and other photographic film.The extensive applications of PET would cause an accumulation of PET waste in the landfill. Recycling PET waste was the current practice of handling accumulated plastic waste. In any case, the massiveness of the holders causes high recurrence of accumulations and along these lines, builds the vehicle costs. To ease the recycling process, the PET waste needs to be sorted into different grades and colors that make its recovery inefficient and uneconomical. Subsequently, other option for PET recuperation, for example, pyrolysis process has been investigated and the item yield was broke down by a few specialists.

1.2.2. High-density polyethylene (HDPE)

HDPE is characterized as a long linear polymer chain with high degree of crystallinity and low branching which leads to high strength properties. Because of its high quality properties, HDPE is generally utilized as a part of assembling of drain bottles, cleanser bottles, oil compartments, toys and the sky is the limit from there. The various applications contribute about 17.6% in plastic waste category which is the third largest plastic type found in municipal solid waste (MSW) . HDPE waste have an awesome potential to be utilized as a part of pyrolysis process since it can deliver high fluid yield relies upon the set up parameters. Numerous examinations have been led on HDPE pyrolysis at various working parameters to research the item yield acquired.

1.2.3. Polyvinyl chloride (PVC)

Unlike other thermoplastics such as polyethylene (PE), polystyrene (PS) and polypropylene (PP) which can be softened by heating and solely derived from oil, PVC is exceptional since it is manufactured from the mixture of 57% chlorine (Derived from Industrial grade salt) and

43% carbon (derived from hydrocarbon feedstock such as ethylene from oil or natural gas). The chlorine property makes PVC an excellent fire resistance, thus very suitable for electrical insulation. The compatibility PVC to be mixed with many additives makes it a versatile plastic. Regular applications of PVC include wire and cable insulation, window frames, boots, food foil, medical devices, blood bags, automotive interiors, packaging, credit cards, synthetic leather, etc. Even though it has wide applications, the research done on the PVC pyrolysis found in the literature was very less due to the dangerous substance that it tend to release when heated at high temperature.

1.2.4. Low-density polyethylene (LDPE)

As opposed to HDPE, LDPE has all the more stretching that outcomes in weaker intermolecular power, in this manner bring down elasticity and hardness. Be that as it may, LDPE has preferable flexibility over HDPE since the side stretching makes the structure be less crystalline and simple to be shaped. It has a superb protection from water, along these lines generally connected as plastic sacks, wrapping foils for bundling, waste packs and significantly more. All these items are commonly used in our daily lives and therefore, LDPE waste has been accumulated day by day that it is known as the second largest plastic waste in MSW after PP. As one approach to recoup vitality and lessen squander, pyrolysis of LDPE to oil item has gotten much consideration by scientists these days.

1.2.5. Polypropylene (PP)

PP is a saturated polymer with linear hydrocarbon chain that has a good chemical and heat resistance. Unlike HDPE, PP does not melt at temperature below than 160oC. It has a lower thickness than HDPE yet has higher hardness and unbending nature that makes it ideal in plastic industry. PP contributes around 24.3% in plastic squanders class which are the biggest measure of plastics found in MSW. The diverse applications include flowerpot, office folders, car bumpers, pails, carpets, furniture, storage boxes and more. The high demand of PP in daily life causes the amount of PP wastes to increase each year and therefore, pyrolysis of PP is one of the methods that can be used for energy recovery. A few analysts have researched the pyrolysis of PP at different parameters to gauge the fluid oil yield and properties.

1.2.6. Polystyrene (PS)

PS is made of styrene monomers obtained from the liquid petrochemical. The structure consists of a long hydrocarbon chain with phenyl group attached to every other carbon atom. PS is naturally colorless but it can be colored by colorants. It is warm flexibility and it offers sensible sturdiness, quality and delicacy that make this polymer alluring to be utilized as a part of assortment of areas, for example, in nourishment bundling, hardware, development, medicinal, apparatuses and toys. The wide range of applications signifies the large waste amount of PS in MSW accumulated each year. Unfortunately, PS is excluded in the roadside reusing program in which the reusing canisters just included glasses, papers, jars, and certain plastics. Even though there is a plastic category, normally people will not throw the foam food packaging into plastics recycle bin and they often go to the general bin. In this way, PS is for the most part not isolated and not financially to gather for reusing because of its low thickness polystyrene froth. Henceforth, the main way the PS waste can be completely used is through pyrolysis process in which it can be transformed into more profitable oil item instead of to wind up in the landfills for eternity

1.2.7. Mixed plastics

As already said, pyrolysis process has an additional favorable position over the reusing procedure since it needn't bother with an extreme arranging process. In recycling process, most plastics are not compatible with each other to be processed together during recycling. For example, a slight measure of PVC contaminant introduce in PET reuse stream will debase the entire PET gum by getting to be yellowish and weak that requires reprocessing.This shows that recycling process is very sensitive to contaminants that it requires all plastics to be sorted based on type of resins, colors and transparency. However, pyrolysis process seems to be more sustainable since liquid oil still can be produced from the mixed plastics in the feedstock. This has been encountered by several researchers who conducted studies of mixed plastics pyrolysis.

Fig 1.1. Different types of Plastics

In order to assist recycling of the waste plastic, Society of Plastic Industry (SPI) defined a resin identification code system that divides plastics into the above seven groups based on the chemical structure and applications.

