**ISLAMIC UNIVERSITY OF TECHNOLOGY**

**THE ORGANIZATION OF ISLAMIC COOPERATION**

# DESIGNING OF AN ADVANCED REACTOR TO HARNESS FUEL OIL FROM WASTE PLASTIC

**Submitted in partial fulfillment of the requirement for the degree of**

**Bachelor of Science**

**In**

**Mechanical Engineering**


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# DECLARATION

We hereby declare that thesis entitled "DESIGNING OF AN ADVANCED REACTOR TO HARNESS FUEL OIL FROM WASTE PLASTIC" is an authentic report of our study carried out as requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of PROF. DR. NURUL ABSAR CHOWDHURY, Dean, FET, IUT during January 2018 to October 2018.

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

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This is to certify that the above statement made by the student concerned is correct to the best of my knowledge and belief.

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# CERTIFICATE OF RESEARCH

The thesis titled "DESIGNING OF AN ADVANCED REACTOR TO HARNESS FUEL OIL FROM WASTE PLASTIC" submitted by Abdullah Al Rafi (141438), Redwanul Haque (141439), Faizan Sikandar (141466) has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical Engineering on November, 2018.

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Although we tried our best to complete this thesis flawlessly, we sincerely apologize for any mistakes that may have been made.

# Contents

# Abstract

Pyrolysis of waste plastic is a prospective way of conversion of waste plastic into low-emissive hydrocarbon fuel. The present research is focused on the conversion of waste plastic into low-emissive hydrocarbon fuel by two process namely vacuum and catalytic cracking (activated carbon, activated carbon with granulated charcoal and activated carbon with calcium oxide). Waste plastic materials viz., polyethylene, polypropylene, polystyrene and polyethylene terephthalate were collected from local convenience store packing materials. Waste plastic material pyrolysis was conducted as individual plastics and as mixed feed in a new laboratory scale batch reactor. Hydrocarbon molecules from the basic materials are split under the impact of catalyst inside the reactor in 70$^{o}$–240 $^{o}$C. The reduction of process takes place from 500–600 $^{o}$C to 240$^{o}$C in the presence of catalyst. The analyses of pyrolysis products suggested that it can be used as a viable alternative to motor fuel. It was observed that the yield was better in the case of individual plastic material as opposed to mixed feed in all cases except polypropylene under non-catalyzed vacuum process. The comparison of the GC-FID (TPH) report of the obtained oil. Process of pyrolysis is a thermochemical process conducted at high temperatures and usually in presence of catalysts. Different type of catalysts, natural and synthetic, can be used for conversion of organic wastes into valuable fuels. The aim of this work is conversion of waste polyolefin mixture and production of liquid fuel using mixture of $Al_2O_3$ and $SiO_2$ as a catalyst. Waste mixture was pyrolyzed at temperature range 400$^{o}$-550$^{o}$C and obtained products were liquid fuel, gas and minor solid residue. Under the optimized reaction conditions, the condensed liquid fraction is much larger than the gaseous fraction. Different amounts of catalyst and polyolefin mixture as a feedstock were used. According to the obtained results, the retention time and the percent of $SiO_2$ in the catalyst mixture have predominant effect on the amount of liquid product. Decreasing the quantity of $SiO_2$ in the catalyst mixture increased the yield of liquid product. The physical properties of obtained liquid products were characterized and according to the measured values, liquid fuel belongs to light fraction of diesel fuel. Energy has many forms such as electricity, transportation fuel and so on. A large amount of energy is produced from crude oil, Energy consumption in the G20 increased by more than 5% in 2010 which is used to produce petroleum and petroleum to produce daily usable plastics. Over 500 billion pounds of new plastic is manufactured each year and roughly 33% of that is single use and thrown away. Considering 70% of total plastic consumption is discarded as waste, thus approximately 5.6 million tons per annum (TPA) of plastic waste is generated in India alone, which is about 15342 tons per day (TPD). Only 8% of waste plastic is recycled in the U.S., 15% in Western Europe, and much less in developing countries, this reuse of plastic could potentially keep enormous amounts of plastic out of landfills and out of the oceans. In developing countries, due to economic growth as well as changes in consumption and production patterns, the increase in use of plastics has been higher than the world average and waste plastics are becoming a major waste stream. Waste plastics are often found to be as litter across cities; they are burnt, buried or disposed of in open dumps along with other waste. The solution to the above mentioned problems can be solved through the utilization of the new develop technology. This new developed technology will remove these hazardous waste plastics from the environment and convert them into eco-friendly liquid fuel. The process is used to convert these waste plastics into liquid fuel creates no harmful emissions and can be produced at a very little overall cost. We need to stop polluting our oceans with plastic before it is too late, and start collecting all plastics suitable for this new fairly simple technology, a technology that is available now.

