WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

TITLE:-PRODUCTION OF HUYDEROCARBON FUEL FROM WAST PLASTIC BY USING PYROLYSIS PROCESESS

A THESIS SUBMITED TO THE SCHOOL OF UNDER GRADUATE STUDIES OF WOLKITE UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIRMENT FOR THE DEGREE OF BACHELOR OF SCIENCES IN CHEMICAL ENGINEERING.

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DECLARATION

We hereby declare that the thesis is based on our original work except for flotation and citations which have been duly acknowledge. We also declare that the paper previously or currently has not been submitted for any other department at Wolkite University.

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ABSTRACT

Pyrolysis of waste plastic is a prospective way of conversion of waste plastic into hydrocarbon fuel. The present research is focused on the conversion of waste plastic into hydrocarbon fuel with the absence of catalyst.

Waste plastic materials polyethylene, polypropylene and polystyrene were collected from local convenience store packing materials. The collected waste plastics were cleaned since they exist with the foreign unwanted materials. Waste plastic material pyrolysis were conducted as individual plastics and as mixed feed in laboratory scale of flask. Since waste plastics were made from different components they have different melting point so the temperature nedded.mellting waste plastic with the absence of catalyst requires high amount of heat energy for our case we use the temperature range of 500^0c -600^0c .plastics contain (gas ,liquid and solid) content we were separate those contents by using a simple distillation processes and the required were the liquid part. Time has its Owen impact on the distillation processes as the time increase the quality of the product decrease even if the amount of conversion were high. The extracted liquid serve as fuel which is named as hydrocarbon fuel which is obtained from the plastics that have hydrogen and carbon content.

Keywords: non-catalytic degradation**,** Hydrocarbon fuel**,** Energy**,** Economics, Thermodynamics

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ACRONYM

GDP-Gross domestic product

BTU –British thermal unit

PE-Polyethylene

PP-Polypropylene

PS-Polystyrene

ABS-Acrylonitrile Butadiene Styrene

PET-Polyethylene terephthalat

HDPE-High density polyethylene

GRO-Gasoline range organic

TPC –Total production cost

C_{RM} –Cost of raw material

C_{OL} –cost of operating labor

FCI –Fixed cost investment

ROI-Return on investment

GC-Gas chromatography

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CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND

Due to the erratic change of energy prices and unfavorable forecast of world economy, considerable efforts have been devoted to substitute raw fossil fuels with various other sources for the production of energy. The various factors, such as ever-increasing diesel consumption, large outflow of foreign exchange, and concern for environment, contribute to the search for a suitable environmental friendly alternative to fossil fuel. It is clearly envisaged that the increasing GDP and the limits of greenhouse gases can only be compensated by the application of waste recycling process (e.g. plastic, paper, metals, etc. Ethiopia spends millions of dollars annually to meet its primary energy requirement. The heavy fuel which was priced Birr 17per liter in July 2009 E.C, now in 2013 E.C costs Birr 27.54 per liter [1]. As a consequence, oil import bill of the country is expected to further increase due to the increase of price of fuel. Currently Ethiopia imports around 2 million tons of fuel costing around US $ 221 a year. According to nationwide survey, conducted in the year 2012 E.C, approximately 10,000 ton (ten thousand tones) of plastic waste were generated every day in Addis Ababa.

The plastics have become one of the most important and indispensable materials in our contemporary world .These plastics are not presently biodegradable and are extremely troublesome components for land filling and that end up in incineration facilities release toxic gases such as carbon monoxide (CO), which causes health hazards; sulfur dioxides (SO2), which contribute to acid rain; nitrogen oxide(NO_X), which contribute to ozone depilation and acid rain; and carbon dioxide (CO_2), a greenhouse gas that contributes to global warming [1, 2].

To avoid the impact of plastic waste, mechanical and thermal recycle of plastic waste method used but, the attractive method to recycle plastic waste is thermal or catalytic method which produces hydrocarbon fuels. Hydrocarbon fuels are the same as fossil fuels and which means they made up of hydrogen and carbon compound. The simplest of these is methane, natural gas. Oil is a hydrocarbon fuel because it is made up of various different compounds rather like methane, but it is liquid rather than gas. These hydrocarbon fuels can be produced from plastic wastes by pyrolysis process because of can be cost effective compared to other processes.

Pyrolysis is the thermal decomposition of plastic wastes in to hydrocarbon fuel in the presence or absence of catalyst. The pyrolysis thermally degrades the plastic component to produce an oil and gas product. This oil may be used as a liquid fuel or returned for refining [3, 4].

The pyrolysis has a wide temperature range and it can be performed with or without a catalyst. The aim of the present research is to investigate the waste plastic pyrolysis in the presence and absence of the catalysts such as activated granulated charcoal or calcium oxide to produce very low-emissive liquid hydrocarbon oil.

The amount of waste plastic residue has to be reduced, with an increase in the efficiency of the fuel oils, thus providing an alternate energy resource to the environment. This would bring about a major reduction in the pollution caused due to landfills of plastic wastes and air pollution through the incineration of plastics.

1.2 STATEMENT OF THE PROBLEM

In a day to day life we use different types of plastics for various purpose due to these reason different company produce many number of plastics either for packaging of foods, drinkings,and for other purpose .but they dispose in informal ways that will affect the environment like by decreasing soil fertility since plastics are non-degradibles.in most urban areas mostly plastics collected and thrown in to the border of cities and nearby water river.

The current condition regarding to energy sources leads to question mark. Since existence of fossil fuels become shortage. These indicate that there is an erratic change of energy price and un favorable forecast of world economy. Ethiopia import different energy sources from foreign country in a high cost which highly affects the economy and it is one factor which lead us to be the developing country.

If we consider the living standard mostly in Ethiopia specially in rural area they use plastic for house holding preparation directly by burning them and also in urban area when they try to clean there environment they directly burn them which is to difficalt.Since they release toxic gases such as carbon monoxide (CO), which causes health hazards; sulfur dioxides (SO_2), which contribute to acid rain; nitrogen oxide(NOX), which contribute to ozone depilation and acid rain; an d carbon dioxide (CO_2), a greenhouse gas that contributes to global warming.

Standing from those problems stated above and other s conversion of those plastics in to hydrocarbon fuel is the solution to overcome environmental effect as well lack of energy source.

1.3 OBJECTIVE

1.3.1General objective

- The general objective of this project is to produce hydrocarbon fuel from wastes plastic by pyrolysis process.

1.3.2Specific Objectives

- To understand the effect of temperature on the conversion of waste plastics
- To determine the effect of time on melting of waste plastics
- To measure the specific gravity of fuel
- Understand the effect of time on the quality of fuel
- To elucidate distillation process

1.4. Scope and limitation of the study

1.4.1 Scope of the study

This thesis's is conducted by collecting the waste plastics and cleaning them with tap water, cutting into small pieces by using knife and sizers,covering the small pieces by using aluminum foil ,melting the sample with furnace(pyrolysis processes) ,distil the melted sample using simple distillation , making material and energy balance .

1.4.2 Limitations of the study

During the time of producing hydrocarbon fuel there were not full existence of instruments and chemicals to obtain the required product such instruments and chemicals like

- ✓ Pensky marten:- for measuring the flammability characteristics of the fuel ,flash point, ignition temperature and fire point.
- ✓ Gas chromatography:- for measuring volatility of the fuel
- ✓ Catalyst:-for speed up the chemical reaction and minimize the heat energy required for melting
- ✓ Pyrolyzer:-used for melting of waste plastics in the absence of oxygen

1.5 SIGNIFICANCE OF THE STUDY

As it stated in the title it is providing an insight for the production of hydrocarbon fuel from waste plastic by using an effective pyrolysis process. The first main significance is since it is process of converting waste plastics in to use full energy source which protects environmental pollutions mostly in areas like our capital city Addis Ababa in which there is dense accumulation of waste plastics. Secondly it minimizes dramatic change of energy (fuel) costs. it also over came on the problem which minimize soil fertility.

As a whole it helps the community from pollution and a country by minimize importing cost of fuel energy. It is also economically feasible since the process is using waste plastic which are thrown in to the environment that causes environmental as well as air pollution and also its raw material can be obtained easily. And since the project performed by using waste plastics from these project not only few people benefit but all community as well as the country economy will be developed.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 HISTORY

Plastics were first invented in 1860; Plastics are made up of long chain of molecules called polymers. Polymers are made when naturally occurring substances such as crude oil or petroleum are transformed into other substances with completely different properties. The world plastic production has been increasing since it was firstly commercially manufactured, from 1.5 million tons in 1950 to 260 million tons in 2007. Plastic is one of the most commonly used materials in daily life which can be classified in many ways such as based on its chemical structure, density, and other properties.