<u>CHAPTER 2.</u>

LITERATURE SURVEY

2.1 – LITERATURE SURVEY

SR NO.	TITLE OF THE PAPER	AUTHORS	KEY FINDINGS
1.	Pyrolysis of Waste Plastics into Fuels.	Feng Gao	By their semi-scale continuous pyrolysis plant, they found it as energy efficient process and can be used to reduce conventional landfill or incineration of waste plastics.
2.	Strategy for repurposing of disposed PPE kits by production of biofuel: Pressing priority amidst COVID-19 pandemic – Journal Biofuels.	Sapna Jain, Bhawna Yadav Lamba, Sanjeev Kumar, Deepanmol Singh	High production of PPEs due to COVID-19 resulted in problem of its disposal owing to its material *i.e.* non-woven polypropylene that can be overcome by conversion of PPE into biofuel.
3.	Production and Purification of Liquid fuel from Household Plastic waste for CL Engine.	Alkazadagaonkar(et al)	The experiments on conversion waste plastic into liquid fuels using new technology. We can convert all types of waste plastics into liquid fuels at a temperature of 350-500c.
4.	Thermolysis of waste plastics to liquid fuel.	Achyut K. Panda, R.K. Singh, D.K. Mishra	In this research projects he used wide range of old and new technologies for chemical recycling of waste plastic to liquid fuel.
5.	Environmental Engineering: Stepwise	Bockhorn H (et al.)	Kinetic study on the thermal degradation or thermal

	pyrolysis of plastic waste		pyrolysis of plastic wastes. They concluded that, the temperature and reaction time thermal pyrolysis is slightly greater than the catalytic pyrolysis
6.	Conversion of Plastic Wastes into Fuels	Antony Raja and Advaith Murali (et al)	He concluded that we can convert all types of waste plastic into hydrocarbon fuel at the temperature profile 350ºC to 500ºC through pyrolysis process
7.	Production of alternative fuel from waste oil and comparison with fresh diesel	Manish Chand Sharma, Neelesh Soni (et al)	This research paper compares the diesel obtained from pyrolysis of plastic oil with conventional diesel oil.
8.	A Comparison of the Use of Pyrolysis Oils in Diesel Engine	C. Wongkhorsub, N. Chindaprasert (et al)	Pyrolysis oils and waste plastic are studied to apply with one cylinder multipurpose agriculture diesel engine. Thus, a comparison between the two is studied.
9.	Study on the thermal Pyrolysis of Medical Waste (Plastic syringe) for the Production of useful Liquid Fuels	Abhishek Dash	thermal pyrolysis of plastic medical waste (plastic syringes) performed in a semi batch reactor at a temperature of 450°C for the production of pyrolytic oil.

CHAPTER 3.

SCHEMATIC PROCESS AND DESCRIPTION.

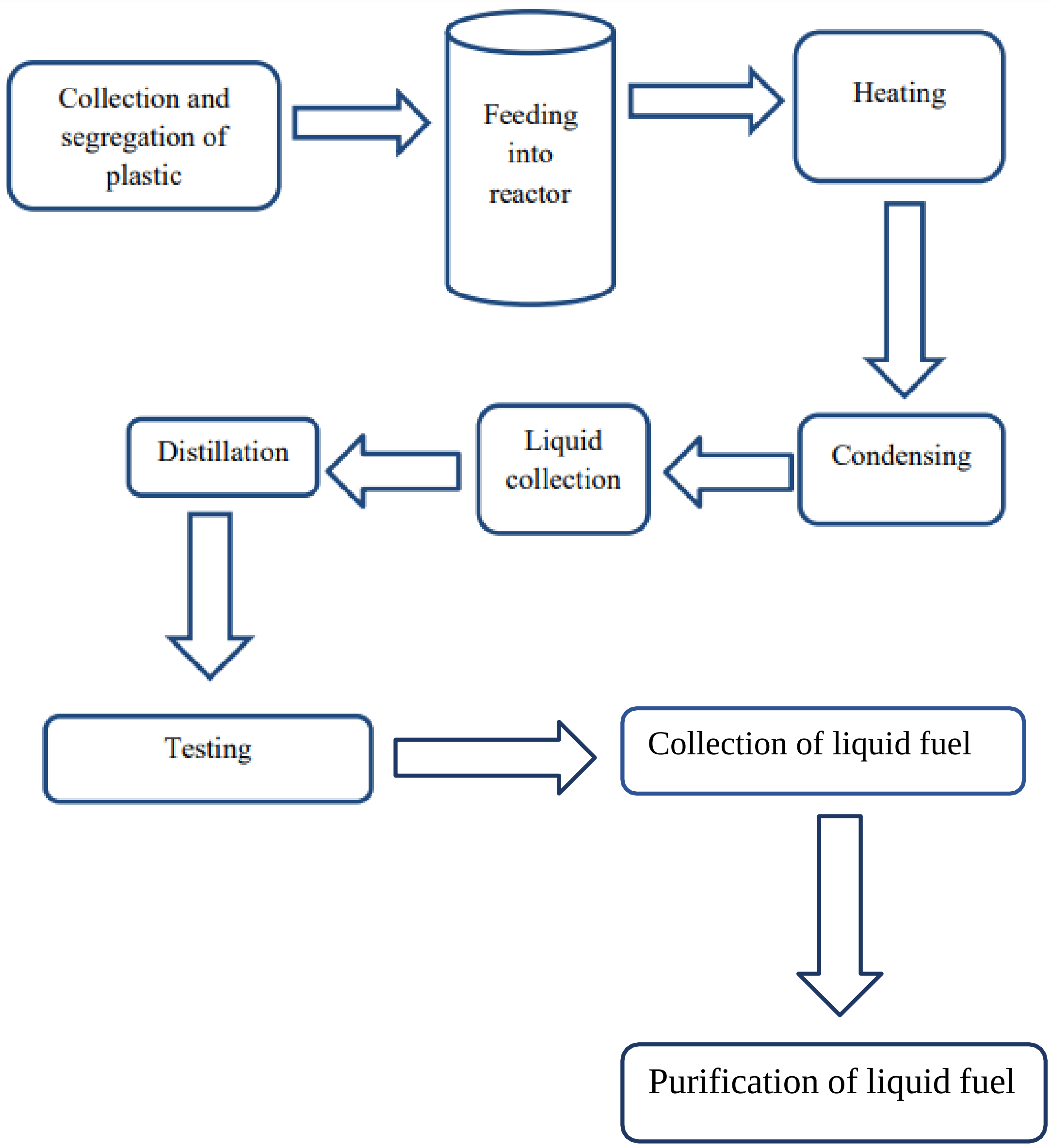


Fig 3.1 BLOCK DIAGRAM OF PROCESS

3.1 PROCESS DESCRIPTION

3.1.1 COLLECTION AND SEGREAGATION OF PLASTIC

COLLECTION OF PLASTIC

The plastic waste is collected from different sources such as household, hotels, market etc. and separated on the basis of their types. The various types of waste plastic include food containers, milk covers, water bottles, packaging foams, disposable cups and plates, broken plastic chair, shopping bags etc. The plastics can be separated as PET, HDPE, LDPE, polypropylene, etc. After the separation, plastic is cleaned to remove any impurities like dust, dirt, with the help of soap water. The plastic is then dried in the sun to remove the moisture present and cut into small pieces of size less than 5cm.