Polyethylene (abbreviated PE) or polythene (IUPAC name polyethene or poly (methylene)) is the most common plastic. It is used worldwide as synthetic fiber, polyester, packaging material, soft drink containers, etc. Many kinds of polyethylene are known, with most having the chemical formula (C2H4)nH2. Thus PE is usually a mixture of similar organic compounds that differ in terms of the value of n. The increased demand and high prices for energy sources are driving force to convert organic compounds into useful hydrocarbon fuels. Waste plastic disposal and excessive use of fossil fuels have caused environment concerns in the world. Both plastics and petroleum derived fuels are hydrocarbons that contain the elements of carbon and hydrogen. The difference between them is that plastic molecules have longer carbon chains than those in LPG, petrol, and diesel fuels.

Therefore, it is possible to convert waste plastic into fuels. The main objectives of this study were to understand and optimize the processes of plastic pyrolysis for maximizing the diesel
range products, and to design a continuous pyrolysis apparatus as a semi-scale commercial plant. Pyrolysis of polyethylene (PE), polypropylene (PP), and polystyrene (PS) has been investigated both theoretically and experimentally in a lab-scale. We have tried a simple and economically viable process to decompose the hydrocarbon polymers of waste plastic into the shorter chain hydrocarbon of liquid fuel. Initial tests with several widely used polymers indicate a high potential for commercialization. Clearly there is growing interest in doing something different with waste plastic than dumping it in landfills or the oceans. The global community must force itself to change
its present path and become truly concerned about the environment in which its descendents will be raised, for what people do today affects everyone tomorrow. The thermal process utilized to break down the hydrocarbon chains of the polymers and convert them into liquid fuel. A Steel reactor with temperature range from 100 ºC to 400 ºC is utilized for the plastic thermal degradation process in general. At lab scale we have used simple glassware in sealed form. The process yield about 80-90% liquid product. The experiment is conducted under a fume hood and open air system, no vacuum process is applied in this particular thermal cracking process. Polyethylene chips and pellets are used in the experiment. Titanium Dioxide (TiO) was used as a catalyst with a ratio of 50:1 (for better yield the other catalyst like $Al_2O_3$, $Al_2O_3/Sio_2$ may also be used).The oil was of yellow colour having obnoxious odour and burnt completely.

# PART-01

## Introduction

In the recent years it is quite common to find in newspapers and publications that plastics are turning out to be a menace. Days are not so far when earth will be completely covered with plastics and humans will be living over it. All the reasoning and arguments for and against plastics finally land up on the fact that plastics are no biodegradable in nature. The disposal and decomposition of plastics has been an issue which has caused a number of research works to be carried out in this regard. Currently the disposal methods employed are land filling, mechanical recycling, biological recycling, thermal recycling, and chemical recycling. Of these methods, chemical recycling is a research field which is gaining much interest recently, as it turns out to be that the products formed in this method are highly advantageous. Plastic is one such commodity that has been so extensively used and is sometimes referred to as one of the greatest innovations of the millennium. There are a numerous ways in which plastic is and will continue to be used. The plastic has achieved such an extensive market due to fact that it is lightweight, cheap, flexible, and reusable, do not rust or rot, and so forth. Because of this, plastics production has gone up by almost 10% every year on a global basis since 1950 [1]. Asia accounts for 36.5% of the global consumption and has been world's largest plastics consumer for several years. The major segment continues to be the packaging, which has accounted for over 35%of the global demand [2]. The global per capita consumption of plastics is shown in Figure 1. The global production of plastics has seen an increase from around 1.3 million tonnes in 1950 to 245MT in 2006 [1]. In recent years, significant growth in the consumption of plastic globally has been due to the introduction of plastics into newer application areas such as in automotive field, rail, transport, aerospace, medical and healthcare, electrical and electronics, telecommunication, building and infrastructure, and furniture. This significant growth in the demand for plastic and its forecast for future have certainly proved that there has been a quiet plastic revolution taking place in every sector.