Pyrolysis is the thermal decomposing of materials at elevated temperature in an inert atmosphere. [6] It involves a change of chemical composition.

Pyrolysis is the most commonly used in the treatment of organic materials. it is one of the processes involved in charring wood .[7]

In general ,pyrolysis of organic substances produce volatile products and leaves a solid residue enriched in carbon ,char, extreme pyrolysis, which leaves mostly carbon as the residue ,is called carbonization. Pyrolysis is considered as the first step in the processes of gasification or combustion. [8][9]

Waste plastics pyrolysis can convert petroleum based waste streams such as plastics into fuels and carbons. [14][15][16]

Plastic waste is becoming a serious global issue, thanks to extensive plastic usage all over the world; the treatment of waste plastic has gained the most importance. Scientists and experts all over the world are concerned over this major environmental problem.

There are various methods for reutilizing the polymers, each one having its shortcomings or limitations. Yet, thermal and catalytic degradation of plastic into fuel is considered to be the most effective way of reusing polymers. Of late, experts have begin to pay attention to pyrolysis, especially thermal

Pyrolysis Definition

Pyrolysis is defined as a chemical degradation reaction that is caused by thermal energy in the absence of air (oxygen). It is supposed to be one of the most effective methods for preserving petroleum resources, in addition to preserving the environment by decreasing the volume of non-degradable waste. Degradation of plastic is achieved by heating at high temperature, with macromolecules breaking into smaller fragments, consisting valuable mixtures of hydrocarbons (gas, liquid and solid). [1]

The degradation of different types of waste plastics has been studied in the presence and absence of a catalyst. It is found that the properties of the products depend significantly on the characteristics of the applied catalyst. A catalyst also reduces the reaction temperature. The pyrolysis process, requiring high temperatures up to 1000˚C can be carried out at much lower temperature (400–500˚C) with the use of a proper catalyst. Recycling of waste plastic by pyrolysis can yield excellent results, even with heterogeneous waste plastic materials, where segregation is not economic Plastics suitable for pyrolysis.

Polymers are structurally made up of carbon atoms linked by single or double bonds. Hence, each polymer has a specific heat value. For example: Polyethylene and Polypropylene have calorific values of 18 720 BTU/lb and 18 434 BTU/lb, respectively. These organic molecules have a low decomposition temperature compared with inorganic matter. Nearly all conventional fuels are organic molecules. The heat content of an organic molecule depends upon number of carbon atoms in the molecular chain and the complexity of the molecular structure (linear, branched, cyclic, etc.). Thus, when any polymer decomposes or the polymer structure gets fragmented randomly, each fragment, depending upon number of carbon atoms, can be classified into various types of fuels. Hence, pyrolysis of polymers such as PE, PP and PS yield valuable hydrocarbons. A few polymers such as polyvinyl chloride, Acrylonitrile-Butadiene-Styrene copolymer (ABS) and Polyethylene terephthalate (PET) are associated with heteroatom such as Cl, N, and O apart from carbon and hydrogen. During pyrolysis these heteroatom get converted into compounds such as HCl, N_2, and H_2O etc. [5]

Types of Pyrolysis

Pyrolysis and cracking of waste polyolefin (plastics) can be categorized as the tertiary mode of recycling. Application of this type of recycling is reasonable especially in case of polyolefin when their further using in primary recycling (conversion into products similar in nature to the original product) and secondary recycling (conversion into products of different shape for less demanding products) is impossible. Pyrolysis and cracking are considered as alternative methods of the final processing of waste plastics such as polyolefin. The tertiary mode of recycling is can be classified into two groups: thermal and catalytic cracking

Thermal Cracking

Thermal cracking often yields a low-value mixture of hydrocarbons with a very broad volatility range that can extend from hydrogen to coke. It is therefore important to determine the optimal pyrolysis conditions and/or the most advantageous catalyst to obtain marketable products (e.g. hydrocarbon fuel) from mixed plastic wastes.

The pyrolysis product yield and composition are controlled not only by the temperature, but also by the duration of the residence time. As a general rule of thumb the higher the pyrolysis temperature, the higher the yield of no condensable gaseous products and the lower the yield of liquid fuels such as hydrocarbon fuel. The optimum temperature range for the production of fuel products from waste plastics is 100 – 267°C. Studies in a flask have highlighted the importance of short residence time with high-temperature pyrolysis for obtaining a high yield of light olefins. There is a dramatic increase in gas yield with increasing temperature of pyrolysis. While the hydrocarbon pyrolysis product yield increases with pyrolysis temperature, the yield of the oil fraction is higher at the lower pyrolysis temperatures.

The composition of the pyrolysis oil also changes with pyrolysis temperature, generally containing larger quantities of aliphatic compounds at the lower temperatures than at higher temperatures where aromatics are the dominant compounds.

Catalytic Cracking

The poor selectivity of the thermal decomposition of polyolefin has promoted the development of catalytic cracking. Catalytic cracking lowers the pyrolysis process temperature and lowers the boiling temperature range of the resultant liquid products. The use of molecular sieves and amorphous silica–alumina catalysts for the cracking of waste polymers into a range of hydrocarbons has been widely studied Catalytic cracking has some distinct advantages over thermal cracking, such as, lowering the cracking temperature, increasing the reaction rate and increasing the production of iso-alkanes and aromatics which are desirable for hydrocarbon fuel. Suitable cracking catalysts have the ability to both substantially reduce the pyrolysis temperature and control the pyrolysis products.

Using catalysts does not only lower the activation energy, reduce the energy consumption and improve the process efficiency, but can also improve the selectivity and quality of the products produced. Catalysts with acidic surface sites and hydrogen ion donating ability enhance the isomerization of products and thereby increase the yield of isomeric hydrocarbons that have a beneficial effect on the cetane rating and fuel quality. Catalysts having stronger acid sites of higher density are thus more effective in cracking polyolefin.

A major problem with using catalysts in the pyrolysis of mixed plastics is that of coke formation deactivating the catalyst over time. The cost of these catalysts also influences their selection and commercial viability. The amount of the catalyst to be added to the waste plastic for catalytic cracking is at least 5 % by weight (typically 5 – 10 % by weight).

❖ The problems associated with the use of a catalyst in the pyrolysis vessel are:

- the catalyst is a consumable and therefore adds to the running cost;
- the catalyst can have a short life-cycle due to poisoning/deactivation;
- The catalyst leads to increased levels of solid residue that requires disposal.

Feed stock options

The composition of the plastic feedstock for pyrolysis processes has a direct bearing on the quality of the resultant fuel products, especially flash point, cetane index, low-temperature properties and heteroatom content (e.g. sulphur, chlorine and nitrogen). While condensation polymers such as PE and polyamides can be broken down into their monomer units by thermal depolymerization processes, vinyl (addition) polymers such as polyethylene and polypropylene are very difficult to decompose to monomers. This is because of random scission of the carbon–

carbon bonds of the polymer chains during thermal degradation, which produces a broad product range.

The most common plastics preferred for the feedstock of the production of liquid hydrocarbon are high density polyethylene (HDPE), polypropylene (PP) and polystyrenes (PS) which yield a mixture

High-density polyethylene

Polypropylene and polystyrene also, plastics are classified by their chemical structure of the polymers backbone and side chains. Some important groups in these classifications are the acrylics, polyesters silicones, polyurethanes, and halogenated plastics. Plastics can also be classified by the chemical process used in their synthesis, such as condensation, poly addition, and cross-linking.

Low-density polyethylene

Low-density polyethylene (LDPE) is used for its toughness, flexibility, and relative transparency. LDPE is used to make bottles that require extra flexibility. To take advantage of its strength and toughness, it is used to produce grocery bags and garbage bags, squeezable bottles, shrink wrap, stretch films, and coating for milk cartons. It can also be found in toys, container lids, and packaging. Polypropylene (PP) is known for its high melting point, which makes it ideal for holding hot liquids that cool in the bottles (for example, ketchup and syrup). It can be manufactured to be flexible or rigid. PP is used to make containers for yogurt,
Margarine, take out meal and deli foods. It is also use for medicine bottles, bottle caps, and some household items of hydrocarbons.

Polyethylene (PE)

There have been many reports on the thermal and catalytic degradation of high-density polyethylene (HDPE), as it is one of the main polymers in municipal solid wastes.