3.1.2 FEEDING INTO REACTOR

Once the waste plastic is cut into small pieces, the next step is feeding into the reactor. The reactor is made from mild steel. The flange is opened and plastic pieces are fed into the reactor and the flange is closed again. It is necessary to prevent any leakage in the reactor. Hence, gasket is provided for that. However, gasket should be able to substand high temperature else it will burn out.

PLASTIC FEEDING INTO REACTOR

3.1.3 HEATING

An electric heater which has capacity of 3KW is used to heat the reactor. A Nichrome coil is used as heating element and power supply is 230V, 50Hz AC. A temperature indicator and controller are used to record and maintain the required temperature. The heater can increase the temperature up to 200°C within 15 minutes and the temperature indicator and controller can record temperature up to maximum of 1200°C.

Heating element

3.1.4 CONDENSING

The plastic waste gets evaporated at temperature 250-350°C. This vapour is condensed to atmospheric temperature by using tube condenser

Condensing process

3.1.5 LIQUID COLLLECTION

The vapour coming out of condenser is condensed and collected at the liquid collector. The liquid collector is basically a small tank filled with 3/4th water. The condensed fuel is collected above the water due to the difference in the density of oil and water. Once the oil stops coming from the condenser, the oil is collected. Two taps are provided at different heights, one for fuel collection and another for draining water out.

3.1.6 DISTILLATION

Once the fuel is collected, the oil is distilled to increase purity. For this, a sample of oil (about 250ml) is taken in a round bottom flask and heated to about 70°C. The oil starts to boil and the vapour is condensed and collected in a separate flask. Water is supplied for condensing the process. Thus, fuel with better property is achieved.

Distillation process

3.1.7 TESTING

The oil sample is finally taken to laboratories for testing its properties like density, calorific value, flash point, fire point, viscosity, etc. The test is carried out for different samples before coming to final result.

OIL SAMPLE

3.1.8 PURIFICATION -

Purify the plastic fuel by using filter papers and vacuum machine.

3.1.9 pH Test-

After purification measure the pH value of plastic fuel by using pH meter. If the pH is less than 7, the fuel is acidic in nature. It is needed to wash with dilution of potassium hydroxide or sodium hydroxide to bring pH value at 7.

3.2 PYROLYSIS PROCESS ON LARGE SCALE

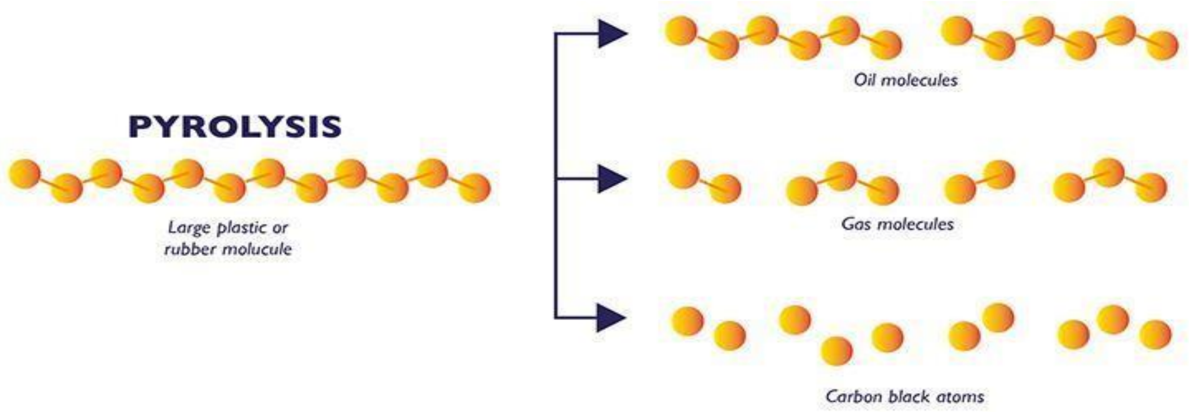


Fig 3.2 Breaking of hydrocarbon chain in pyrolysis process

Pyrolysis is a thermo-chemical process for conversion of plastic waste by heating the feedstock at high temperature in absence of air which produces gaseous products which is then condensed to give liquid fuels consisting of pyrolytic oil or liquid-oil.It involves thermal degradation of long hydrocarbon chains into smaller ones.

At any given temperature, the molecules is in vibrating stage called molecular vibration. The frequency at which the molecule vibrates is directly proportional to the temperature of molecules. During Pyrolysis the object molecules are subjected to very high temperature leading to high molecular vibration. At these high molecular vibrations, everymolecule in the object is stretched and shaken to such an extent that molecules start breaking down into smaller molecules.This is called Pyrolysis. Pyro means heat, Lysis means Breakdown. This process is also called as ‘ Thermocatalytic Depolymerisation’. In general, each pyrolysis technology consists of three parts: feeding system, pyrolysis reactor and separation system.

The plastic waste is collected, cleaned, dried, and size reduced. The collected plastic is shredded and crushed into small pieces to reduce the volume of the plastic in the reactor.The plastic pieces are washed to remove any toxic materials. In most commercial processes, the raw materials are firstly heated and melted in the feeding system before flowing into the reactor. The air, moisture and other solid materials can be separated from the raw plastic materials in the feeding system. In addition, the pre-treatment may be required for cracking the PVC at 250 ºC. In some rotary kiln reactors, solid plastic particles with appropriate sizes can be extruded into the reactor directly. Most feeding systems move the highly viscous melted plastics into reactors by its gravity or by an extruder. However, a required temperature gradient should be maintained from the feeding system to the pyrolyzer although this may not be an issue for the rotary kiln reactors. The required temperature gradient is to prevent plastic cracking before entering the pyrolyzer. The feedstock (plastic waste from different types of synthetic plastic) is shredded and mixed with the catalyst into the pyrolysis reactor with certain quantities and ratios.