Today, plastics materials are very frequent in daily life and provide a fundamental contribution to our society. The typical distribution of household plastics as a part of the overall solid waste stream is: polyolefins 66.9%, polystyrene 13.3%, PVC 10.3%, PET 5.3% and others 4.2%. Waste plastic ends its lifetime as municipal solid waste on the landfill [3]. Over the world plastic waste has continuously grown in the last decades. Disposal of waste plastics causes serious environmental problems. Thus, plastic waste recycling has been a focus of many researchers in the past few decades. Pyrolysis appears to be promising technic of conversion of solid wastes plastic (SWP) to more usable materials such as gas fuel and/or fuel oil or to high value feedstock for the chemical industry. Degradation of the waste plastic materials, by heating in an inert atmosphere-pyrolysis, is usually conducted at moderate temperatures between 400-800°C. Obtained products are volatile condensable hydrocarbon oil and a non-condensable high calorific value gas [4]. The dominant components of domestic plastics are rich in carbon and hydrogen so that there is a good possibility for converting waste plastic into liquid fuels [5]. The extent of reaction, oil yield, and its composition depend on the type of plastic and process conditions [6]. Thermal pyrolysis of plastic materials leads to a wide product distribution and requires high degradation temperatures [7]. During the cracking process of long polymer molecules the degradation of polymer chains can be enhanced by applying of various catalysts. The catalytic pyrolysis of plastic wastes gives valuable products similar to diesel and gasoline [6]. The most frequently used catalysts are zeolites and

mesoporous materials because of their porous structure and acid properties [8]. In the case of the polyolefin catalytic cracking like HDPE and PP a number of acid porous solids, such as amorphous silica-alumina, zeolites and ordered mesoporous materials, have been used as catalysts [7-9]. The used catalysts have high conversion effect over the plastic wastes at lower temperature and decrease the activation energy [10]. Many researchers studied the catalytic degradation of polymer wastes in the last decades. The addition of catalyst is expected to reduce decomposition temperature and to modify the products. Different types of reactors has been used for pyrolysis of waste plastic like, batch [11] or autoclaves [12] semi-batch [13], screw conveyors or fluidized beds [14] and fixed beds[15], shaft kilns or rotary kilns[16]. Most studies are carried out in beds or batch processes where all products are collected as a single sample, and subsequently analyzed. Often focus of the studies is effect of experimental conditions (reaction temperature and time) on product yield and composition [16, 17], but others are focused on characterization of obtained products. The aim of this work is catalytic conversion of high density polyethylene (HDPE) and polypropylene (PP) waste mixture into liquid products that could be used as fuel and feedstock for chemical industries. The process of pyrolysis was carried out in the presence of mixture Al2O3 and SiO2 catalysts using a semi-batch reactor. Emphasis will be given to high conversion of waste plastic to liquid products. Different amounts of catalysts and polyolefin mixture were used. The physical properties of obtained liquid products also were determinate.

## Experimental Setup:

### Working Principle of Reactor:

When the reactor is filled with Waste mixture of Plastic and catalysts , it has to be checked there is no oxygen

as it may cause serious fire when the temperature will be risen to 450°C. So Two ways to eliminate oxygen-

1. Vacuum Pumping
2. Before closing the reactor set fire inside the reactor and then close the reactors with all the valves closed and when all the oxygen with in the cylinder is burn out fire will be stopped.