PE-derived fuel has a very low Cetane rating and is very high in linear paraffins and 1-olefins. Paraffins are straight-chain hydrocarbons that are normally present in diesel. They are the first components to come out of solution as diesel cools. The tendency of paraffin crystals to aggregate up at low temperatures to form sheets can result in fuel-filter blockages, ultimately leading to interruption of the fuel flow. Paraffin crystals form in the fuel, making the gelled suspension appear cloudy. As these suspended flakes pass through the filter, they gum up its micro porous surface. Due to the high concentration of linear n-paraffin hydrocarbons in fuel derived from PE, it is desirable to isomerize them in order to lower the cloud point and the freezing point of the fuel. The branched isomers do not exhibit the same tendency to crystallize as linear paraffin's, so that wax crystals do not form until lower temperatures are reached.

Polypropylene (PP)

The liquid products of the pyrolysis of PP contain primarily olefins that resemble the molecular skeleton of PP (i.e. branched hydrocarbons). A distinguishing feature of PP pyrolysis is the predominant formation of a particular C_9 olefin in the pyrolysis product. The level of this C_9 compound identified as 2, 4-dimethylhept-1-ene can be as high as 15 %. Also present are C_5 olefin, C_6 olefin, several C_{15} olefins and some C_{21} olefins.

The tertiary carbon sites in PP allows for the facile chain cleavage and rearrangements according to the Rice Kossiakoff cracking mechanism. The no condensable gas from PP pyrolysis contains elevated levels of propylene, isobutylene and n-pentane. Compared with PE, PP produces less coke residue and more liquid products, but with a higher content of 'lights'. In the pyrolysis process of PP the intermolecular radical transfer is preferred to the intermolecular one, thus the low oligomer formation predominates, skewing the carbon number distribution towards the light end of the distillate spectrum. Consequently the pyrolysis oil of PP is much more volatile than that of PE, decomposing mainly through intermolecular radical transfer. The difference in the backbone structure of the products of these polymers is more important from the point of view of fuel properties. Theisoalkanoic structure of PP is maintained in the thermal decomposition products, thus the octane number of the pyrolysis oil is typically high.

Polystyrene (PS)

Neat polystyrene feedstock will depolymerize in a pyrolysis process to give predominantly styrene monomer–a liquid fuel with good energy content. The optimum pyrolysis temperature is 127˚C to give a recovery ratio of 0.97 (i.e. 1000 kg polystyrene will yield 970 L liquid monomer) and 5 to 10% char residue. Fuel made from polystyrene feedstock will be high in aromatic character and have an energy content of 50 MJ/kg and a vapor point of −450˚C. However the flash point is only 65˚C and the certain rating only 12.6. The fuel needs to be blended with polyolefin-derived diesel or regular diesel in order to upgrade the flash point and cetane rating to within specification. Polystyrene has somewhat lower thermal stability than the polyolefin and its pyrolysis can be undertaken between 380 and 420˚C without producing gases or leaving significant amount of residue after total conversion. PS cracks to styrene, ethyl benzene, toluene, tri methyl benzene and some benzene.

In spite of the fact that the majority of the carbon atoms are assembled into phenyl side groups in this polymer, a negligible amount of benzene is formed (1–3%) at these temperatures. This is because the aryl–alkyl bond connecting the phenyl group to the polymer chain is stronger than the bond of alkyl carbons along the chain. The pyrolysis of PS yields dominating components, Styrene(BP 145˚C) in the gasoline boiling range, styrene dimmer in the diesel oil range, and styrene trimmer boiling at 400˚C. This pyrolysis product distribution suggests that the intermolecular radical transfer is negligible in PS. The pyrolysis of PS produces fuel with high aromatic content and low storage stability. The high aromatic content of PS-derived oil helps to compensate for the low cetane number of PE oil.

Table 2.1: waste plastics elemental composition

Sample name	Composition	Of	Element
	Carbon%	Nitrogen%	Hydrogen%
HDPE	83.57	14.78	<0.3
PP	79.93	14.17	<0.3
PS	78.60	7.21	<0.3

CHEMICAL FORMULAS FOR DIFFERENT PLASTIC

Example of some monomer

Monomer polymer

Ethylene $CH_2=CH_2$ polyethylene (PE) – $[CH_2=CH_2\,]_n$

Propylene $\underset{\displaystyle CH_3}{\underset{|}{C}}H=CH_2$ polypropylene (pp.) $-\underset{\displaystyle CH_3}{\underset{|}{C}}H-CH_2$

Vinyl chloride $H-\underset{\displaystyle Cl}{\underset{|}{C}}=\overset{\displaystyle H}{\overset{|}{C}}-H$ Polyvinylchloride (plc.) – $[\underset{\displaystyle Cl}{\underset{|}{C}}H-CH_2]_n{}^-$

Physical properties

The raw materials used are HDPE, PP and PS.

HDPE waste plastic sample was white colour milk container, PP waste plastic samples was white colour food container and PS waste plastic samples was transparent food containers.

Advantages and problems of Pyrolysis

Advantages of pyrolysis process are

(a) Volume of the waste is significantly reduced (<50–90%),

(b) Solid, liquid, and gaseous fuel can be produced

(c) storable/transportable fuel or chemical feed stock is from the waste, obtained,

(d) Environmental problem is reduced,

(e) Desirable process as energy is obtained from renewable sources like municipal solid waste or sewage sludge,

(f) The capital cost is low.

Man’s productive activities continue to increase each day. The rate at which new products are manufactured is quite high. The shortcomings of such activities cannot be overlooked especially the effect they have on the environment. New discoveries in technology are made each day.

Environmental degradation has become the order of the day. It has gradually led to climate change. If the trend continues, we shall be engraving life on earth. Future generations may not be able to produce anything since the conditions shall have been messed up. People have effortlessly worked on coming up with solutions to curbing the trend and making the environment a better place. Among the feature solutions that have come up successfully is the waste plastic/rubber pyrolysis. The technology uses waste materials to produce useful products such as oil. This article will focus on the advantages of using the pyrolysis plastic waste to oil technology

Economic advantage

Plastic waste to oil pyrolysis technology is used to produce useful products such as oil. The products can, in turn, be sold to generate income. On the same note, people involved in the process earn their living from working in the plant. The technology thus contributes significantly to the economy. .

Problems with many pre-existing plastic cracking technologies include:

- noncontiguous (batch) processes (not commercially viable)
- coking and carbon deposits on heat exchanging surfaces
- stickiness of sand particles in fluidized-bed processes
- unsatisfactory fuel quality;
- relatively high Sulphur levels (100–700ppm) in end product

Cheap raw materials are used

The technology uses raw materials that would otherwise have been useless. Wastage plastic is used to produce useful oil. The implication is that since it is easy and cheap to get the raw, the system is economical to work with. In every productive activity, the cost is a factor every producer wishes to keep low. Consequently, using the waste plastic into fuel oil pyrolysis technology saves a substantial amount of resources.

Noise produced is low

Plastic waste to oil pyrolysis technology produces noise that is within the acceptable limits. As such, the technology is user-friendly. It can thus be located anywhere even within people's residential areas. You need not take it too far from people. The advantage is that the traveling costs will be low. Moreover, the raw materials can easily be got from the locality. It only requires some effort to move around collecting waste plastic for use in the process

Offering a substitute to petroleum

The oil produced using the plastic waste to oil pyrolysis technology is an excellent substitute for petroleum products. Petroleum is known for its high rates of environment pollution caused by the gasses emitted to the environment. Such emissions affect the ozone layer in the atmosphere thereby leading to global warming among other effects. It compromises the productivity of the environment. As such, using the plastic waste to oil pyrolysis technology saves the environment from such production.

Enriching the environment

Governments and local authority always have the challenge of removing waste from the environment to keep it clean and productive. They face the challenge of finding where to take the collected waste especially those that do not decompose easily such as plastic and tyres. Embracing the plastic waste to oil pyrolysis technology reduces the hustle since the materials that governments and local authorities strive to eliminate from the environment are used as raw materials in the system.

Influence of main operational parameters

Both the activity and selectivity of the catalysts depend on the following reaction variables:

- temperature;
- catalyst amount;
- time;
- Plastic composition.

Temperature

Temperature is likely the most important variable affecting the catalytic cracking of plastics. Reaction temperatures are usually in the range 100 –267 ˚C. In general, a temperature increase leads towards a parallel activity enhancement of the catalysts. Nevertheless, it must be taken into account that at high temperatures the simultaneous occurrence of thermal cracking reactions is favoured, which may modify the product selectivity.

Catalyst

The catalyst influences not only the structure of the products, but also their yield. Hence the results of pyrolysis in the absence of catalyst were compared with results obtained by pyrolysis which was carried in the presence of catalyst. Activated granulated charcoal and calcium oxide. Due to its high degree of micro porosity, just one gram of activated carbon has a surface area in excess of 500 m^2/g, as determined by Nitrogen gas adsorption.