Continuous pyrolysis process is applied on most commercial plants with capability to use catalysts in which the plastic retention time is relatively short. Very few of the commercial plants use high pressure operation condition and most of the plants operate at or slightly above atmospheric pressure. The operating temperature in the reactors varies largely from 250 ºC (Mazda fixed-bed catalytic process in Japan) up to 800 ºC (Compact Power fixed-bed pyrolysis in United Kingdom) but most of the pyrolysis reactors operate between 400 ºC and 550 ºC. It must be noted that if the operation temperature is above 800 ºC, the process becomes gasification and the products are mainly short chain hydrocarbons which remains as gases under room temperature and atmospheric pressure. All of the commercial plants are fast or flash pyrolysis. In the reactor, a catalyst is added , the catalyst is mostly zeolite. The addition of the catalyst massively reduces the time needed for the processas well as the temperatures of the pyrolysis process, which results in an increase in the conversion rates for a wide range of polymers, which face significantly lower temperaturesthan they do during purely thermal pyrolysis. It also provides a high level of control in the distribution of the hydrocarbon products in LDPE, HDPE, PP, and PS pyrolysis. The process takes place in the absence of oxygen because if there is excess oxygen present, the compounds react with the oxygen at high temperature to burn,the reaction is then called combustion. When no oxygen is present, the compounds simply dissociate and breakdown which we call Pyrolysis. The products of the pyrolysis process are oil and gas vapor.These products go through a condensation process to produce fuel oil, heavy oil, and light hydrocarbon gas. Hydrocarbons are stored and reused in the combustion process, so the energy in this system is self-sufficient.Biofuel oil is transported to refineries and converted to gasoline and diesel using catalysis. Heavy oil is supplied to ships.

The pyrolysis of plastics and other MSW (end-of-life tires, organic wastes, etc.) for fuel production is practiced by several small-size companies worldwide, especially those of emerging economies,where industries such as cement, glass, and other energy-intensive sectors represent the reference market for this type of fuel (diesel-range hydrocarbons produced via the pyrolysis of plastics and MSW). The pyrolysis of plastics yields on average 45–50% of oil, 35–40% of gases, and 10–20% of tar,depending on the pyrolysis technology. According to previous research, there are some cases where a high amount of liquid yield, more than 80 wt %, could be produced in the pyrolysis of individual plastic, which is higher than the pyrolysis of wood-based biomass in general.

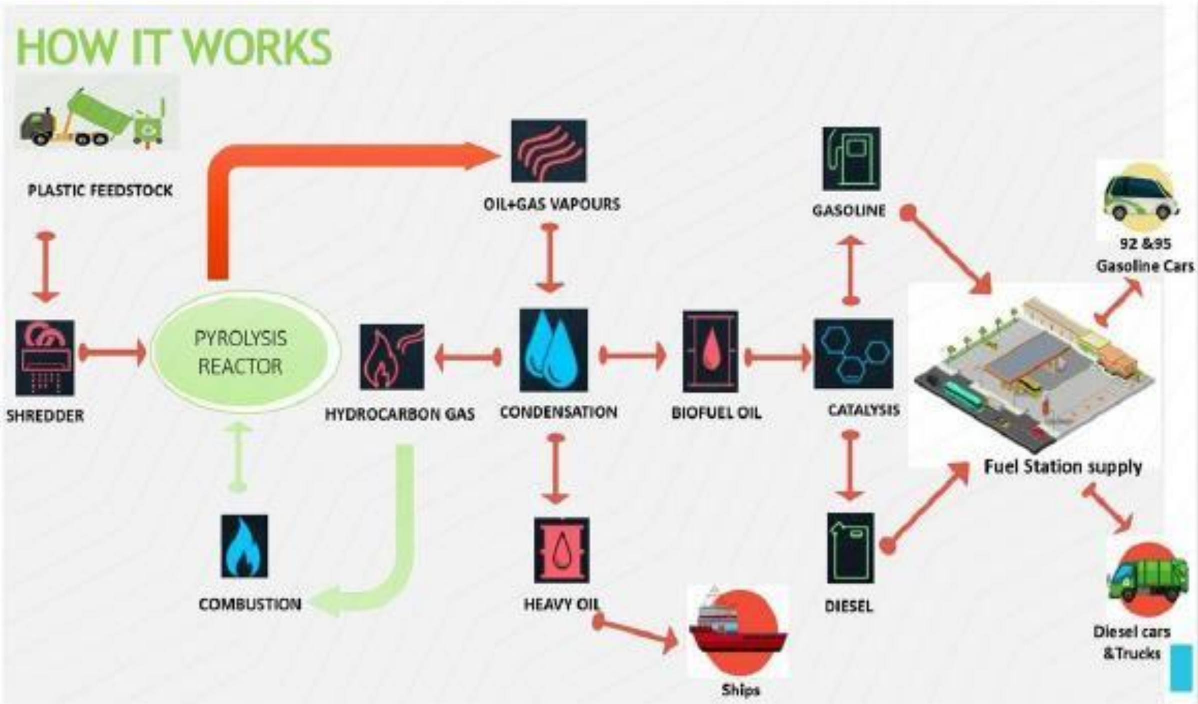
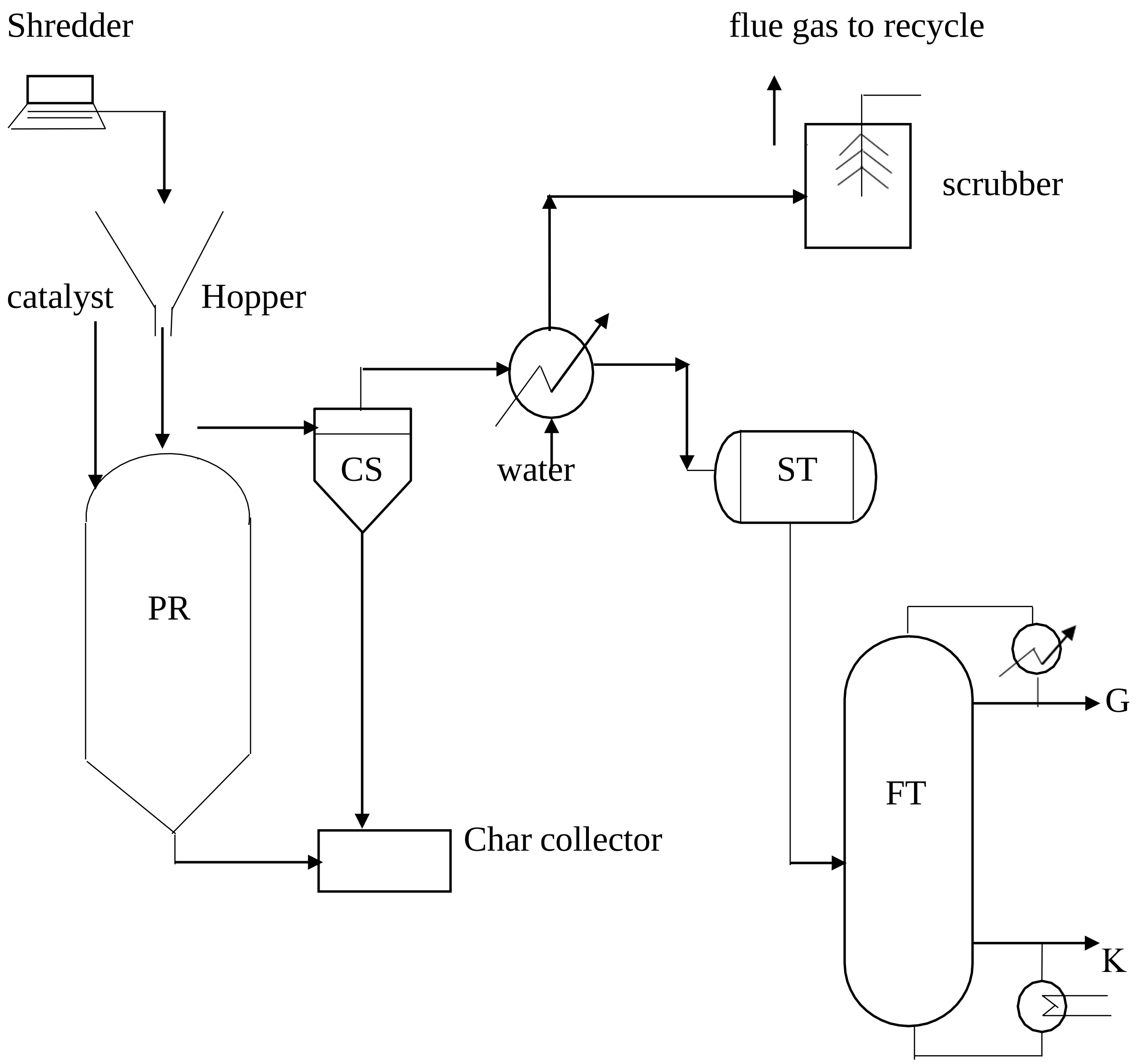