Time

Changes in the performance of catalysts with time are directly related to their deactivation kinetics and the effect of temperature depends on the increase in the time taken for the pyrolysis process

Waste Plastic composition

The composition of the raw plastic wastes may have a huge influence on the performance of the catalysts. Hence, catalysts leading to high conversions for the cracking of pure polymers have often been observed to lose their activity to a large extent when cracking a real mixture of plastic wastes. After the product obtained the result should be characterized by measuring the characteristics of the fuel content

Analysis of products

After the product obtained there should be some analysis regarding to the characteristics of product. The liquid products will be analyzed by gas chromatograph (TRACE GC) with a flame ionization detector. To further narrow down the qualitative analysis, a GC-FID total petroleum Hydrocarbons (TPH) will be also used. Such points will be analyzed like, flash point, fire point and density. The results which will be observed for the prepared oil will compared with the GC-FID report of commercial petrol after that the effect which will obtained can be easily determined.

A. **Physical properties of oil**

1. Specific gravity and density

A certain ml specific gravity bottle will be used to determine the specific gravity of the samples. That ml sample will pipette out into a pre-weighed bottle up to its brim. This gives the weight of the sample when divided by 10 gives the specific gravity and hence the density of the sample can be found out.

2. Flash point

The flash point of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air. The flash point is used to determine the `

(1) Volatility of liquid fuels,

(2) Amount of low boiling fraction present in the liquid fuel, and

(3) Explosion hazards.

The flash point of the sample can be determined using PENSKY MARTENES closed cup flash point test. About a certain amount of the sample will be heated and stirred for every 1 °C rise in temperature. An ignition source will directed in to the cup at regular intervals with intermittent stirring until a flash that spreads throughout the inside of the cup is seen.

3. Fire point

It is the temperature at which the fuel will continue to burn for about 5 s after ignition by an open flame source. It is the temperature at which the vapor is produced to sustain a flame. The fire point will determined using the pensky Martens open cup apparatus .in her also a certain sample will heated and stirred continuously for every 1 °C rise in temperature. The fire point of the light fraction oil sample can be known.

4. Flame characteristics

The chemical properties of the light fraction oil will be checked by the GC-FID TPH analysis.

Gas chromatography (GC-FID TPH analysis)

Gas chromatography (GC) is the group of analytical separation techniques used to analyze volatile substances in ionization detector (FID) is one of the most widely used detectors for GC. It has a wide field of application. For instance, the fuel for air planes, kerosene, is carefully analyzed with GC-FID as a routine control. The overall complexity of the problem and of the spectrum of hydrocarbons is likely to be encountered. It is inevitable to view TPH as a single entity. This also relates to the sampling methodology employed.

An Erlenmeyer flask is used as a receiving flask .here the distillation head and fractionating column are combined in one pieces.[10]

Fractional distillation is the most common form of separation technology used in petroleum refineres,petro chemical and industrial distillation typically industrial fractional distillation columns chemical plants ,natural gas processing and cryogenic air separation plants .[11][12]

Now a day a considerable amount of work has been done to develop efficient and reliable computer- aided design procedure for fractional distillation.[13]

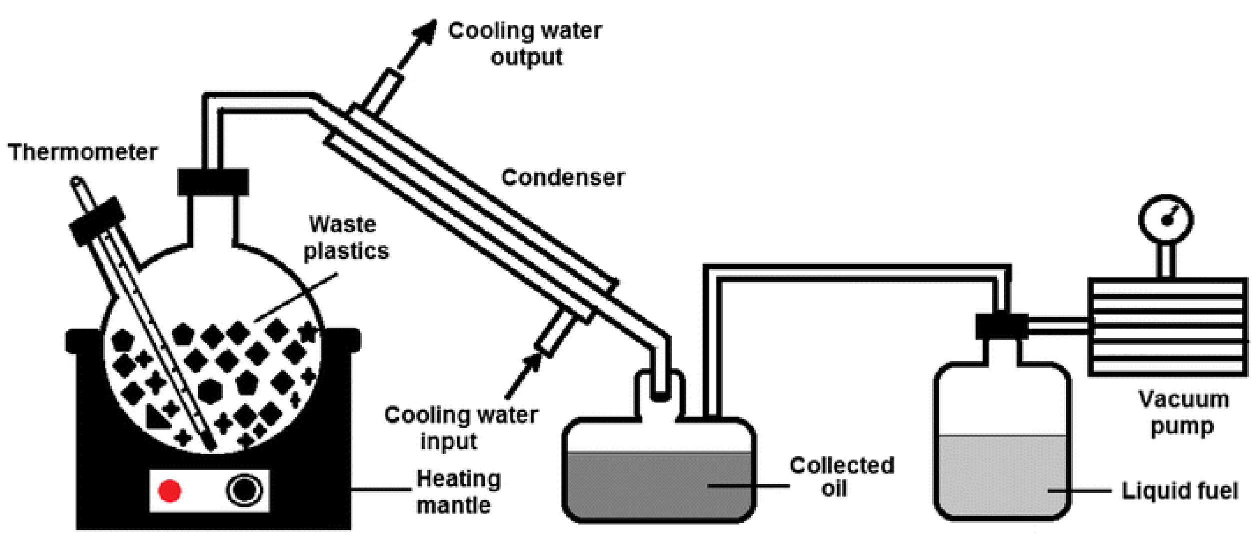


Figure 2.1 distillation processes description

Process description

The waste plastic is stored based on the physical properties such as hardness, softness firms, etc. Size reduction is carried out using shredder and cutter and graded to uniform size. The graded feed is mixed and fed to the melting vessel through a pre heater feeder and heated to 100-267^{o}c.the impurities such as clay, metals, glass etc. settle at the bottom and sent to water column for separation of HCL gas and gaseous hydrocarbons. The molten plastic is sent to main reactor which is maintained at (300-500) ^{o}c and atmospheric pressure.

The reaction takes place in presence of charcoal and catalyst to convert the molten plastic in to hydro carbons .the gaseous hydrocarbon shall be condensed and separated in to liquid and gas stream.

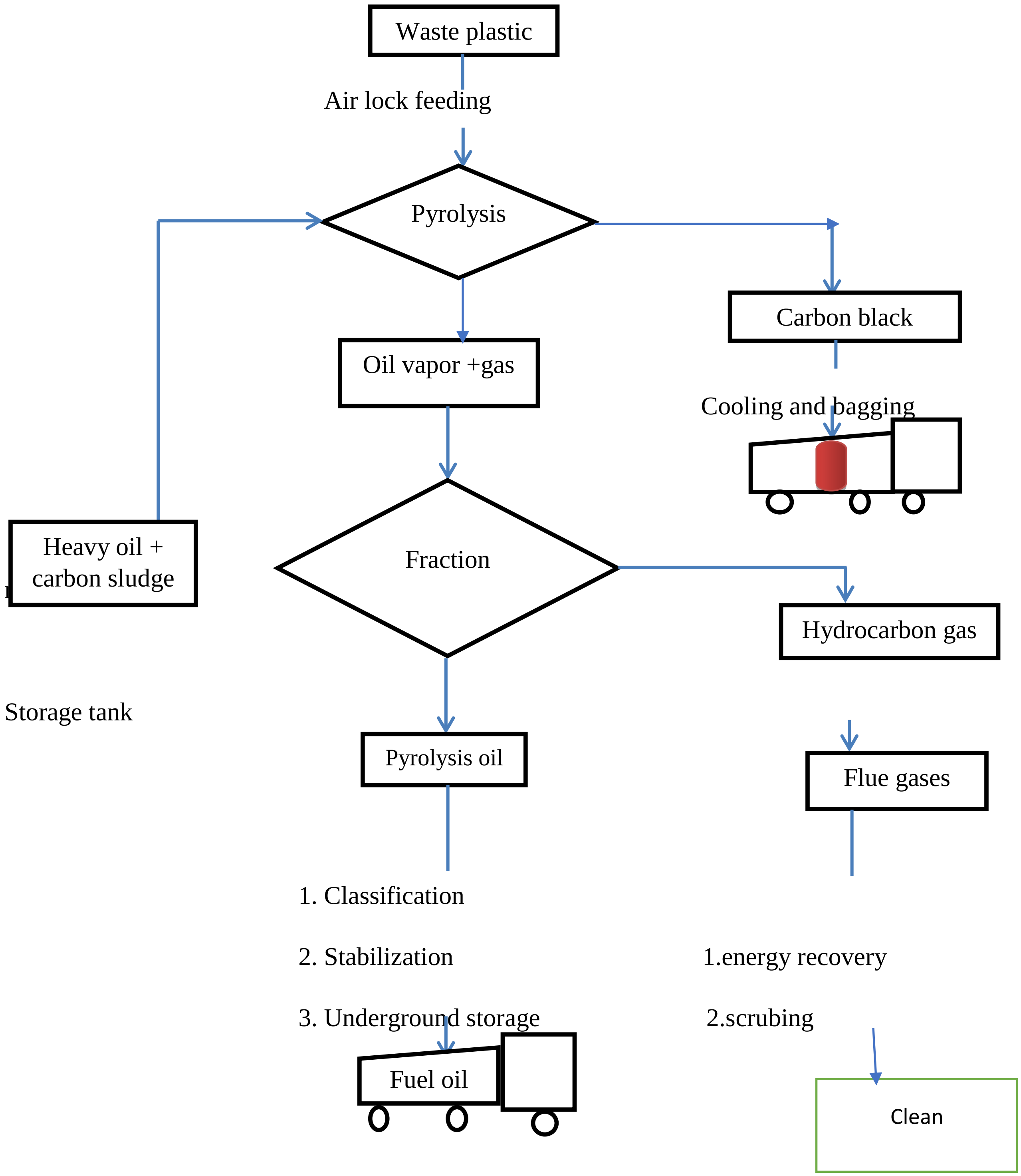


Figure.2.2 Flow chart for hydrocarbon fuel production

CHAPTER THREE

3. 1 MATERIAL AND METHODOLOGY

3.1.1 RAW MATERIAL USED

●The main raw material for production of hydrocarbon fuel from waste plastic

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

●The equipment's used for pyrolysis are

- Seizers and knife- used for reducing the size of all kinds of waste plastic materials
- furnace -used for melting the waste plastic and help to obtain energy
- Flask-can be used for making solutions or for holding, containing, collecting, volumetrically measuring samples, solutions,
- liquid oil storage biker -used to store the oil extracted from waste plastics
- Distillation equipment:- for the distillation purpose
- Heater :-used for heating of the borosilicate glass which contain the sample to be distillate
- Aluminum foil:-for covering the sample during the time of melting to make it free from oxygen.
- Balance :-for measuring the mass of sample
- Lab Cup:-for holding the plastic Sample during melting the sample in the furnace

3.1.2 Methodology

Methodology is the essential part of the project which helps to obtain the pre-determined product in the required manner. And this methodology includes all raw materials required to get the product and steps which must be followed to convert waste plastic materials to useful hydrocarbon fuel.

The hydrocarbon fuel production process involves a series of steps, each of which has to be done correctly for one to achieve good results. The raw materials used for the experiment were HDPE, PP and PS.

Figure.3.1 raw materials

Procedures

- ❖ Firstly- Raw samples was collected from municipality.
- ❖ Secondly-The waste plastics which were collected was dirty and come with foreign materials. All foreign materials was separated by manually
- ❖ Thirdly-the collected waste plastic was cleaned and washed with tap water.

- Fourthly-the Washed waste plastics were cut manually into small pieces by scissor and knife since there are different type of plastics to be melt so there melt flow index (MFI) and the temperature of individual and mixed raw materials are different.
- Fifthly-the small pieces of plastics were covered with aluminum foil to make the plastics free from air during the time of melting

Pyrolysis process

After those processes mentioned above performed the next one pyrolysis process comes which is the processes of melting waste plastics with high temperature in the absence of oxygen. The pyrolysis process is an advanced conversion technology that has the ability to produce a clean, high-calorific value fuel from a wide variety of biomass and waste streams. It is the thermo-chemical decomposition of organic material at elevated temperatures in the absence of oxygen. The pyrolysis provides various operational, environmental and economic advantages. Hydrocarbon molecules from the basic materials are split under the impact of the catalytic (carbon material) convertor inside the flask at 100–267 °C. The higher yield of liquid fuel assumed to be 95%.

Distillation

The distillation is a method of separating mixtures based on differences in their volatilities. The collected oil from pyrolysis process was found to contain various percentages of gases and various densities of oil. The presence of the catalyst has enhanced the medium to reflux and then distilled to obtain three fractions viz. gas, light oil, and heavy oil.

1. Experimental setup

The Wide ranges of flask have been used on a laboratory scale for the plastic pyrolysis process. The two types of feed patterns were used, namely individual types of plastics and mixed types of plastics. The pre-processed waste plastic materials were transferred into an empty round bottom borosil glass flask of capacity 1000 ml The empty weight of round bottom flask was found to be 350 g. After the raw materials were loaded into the round bottomed flask, the opening was connected to a condenser and the condenser was connected to a receiving adapter. The round bottom flask is fixed with heating mantle. The oil is collected at the bottom end. During the whole process, the temperature was maintained around 100 to 267 °C and a vacuum pressure of about 300 mm Hg maintained. A vacuum pump was used to create vacuum inside the round bottom flask. The temperature was raised according to the gradient. The experimental setup is shown in Fig bellow. The condensed oil was collected in the oil collector. The collected oil was refluxed and further distilled. After distillation process, three types of fractions were obtained from the present research. The whole process of pyrolysis took place under 50 min to complete.

Figure.3.2 distillation equipment set up

The distillation process has been conducted twice in order to determine the effect of temperature on the composition of waste plastics.

Effect of temperature on melting of waste plastic

As temperature increase during the time of melting the amount product obtained were decreased since high amount of temperature convert the waste plastic in to ash.

Figure.3.3 Effect of temperature on melting of waste plastic

Effect of temperature on distillation for different composition of waste plastics

When we distil single waste plastic without mixing one with others the temperature required for distillation is to low. Whereas when there is mixing of waste plastic it requires high amount of heat energy source.

Effect of time on quality of product in distillation processes

As the time of distillation increase the quality of product were decreased even if the quantity of product increase and if we distil in the appropriate time the quality of product obtain as the pree determine