Fig 3.3. The Pyrolysis Process

3.3 PROCESS FLOW DIAGRAM (PFD)



CODE	DESCRIPTION
PR	Pyrolysis Chamber
CS	Cyclone Separator
ST	Storage Tank
FT	Fractionating Column
G	Gasoline
K	kerosene

CHAPTER 4.

PROPERTIES OF FUEL

4.1 FUEL PROPERTIES

One of the most important thermodynamic properties is cetane number or cetane index that can be a substitute as cetane number, which indicates the auto-ignition conditions of the fuel. Cetane index is calculated from fuel density and distillation range which is also listed in the regulation requirements. Therefore, cetane number, density, and distillation range are all important properties to diesel fuel.

The next important properties are the fuel flow properties which include viscosity, cloud point, pour point, cold filter plugging point and flash point. The importance of these properties will depend on the extent of known information of fundamental properties mentioned above, e.g., density and distillation range. If all of the fundamental properties are well known, the flow properties are less critical.

Effects of the minorities in diesel fuels, include carbon residues, sulphur content, water content, ash content and polycyclic aromatic hydrocarbon content. The carbon residue is fine solid particles in the fuel that may form combustion chamber deposits. The sulphur content in the fuel above a certain level causes high engine wear and poisons catalysts. The water content can contribute to corrosion in tanks and fuel injection equipment whereas the ash content is the solid residue when fuel is burnt off. The polycyclic aromatic hydrocarbon content is used to increase the cetane number due to their low boiling point and high density.

Density : It is defined as mass per unit volume. It is given as
Density = Mass/Volume
Its SI unit is kg/m^3
Calorific value : One of the important properties of a fuel on which its efficiency is judged is its calorific value. The calorific value is defined as the energy produced when the unit mass of fuel is burned completely in sufficient air or Calorific value of a material is the amount of heat liberated when 1Kg of that material is burnt.Its SI unit is kJ/kg or kcal/kg.It is determined by using bomb calorimeter It is given by formula
Calorific value = heat generated /mass flow rate
Viscosity : It is defined as the resistance offered by the fluid for the flow of fluid over another layer when they are in motion relative to each other. Viscosity is an important property fuel and it is fluid‘s resistance to the flow (shear stress) at a given temperature. Fuel viscosity is specified in the standard for diesel fuel within a fairly narrow range. Hydrocarbon fuels in the diesel boiling range easily meet this viscosity requirement. The viscosity range for typical fuels

overlaps the diesel fuel range with some fuels having viscosities above the limit. If fuel viscosity is extremely excessive, there will be a degradation of the spray in the cylinder causing poor atomization, contamination of the lubricating oil, and the production of black smoke. Kinematic viscosity takes into account the fluid density and centistokes is the engineering unit used to express the kinematic viscosity

Flash point : It is the minimum temperature at which fuel produces sufficient vapour to produce a flash when a flame is brought near it.

Fire point : It is the minimum temperature at which fuel produces sufficient vapour such that it continues to burn at least for 5 seconds when a flame is brought near it.

Cloud point : cloud point refers to the temperature at which there is a presence of a wax cloud in the fuel i.e the temperature at which the first crystals appear in diesel.

Pour point : Pour point of a fuel is an indication of the temperature at which fuel can still be pumped. pour point is the lowest temperature at which the fuel can flow and below which the fuel tends to freeze or ceases to flow.

CHAPTER 5.

COMPARISON OF OBTAINED FUEL PROPERTIES

The purified fuel is to be tested to find out its characteristics . In order to interpret the quality and properties of fuel, various tests were carried out in the laborotary by various researchers under various testing conditions. The tests performed were:

(GC/MS - Gas chromotography / Mass Spectroscopy)

(FTIR - Fourier Transform Infrared Spectroscopy)

FTIR analysis suggests that the functional groups like alcohols, ketones, carboxylic acids, esters, alkanes, alkenes, alkynes, amide, nitriles, nitro compounds, ethers, aromatic rings may be present in the liquid-oil.

The chemical composition of the liquid product is determined using GC-mass spectrometry. The compounds present in the liquid-oil are identified by comparing the chromatogram obtained with standard chromatogram data available.

Physical properties such as density, specific gravity, viscosity, conradson carbon, flash point, fire point, pour point, cloud point, calorific value, sulphur content, distillation boiling range and cetane index of the liquid-oil was determined using the following standard methods shown below

Physical Property	Method
Density	ASTM D1298 - 99
Kinematic Viscosity	ASTM D445 - 11
Conradson Carbon	ASTM D189 - 06(2010)e1
Flash Point	ASTM D6450 - 05(2010)
Fire Point	ASTM D1310 - 01(2007)
Pour Point	ASTM D5853 - 09
Calorific Value	ASTM D5468 - 02(2007)
Distillation Boiling Range	ASTM D2887 - 08
Cetane Index	ASTM D4737 - 10

Based on the diesel regulation, the fundamental properties of plastic derived fuels are examined in most studies because the diesel fuel is produced from synthetic hydrocarbon polymers that do not contain any other elements except for carbon and hydrogen.

Therefore, some of the miscellaneous properties are not important for the diesel from plastic pyrolysis, such as sulphur content and water content. The quality of the liquid fuels from pyrolysis of plastics will vary with pyrolysis operation conditions, pyrolysis reactor type and types of plastic feedstock.

De-waxing, hydrogenation, isomerization and cyclization are normally used in the pyrolysis processes to change the chemical composition in the products. Other properties of plastic derived fuels are controlled in the producing processes such as distillation range and carbon residue in the fuel.

Table 8.1. Physical properties analysis of obtained liquid product

Tests	Result Obtained
Specific Gravity @ 15°C/15°C	0.8288
Density @ 15°C in kg/cc	0.8281
Kinematic Viscosity @ 40°C in Cst	2.97
Kinematic Viscosity @ 100°C in Cst	1.14
Viscosity Index	N.A
Conradson Carbon Residue	0.05%
Flash Point by Abel Method	Minus 6°C
Fire Point	Minus 2°C
Cloud Point	3°C
Pour Point	18°C
Gross Calorific Value in Kcal/Kg	10,179 Kcal/kg
Sulphur Content	Less than 50 ppm
Calculated Cetane Index (CCI)	48

Table 8.2. Comparison of fuel Properties

Properties of fuels	Specific Gravity 15°C/15°C	Kinematic Viscosity @40°C(cst)	Flash Point	Pour Point	GCV (MJ/Kg)	Chemical Formula
Plastic Syringe Oil	0.8288	2.97	-6	18	44.8	C8-C40
Gasoline	0.72-0.78	-	-43	-40	42-46	C4-C12
Diesel	0.82-0.85	2-5.5	53-80	-40 to -1	42-45	C8-C25
Bio-Diesel	0.88	4-6	100-170	-3 to 19	37-40	C12-C22

Heavy Fuel Oil	0.94-0.98	>200	90-180	-	40	-

From comparison of physical properties of liquid fuel with transportation fuels it can be observed that plastic syringe liquid fuel is lighter than water and has very low viscosity which is suitable for injection of fuel in the engine even at lower temperatures. Flash point of liquid fuel is in comparable range and hence will ensure safe storage. Calorific value is in the similar range of that of gasoline and diesel which is actually good enough for we have a fuel which will have somewhat comparable performance of engine. As it can be observed from table, the properties of liquid fuel were in similar range to that of other commercial oils

CHAPTER 6.

SAFETY ASPECTS

The Material Safety Data Sheet taken from Indian Oil Corporation gives detailed information about various safety aspects of the material used.

SECTION 1 - CHEMICAL PRODUCT AND COMPANY

- Chemical Name & Synonyms : Polypropylene (PP) Homopolymer
- Chemical Family : Polyolefin
- C.A.S. No. : 9003-07-0
- Manufacturer's Name : Indian Oil Corporation Limited
- Address : Product Application and Development Centre (PADC), Panipat Petrochemical Marketing Complex (PPMC), Panipat Refinery, Baholi, Panipat – 132 140
- Telephone No : +91 180-2578091
- Fax No. : +91 180-2578098

SECTION 2 - COMPOSITION / INFORMATION ON INGREDIENTS

CHEMICAL NAME	CONTENT (Normal)*	CAS NUMBER	EXPOSURE LIMITS IN AIR		
			ACGIH TLV-TWA	ACGIH TLV-STEL	IDLH
Polypropylene	99.25 wt%	9003-07-0	10 mg/m3 (inhalable fraction)	NA	NA
Proprietary additives	<=0.75 wt%	Mixture			

* For different grades of PP; minor changes may be there.

SECTION 3 - HAZARDS IDENTIFICATION

Information Pertaining To Particular Dangers for Man and Environment. Negligible hazard at ambient temperature (-18°C to +50°C).

Classification System

Product is not considered to be hazardous under normal processing conditions.