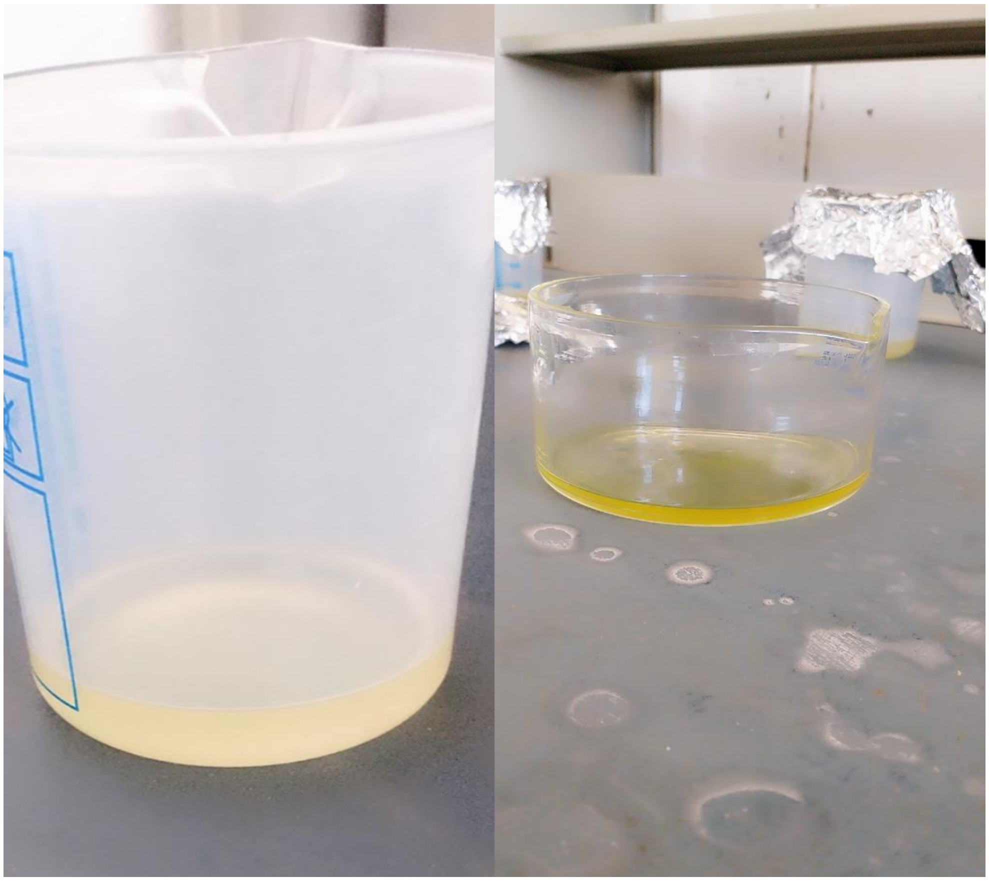


Figure.3.4 Effect of time on quality of product in distillation processes

The sludge of wast plastic after distilation procesess takece place

Figure.3.5 sludge after distillation

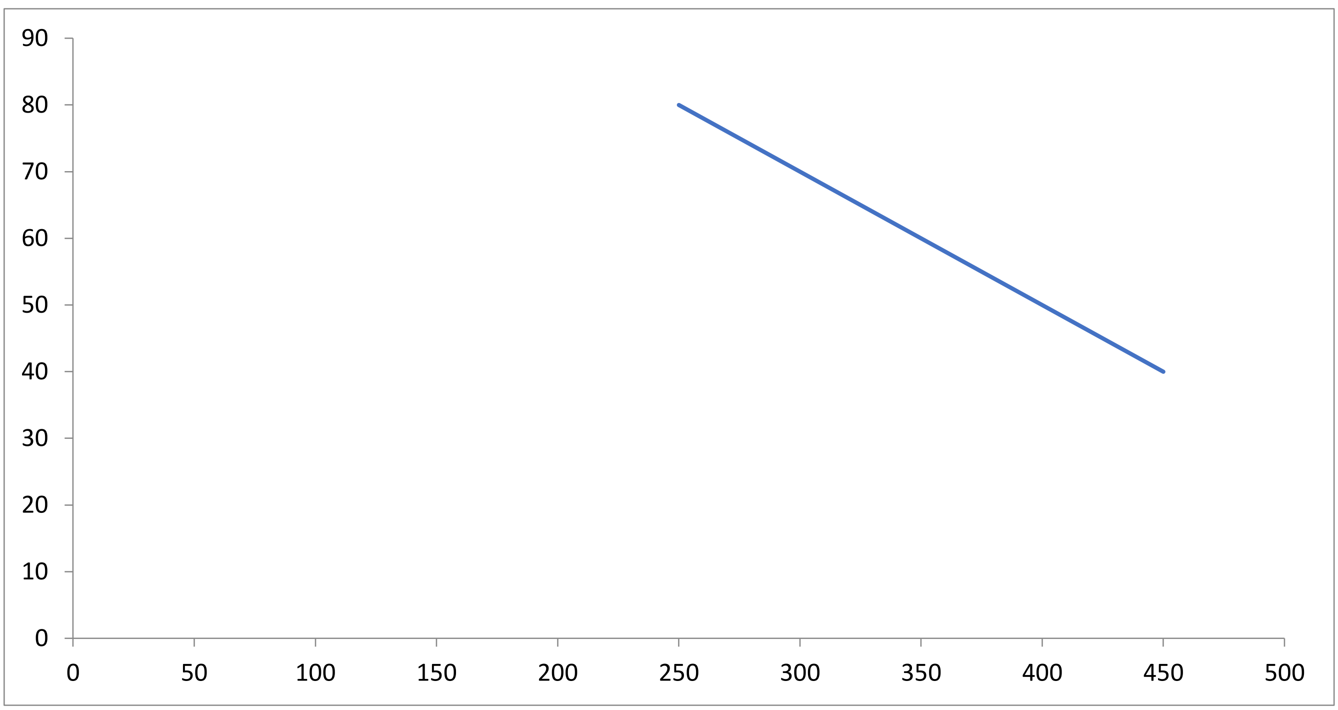
CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1PRODUCT ANALYSIS

The conversion of waste plastic to hydrocarbon fuel follow the steps /methodology which is stated above .from the experiment we have seen the effect of temperature on the amount of conversion of waste plastic to hydrocarbon fuel and quality of product. As well it is possible to saw the effect of time duration on the conversion of waste plastic to hydrocarbon fuel and quality of product .

- ❖ As the temperature increase beyond 267 ^{0} c during distillation the amount of conversion increase but the quality of product decrease



Temperature vs quality

Figure.4.1 effect of temperature on quality of product

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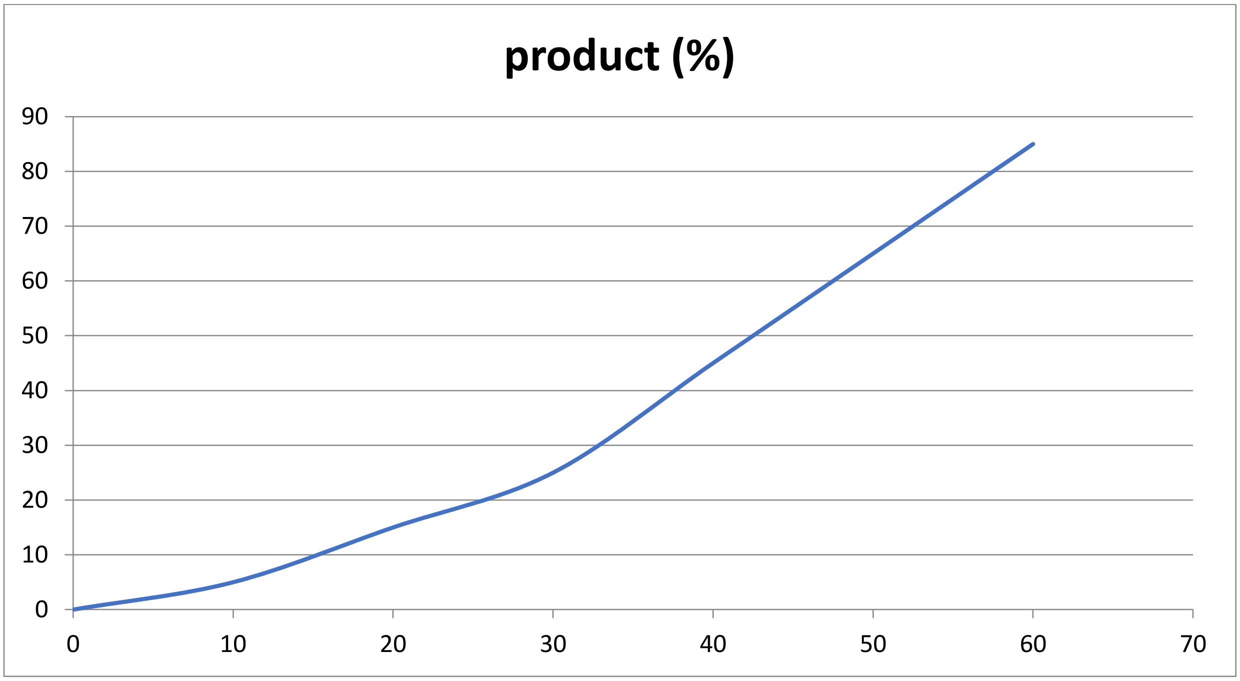
In distillation processes when the durationof time increase the amount of product also increased mean that duration of time has directly proportional to amount of product conversion even if the quality decreased .to show it graphically.



Time (min)

Figure.4.2 effect of time on melting of plastics

Effect of time on the product during melting of plastics in furnace

As the time increase for melting beyond 50 minute the required liquid plastic was converted to ash .Managing the time or wise control of time is needed to obtain the required product.

Specific gravity and density

A 10 ml specific gravity bottle was used to determine the specific gravity of the samples. 10 ml of the sample was pipette out into a pre-weighed bottle up to its brim. This gives the weight of the sample which when divided by 10 gives the specific gravity and hence the density of the sample can be found out. It can be found to be having a specific gravity of 0.811 and a density of 811.7 kg/m3.

CHAPTER FIVE

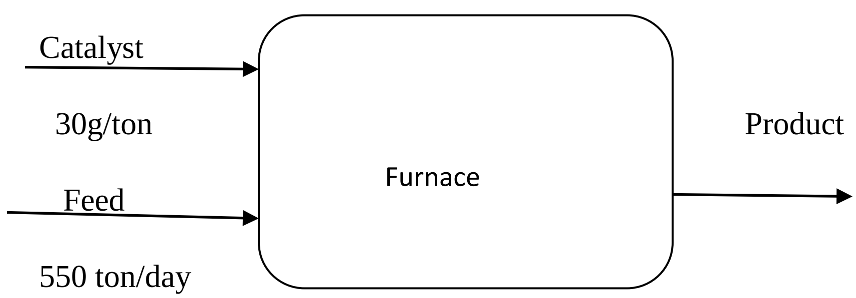
5. MATERIAL AND ENERGY BALANCE

5.1 MATERIAL BALANCE

The material balance taken over the complete process will determine the quantities of raw materials required and products produced. Balance over individual process units set the process stream flow and composition. A good understanding of material balance calculation is essential in process design. Material balances are also useful tools for the study of plant operation and trouble shooting. They can be used to check performance against design; to extend the often limited data available from plant instrumentation; to check instrument calibrations and to locate sources of material loss. The data obtained and interpreted by using measured data. This will be done by evaluating the Material balance on each equipment /steps in the process. The determination of materials that Exits and enters to the process equipment/ unit will help us to determine the equipment's to Industrial level. Finally the method that we are going to analyze the data helps us to finalize and conclude the project in an accurate way. The material balance calculation will be based on the following assumptions:

General mass balance equation

Input +generation =out put +consumption + accumulation



General mass balance

Input =out put

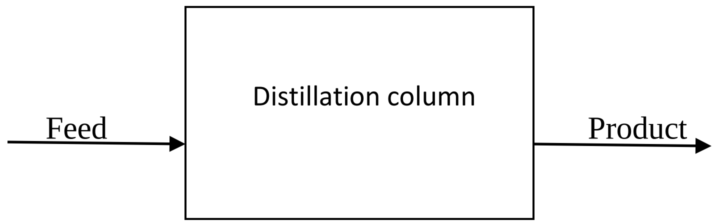
550,000,000g +16,500g=550016500g

=550016.5kg

Mass balance for the distillation

General mass balance

Input +generation =out put +consumption +accumulation



Assume mixed plastic at 267°C (PE= 65%, PP= 15%, PS= 20%) yields the following products.