SECTION 4 - FIRST AID MEASURES

GENERAL INFORMATION

- At room temperature the product is neither an irritant nor gives off hazardous vapors.
- The measures listed below apply to critical situations (Fire, incorrect process conditions).

Skin Contact

If molten material contacts the skin, immediately flush with large amounts of water to cool the affected tissues and polymer. Do not attempt to peel the polymer from skin. Obtain immediately emergency medical attention if burn is deep or extensive.

Eye Contact

Flush eyes thoroughly with water for several minutes and seek medical attention if discomfort persists.

Inhalation

If symptoms are experienced, move victim to fresh air. Obtain medical attention if breathing difficulty persists.

Ingestion

Adverse health effects due to ingestion are not anticipated.

SECTION 5 - FIRE FIGHTING MEASURES

Flash Ignition Temperature : 335°C

Auto Ignition Temperature : 350°C

Flammable Limits : NA

Suitable Extinguishing Media: Water, Foam, Carbon Dioxide, Dry ChemicalPowder

For Safety reasons, unsuitable extinguishing media: None

Protective Equipment: Respiratory & Eye protection for firefighting personnel

Special hazards caused by the material, its products of combustion or resulting gases:

In case of fire it can release: Carbon dioxide ($C0_2$), and when lacking oxygen (0_2), carbon monoxide (CO), Ketones & Aldehydes. The products of the burning are dangerous. The formation of hydrocarbons and aldehydes are possible in the initial stages of a fire (especially in between 400°C and 700°C).

Additional information: Heat value: 8000 -11000 kcal/kg

SECTION 6 - ACCIDENTAL RELEASE MEASURES

Spill and Leak procedure: Sweep up spilled material for use or disposal. Good housekeeping must be maintained to avoid potential slipping problem.

Caution: Keep walking surface free of spilled material to avoid slipping hazard.

SECTION 7 - HANDLING AND STORAGE

HANDLING

Information for safe handling:

No special requirements necessary, if handled at room temperature-Avoid spilling the product, as this might cause falls.

STORAGE

Requirements to be met by storerooms and containers:

This product may react with strong oxidizing agents & should not be stored near such materials. Store the bags in areas protected with automatic sprinklers.

- Storage temperature should be below 60°C.
- Do not smoke.

- Take precautionary measures to prevent the formation of static electricity.
- Electric safety equipment.
- Open flames prohibited.
- Store the product in bags, car silos, container, or large cartons.

Information about storage in one common storage facility: Not required

Further information about storage conditions:

- Protect from heat and direct sunlight.
- Store container in a well-ventilated position.
- Store under dry conditions.
- Specific applications for safe stacking follow the storage recommendations specific for this product.

SECTION 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS:

Use in a well-ventilated area. If handling results in dust generation, special ventilation may be needed to minimize dust exposure. If heated material generates vapor or fumes, use process enclosures, local exhaust ventilation, or other engineering controls to control exposure.

PERSONAL PROTECTIVE EQUIPMENT:

Respiratory system

Product processing, heat sealing of film or operations involving the use of wires or blades heated above 300°C may produce dust, vapor or fumes . To minimize risk of over exposure to dust, vapor or fumes it is recommended that a local exhaust system is placed above the equipment, and that the working area is properly ventilated. If ventilation is inadequate, use certified respirator that will protect against dust/mist.

Skin and body

Hot material: Wear heat-resistant protective gloves, clothing and face shield able to withstand the temperature of the molten product. Cold material: None required; however, use of gloves is good industrial practice.

Hand

Hot material: Wear heat-resistant protective gloves able to withstand the temperature of the molten product. Cold material: None required; however, use of gloves is good industrial practice.

The correct choice of protective gloves depends upon the chemicals being handled, the conditions of work and use, and the condition of the gloves (even the best chemically resistant glove will break down after repeated chemical exposures). Most gloves provide only short time of protection before they must be discarded and replaced. Because specific work environments and material handling practices very, safety procedures should be developed for each intended application. Gloves should therefore be chosen in consultation with the supplier/manufacturer and with a full assessment of the working conditions.

Eyes

Safety glasses with side shields. Use dust goggles if high dust concentration is generated.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

General Information	
Form	; Solid Granules
Colour	: Translucent to White
Odor	: Slight Waxy Odor
Melting point/Melting range	:130-167°C
Flash point	: > 329°C
Ignition temperature	: > 400°C
Decomposition temperature	: > 300°C
Danger of explosion	: Product is not explosive.
Density	: 0.89-0.94 q/cm3

Solubility in / Miscibility with Water	: Insoluble
Additional information	: Soluble in boiling, aromatic chlorinated solvents

SECTION 10 - STABILITY AND REACTIVITY

Chemical stability

This product is stable under normal use conditions for shock, vibration, pressure or Temperature.

Chemical stability - Condition to Avoid

Avoid strong oxidizing agents. Avoid Processing Material over 300°C

Hazardous Polymerization

Not likely to occur

Corrosivity

Product is not corrosive

Dangerous products of decomposition: No hazardous decomposition products known at room temperature. At elevated temperature the material will begin to decompose producing fumes that can contain $C0_2$. CO, Ketones & Aldehydes.

SECTION 11 - TOXICOLOGICAL INFORMATION

ACUTE TOXICITY:

Primary irritant effect:

- On the skin: No irritant effect.
- On the eye: No irritant effect.
- Sensitization: No sensitizing effect known.

ADDITIONAL TOXICOLOGICAL INFORMATION:

When used and handled according to specifications, the product does not have any harmful effects according to our experience and the information provided to us.

SECTION 12 - ECOLOGICAL INFORMATION

Information about elimination (persistence and degradability):

Other information: The product is not biodegradable.

General notes:

The product is not toxic, small particles can have physical effects on water and soil organisms.

SECTION 13 - DISPOSAL CONSIDERATIONS

Product: Recommendation

1) Recycle (Reprocess)

2) Disposal through controlled incineration or authorized waste dump in accordance with Local, State or Federal Regulations.

Uncleaned Packaging:

Recommendation: Disposal must be done according to official regulations.

SECTION 14 - TRANSPORT INFORMATION

Transport/Additional information:

Not regulated as a dangerous goods for transportation.

SECTION 15 - REGULATORY INFORMATION

National regulations, other regulations, limitations and prohibitive regulations PP manufactured by IOCL shall meet the requirement stipulated in IS: 10910 on "Specification for Polypropylene and its copolymer for safe use in contact with foodstuff, Pharmaceuticals & Drinking Water".

Additives incorporated in this grade conform to the positive list of constituents as prescribed in IS: 10909.

The products additives incorporated in it also comply with FDA: CFR Title 21.177.1520 Olefin Polymer.

SECTION 16 - OTHER INFORMATION

The information supplied has been based upon the current level of information available, for the purpose of specifying the requirements regarding environment, health and safety in conjunction with the product. They are not to be interpreted as a warranty for specific product characteristics. **Indian Oil Corporation Ltd**. takes no responsibility for inappropriate use, processing and handling by purchasers and users of the product.

CHAPTER 7.

FUTURE WORK

7.1 FUTURE WORK

In order to commercialise the pyrolysis technology to recycling of the waste plastics and to better understand the pyrolysis process, the following work is recommended for further studies:

- In the semi-scale plant, the current continuous feeding system has minor leaks and needs some modification. The feeding system should be able to control the required feeding rate and prevent back-flow of the high temperature pyrolysis vapour. On the other hand, the oxygen leaking into the feeder must be prevented. Better and effective distillation columns should be applied on the semi-scale plant for refining of the pyrolysis products.

- The effect of contamination in post-consumer plastics is still not clear due to the variation of the contamination on different post-consumer plastics. Virgin and post-consumer plastics on the process and the distribution of the product should be investigated on the semi-scale plant. The detailed interaction among different plastic materials during the cracking reactions is unknown, thus further investigation is needed to quantitatively analyse the interaction effect of different post-consumer plastics. This could be very valuable for commercialization of the technology.

- The non-condensable gases were flared off in the experiment. It would be valuable to collect some of the gases and investigate its composition. The diesel range product should be separated out of the condensed products in the semi-scale plant. The diesel range product should be tested in accordance to New Zealand diesel requirements standard for the properties of commercial uses. It is worthwhile to add hydrogen into the reaction to saturate the hydrocarbons thus to modify the product to increase the target diesel products. Hydrogenation can significantly improve the product quality towards transport use. Many oil refinery 186 factories apply this process to convert alkenes into alkane in order to get higher stability oil.

1. It can be used as alternate source of fuel in diesel engines.

2. It can be used as a fuel in diesel generators.

3. It can be used for heating in sugar industry, steel industry, etc.

4. It can be used for heating boilers

7.2 FUTURE WORK FOR MEDICAL WASTE (PPE KITS AND MASKS)

Mitigating our energy crisis during a health crisis

A team of researchers reviewed many research articles as they explored the methods currently being used to dispose of PPE and whether turning it into biofuel would be a feasible option. They came to the conclusion that recycling these polymers requires physical as well as chemical methods.

In particular, the researchers focused on the structure of polypropylene and the damaging role it has on the environment. Their findings conclusively state that PPE waste should be converted into fuel using pyrolysis — a chemical process that breaks down plastics at temperatures between 300-400 degrees centigrade without oxygen.

"Pyrolysis is the most commonly used chemical method whose benefits include the ability to produce high quantities of bio-oil which is easily biodegradable" There is always a need for alternative fuels or energy resources to meet our energy demands. The pyrolysis of plastics is one of the methods to mitigate our energy crisis."

The liquid fuel that would be produced from PPE is clean and would have similar properties to fuel made from fossil fuels. Effectively, by also helping to reduce the reliance on damaging fossil fuels, turning PPE waste into biofuel would be tackling two environmental problems at once.

The obtained fuel could be utilized in diesel generators vehicles such as tractors and also passenger vehicles such as cars

- The fuel has to be refined at the industrial establishments, based on the results of which small scale industry can be established
- As there is high demand of crude oil and due to its sky reaching prices, we could and produce the fuel locally at much cheaper rates directly benefiting the national economy and also a step towards SWAACH BHARAT by recycling the plastic waste.
- The application of this project could help in reducing the dependency on the gulf countries promote a step towards innovation.

CHAPTER 8.

CONCLUSION

Conclusion

This study demonstrated the importance of recycling plastic waste, especially in developing countries, as a means of saving unnecessary energy usage which in return decreases the production costs. Plastics can be easily converted into high-value fuel, which can be used as an alternative fuel. The volume of plastic waste present in the environment will be reduced along with the environmental effects such as excessive heating and greenhouse effects. The pyrolysis process is considered an effective, clean, and exceptionally successful technique in handling plastic solid waste, and it provides a cheap source of energy.

Pyrolysis of hydrocarbon polymers is a very complex process, which consists of hundreds of reactions and products. Several factors have significant effects on the reactions and the products. With temperature increasing, plastic will go through glassy state, rubbery state, liquid state, and decomposition. Decomposition of plastic in an inert environment into liquid is called pyrolysis. There are four stages of reactions during the plastic pyrolysis process: initiation, propagation, hydrogen transfer, and termination reactions.

Waste plastic is a grey area of concern and pyrolysis though a difficult process can be made feasible with better optimization and equipments. Maximum yield of liquid product is 83 wt% by thermal pyrolysis of shredded plastic syringes at temperature 450 °C. Plastic syringe/waste has high volatile matter content and high calorific value in the range of diesel oils which is converted to liquid fuel. The liquid fuel obtained shows comparable fuelproperties and can be treated as moderate grade commercial fuels. In order to utilize it as commercial transportation fuel certain enhancement in properties like density, viscosity,corrosiveness and volatility have to be taken care off. The liquid-oil contains nearly 56 chemical compounds of varying carbon chain length from C8-C40 and functional groups suchas alkanes, alkenes, alkynes, alcohols, ketones, aldehydes, C-H aromatics rings and nitro compounds.

Industrial scale-up and economic assessment was studied for the process and assumptions had to be taken to simplify the calculations. The result of the economic assessment was overwhelmingly satisfactory as it made a profit of 52 Million INR annually.

CHAPTER 9.

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