Gas 25% by weight

Liquid 63%by weight

Solid residue 12%by weight

Total Products

Assumption

- The processes is steady
- The waste plastic which is generated per day is around 3.5% of 550ton.

Capacity of the plant $=\frac{550\text{ton/day}}{100} * 3.5 = 19.25\text{ton/day}$

By giving some allowance we approximate the capacity to15 ton/day. For our capacity 15 ton/day, the products will be

Gas $=\left(\frac{25}{100}\right) *15$ ton/day =3.75 ton/day

Liquid = $(\frac{63}{100}) * 15$= ton/day =9.45 ton/day

Solid = $\frac{12}{100} * \frac{15ton}{day} =$1.8 ton/day

Catalyst consumption

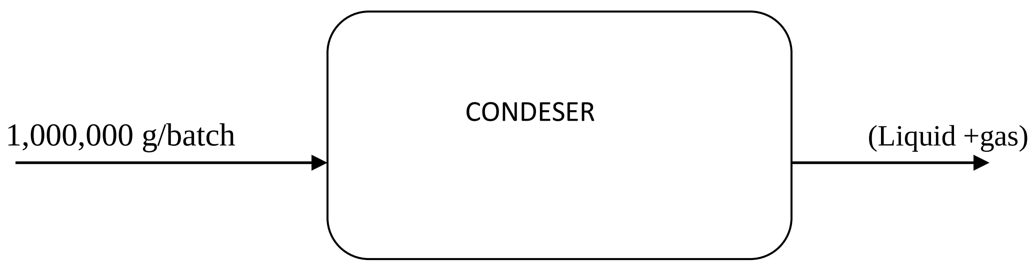
By assuming plastic to catalyst ratio 40 by weight

Total catalyst required will be $(\frac{15}{40})(t/day)$=0.375 t/day

Solvent consumption for cleaning

In order to clean the flask we use a solvent which is is amyl alcohol which has a reasonable cost with good cleaning ability. The flask is cleaned at the end of each shift

5.2 ENERGY BALANCE



We want to do experiment for fourteen hour pyrolysis

Let the maximum energy required is 0.4kwh/g.

0.4 kwh/g*1,000,000 g/batch =4,000,000 kWh required per day= 4GJ/day

The product gas calorific value is 40 MJ/m^3

Total gas production per day = 15 t/day*0.25= 3.75 t/day

Density of the gas = 1.170 Kg/m^3

Total energy per day= $\frac{3.75 \text{ t/day}}{1.170 \text{ Kg/m3}} * 40$ MJ/m^3

$$= 128.21 \text{GJ/day}$$

$$= \frac{128.21 \text{GJ/day}}{14 \text{hrs/day}}$$

Total energy per day = 9.16 GJ/hr = 2.5

CHPTER SIX

6.1 COST ESTIMATIOM AND ECONOMICAL FEASIBILITY ANALYSIS

Purchased equipment cost

The Purchased equipment cost can be calculated as follows

Table 6.1 Purchased equipment cost

	Equipment	price (birr)
1	single shaft plastic shredder	7,500
2	mechanical sieve	1,000
3	bucket elevator	1,500
4	belt conveyor	2,000
5	plastic extruder and heater	10,000
6	Flask	12,946.3
7	liquid oil storage tank	540,000
8	screw conveyor	1,500
	Purchased equipment cost	576,446.3

6.2 TOTAL CAPITAL INVESTMENT

Table 6.2 Total capital investment

Direct cost	Price (birr)
Purchased equipment cost	576,446.3
Purchased equipment installation	224,814.057
Instrumentation and controls	74,938.019
Piping	178,698.353
Electrical	57,644.63
Buildings	167,169.427
Yard improvements	57,644.63
Service facilities	317,045.465
Land	34,586.778
Total Direct Plant Cost	1,688,987.659
Indirect Cost	
Engineering and supervision	184,462.816
Construction expenses	195,991.742
Total Direct and Indirect Plant Cost	2,069,442.217
Contractors fee	103,760.334
Contingency	207,520.668
Fixed Capital Investment	2,380,723.219
Working Capital	426,570.262
Total Capital Investment	2,807,293.481

6.3 TOTAL PRODUCTION COST

Raw Material cost

1. Waste plastic

From literature 35 birr per $m^3$of plastic is invested

Assuming 40kg of plastic per m^3 volume

For 15 ton/day the money invested will be $=(\frac{(15)}{(40)})$*1000*35 = 13,125 birr/day

13125 birr/day*210 day/year = 2,756,250 birr/year

2. Catalyst

Taking calcium oxide and charcoal as a catalyst

Dollar per ton, Cost of catalyst = 0.375ton/day* 112dollar= 42 dollar/day*27 birr/dollar=1,134 birr/day

1,134 birr/day *210 days/year = 238,140 birr/year

3. Solvent

Amount of money invested on solvent (iso amyl alcohol) will be 1liter = 0.847dollar*27 birr/dollar=22.87 birr

8 liter/day consumption*0.847dollar=6.776 dollar/day

6.776 dollar/day*210 days/year = 1422.96 dollar/year*27 birr/dollar=38,419.92 birr/year

Raw material cost annually = (2,756,250 + 238140+38,419.92)

Raw material cost=3,032,809.92 birr /year

Operating labor

The factory works 24 a day, 2 shifts per day and 2 hr cleaning time

Table .6.3 Cost of operating labor

Process	Personnel requirement	Per shift	Unit Personnel wage birr /month	wage birr/month
Sorting and drying	36	18	500	18,000
Shredder	4	2	1,000	4,000
Sieving	4	2	1,000	4,000
Extrusion	4	2	1,000	4,000
Flask	4	2	1,000	4,000
Material handling	4	2	1,000	4,000
			Total wage/month	38,000

38,000 birr/month*dollar/27 birr = 1,026,000 dollar/month

Total operation labor cost annually= 1,026,000 dollar/month*12 months /year

Total labor cost = 22,800 dollar/year *27 birr/dollar=615,600 birr/year

TPC = C_{RM} + C_{OL} + FCI

3,032809.92 birr /year +615,600 birr/year +2,380,723.219 birr/year=6,029,133.139 birr/year

Total Production cost/annum= 6,029,133.139 birr/year

Unit cost

Liquid production per annual = 7400 liters/day * 210days/year = 1,554,000 liter/year

Unit cost = Total Production cost/ annual production capacity

Unit cost =6,029,133.139 birr/year /1,554,000 liter/year =3.88 birr/ liter of oil *dollar/27 birr=104.75 dollar/liter of oil.

Taking a profit margin of 50% the selling price = 0.28 dollar/ litter

Gross profit

From literature oil which is produced from pyrolysis of plastic which is further purified by fractional distillation is around 15 – 30 dollar per barrel

Annual Sales = Total rate of production * Unit selling cost

= 1,554,000 liter/year *0.28 dollar/liter = 435,120 dollar *27 birr/ dollar=11,748,240 birr

Gross profit = sales – TPC = 11,748,240 – 6,029,133.139=5,719,106.86 birr

Depreciation $= \frac{\mathbf{FCI}}{10\text{years}}$ =2,380,723.219/10

Depreciation = 238,072.3219 birr

Assuming income tax = 25%

Income tax = Tax rate * (Gross profit- Depreciation)

Income tax = 0.25*(2930167.6–238,072.3219) = 673,023.82 birr

Net profit = gross profit – income tax – depreciation

=2,930,167.6 birr -673,023.82 birr -238,072.3219 birr

= 2,019,071.46 birr/year

Return on investment (ROI)

Before income tax

$$\text{ROIoverall} = \frac{(\text{Total gross profit} - \text{Total depreciation})}{(\text{Total capital investment})} * 100$$

$$\text{ROI}_{\text{overall}} = \frac{(10*6176120.789 - 10*238{,}072.3219)}{(10*2{,}807{,}293.481)} *100\%=97.9$$

After income tax

$$\text{ROI}_{\text{overall}} = \frac{\text{Total net profit}}{\text{Total capital investment}}*100\%$$

$$\text{ROI}_{\text{overall}} = \frac{((10*6176120.789)}{(10*2{,}807{,}293.481))} *100\%=74.6\%$$

Payback period = $\frac{((\text{Total capital investment})}{(\text{Net profit/year} + \text{Depreciation/year}))}$

$$= \frac{((2{,}807{,}293.481)}{(4453536.357 + 238{,}072.3219)} == \quad 0.598 = 1/2 \text{ year.}$$

6.4. MARKET STUDY

In order to estimate the capacity of the plant we use overview of Dima and surrounding it.

Solid waste management system as a main source of Solid waste generation

Dima and surrounding it generates a solid waste of 0.4kg/c/day

More than 200,000ton are collected each year

About 550ton/day, 85% of the total waste collected

The municipality increased the collection rate from 65% to 85%

Sources of Waste Generated

- 76% households,
- 18% institutions, commercial, factories, hotels,
- 6% is street sweeping.
    - Physical composition

- Organic 60%, Recyclables 15 %, Others 25%
- Vegetable 3.2 %,
- Paper 12.5%,
- rubber/plastics 3.5%,
- Wood 2.3%,
- Bone 1.1%,
- Textiles 2.2 %,
- Metals 0.5%,
- Glass 0.7%,
- combustible leaves 13.1%,
- Non-combustible stone 2.5%,
- All fine 56%

CHAPTER SEVEN

7. SITE SELECTION AND PLANT LAYOUT

7.1 SITE SELECTION

For one factory the profitability mostly determined by the existence of the row material nearby and the location of the factory to the market as well labor force .due to these reason hydrocarbon fuel production company must be in the area of Dima near to Addis Ababa in which there is a dense accumulation of waste plastics and because of the reason/factors

- Factors that we considered during site selection are as follows:
  - Raw material availability: in Dima around Addis Ababa there is a huge waste plastic that can be expanded during establishment of this plant.
  - A market: satisfactory location with respect to the market area.
  - Energy availability: due to presence of electric power station there will not be problem regarding power supply to the plant.
  - Availability of suitable land
  - Transportation facilities (road, train,)
  - Political and strategic consideration
  - Water supply
  - Labor supply

7.2 PLANT LAY OUT

After the process flow diagrams are completed & before detailed piping, structural and electrical design can begin, the layout of process units in the plant must be planned. Plant layout means the allocation of arrangement of equipment & machinery in such a manner so that maximum utilization of manpower, machines & material is done

Major plants involving in the hydrocarbon fuel production process are:

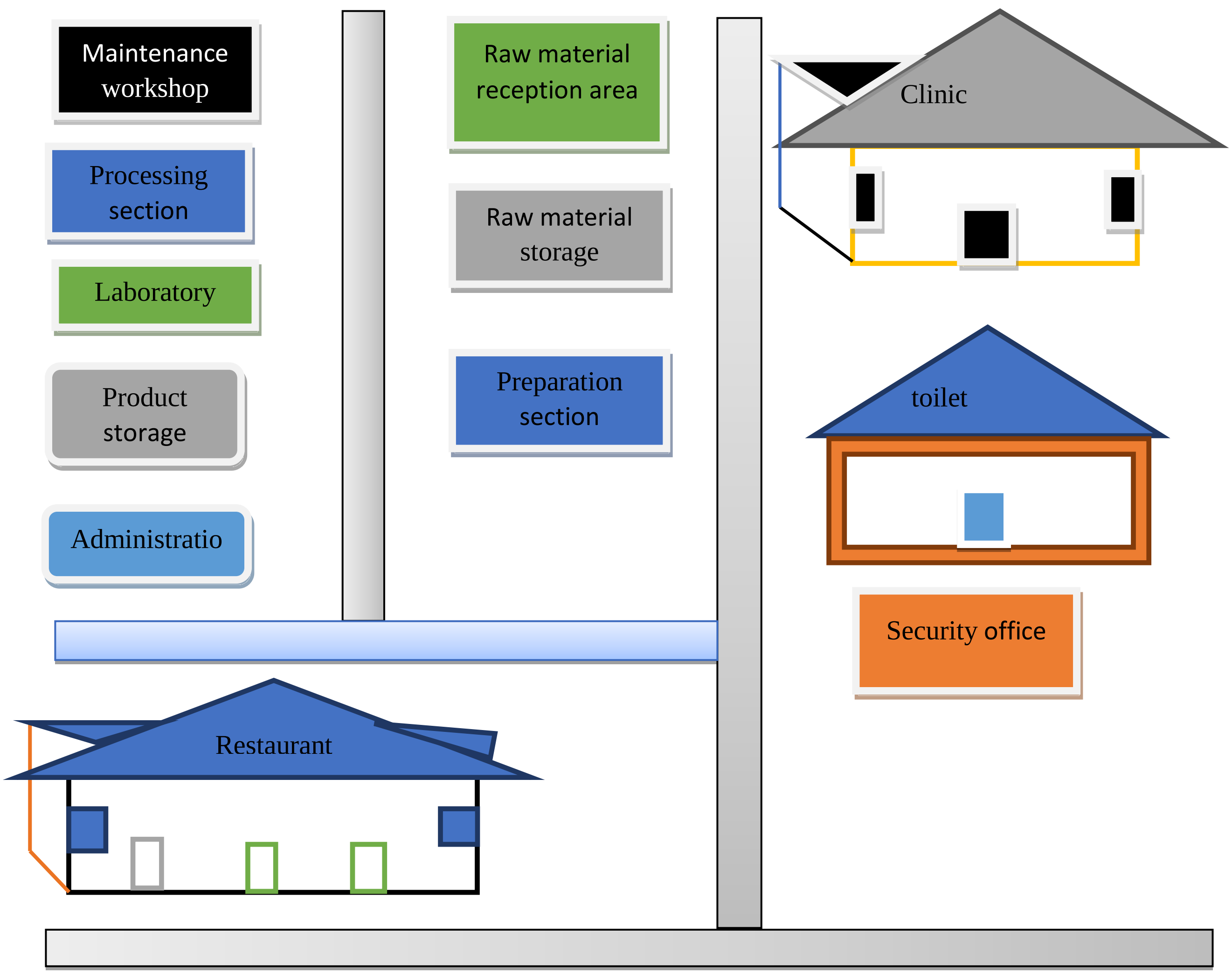


Figure 7.1: Plant lay out for hydrocarbon fuel production.

CONCLUSION

Plastics are the polymers which contain the element carbon ,hydrogen and others which are non-biodegradable and stay on land for a long period of time without any conversion and if they are directly burned thy affect the environment by combining with the atmosphere elements like oxygen, nitrogen sulphure etc..

Pyrolysis is economically and environmentally valuable technology they produce oil or fuel from plastic waste with and without catalytic decomposition in the absence of oxygen. Because of pyrolysis process doesn't consume oxygen use cheap raw material, produce low noise and decrease the erratic change of the energy price. By the nature plastic waste contain the component of petroleum pyrolysis produce oil or fuel without any additional chemicals.

The conversion of waste plastics in to hydrocarbon fuel requires heat energy source and the conversion depends on the composition of waste plastics. Duration of time for distillation has also its on effect on its pree determined product. The quality of product decrease with increasing duration of time in distillation process. It is possible to reduce environmental effect of waste plastic by converting it in to hydrocarbon fuel and decrease fossil energy cost.

The production of oil can be done by simple non catalytic depolmization of individual and mixed plastic waste and required by laboratory scale distillation followed by condensation.

The residue obtained from the distillation process can be used as lubricants for various types of equipment.

RECOMMENDATION

Pyrolysis of plastic waste consumes maximum temperature without catalyst up to 500°C and with catalyst up to 300°C. So, using flask/reactor which has no ability to resist this temperature is impossible. To consume the heat energy source it is better to use catalyst for melting of waste plastics

Existence of different characterization materials were able us to know the end product behavior such like instruments (penskymarter for measuring the flash point, flammable characteristics ,fire point etc) and gas chromatography(GC) to measure the volatility of the hydrocarbon fuel and others.

Without converting plastics into gas form storage of melted plastic in liquid form is impossible.

Opening of flask at the time of pyrolysis is not possible because of bad odor of plastics can affect human health and environment.

Careful selection of reactor/ flask and catalyst is required to have better yield of quantity and quality, extended time.

Rather than using furnace for melting of waste plastics in the absence of oxygen using payrolizer is better.

Managing the time during distillation processes help us to obtain the required /pree determined product

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