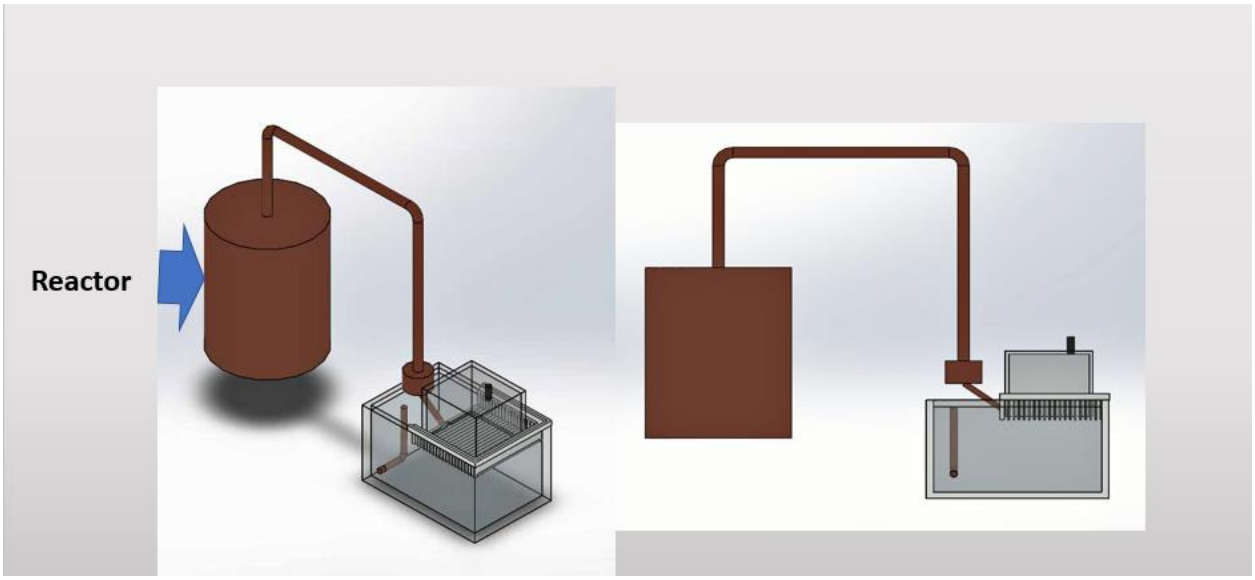



**Figure 2: 3d Model of experimental setup**

## 1. Background

"Dhaka Metropolitan city" in Bangladesh gradually polluting day by day. Waste plastic is one of them to increase the environmental pollution. We know that every year, the population of the city is increasing, for that its really very difficult to control the huge amount of uses of plastics and its wastes. Every year, Bangladesh is importing high volume of diesel with paying the high amount of money.[1] My study helps to you to reduce the environmental plastic wastes pollution in Dhaka city as well as to covert the plastic waste into wealth.

Every year, worldwide more than 100 million tons of plastics are produced. From my paper, People can learn how the waste plastic convert into value added fuel can by the recycling of the plastics. From my study , people will be able to know , low density polyethylene were used to get the fuel oil, which fuel have same properties as like as petrol, diesel etc.

Pyrolysis occur without oxygen with high temperature inside the reactor in 300 degree Celsius for reaction. Through the process of pyrolysis, de-polymerization, thermal cracking, distillation to attain the petrol and diesel oil. To convert the waste plastic into fuel it has two impact on economic and environmental area in any country.

The process of converting the plastic, to make the wealth from waste, to solve the plastic problem which is occurring the environmental pollution in Dhaka city.At present, the solid waste disposal is a great concern topic in cities.Specially in Dhaka city solid waste problem has a great impact on the environmental pollution. Also it seems to many cities in the developing countries.Per day more than 4000 Metric tons solid wastes are produced in Dhaka city. Where the 200 Metric tons comes from the various clinic and hospital which is called "the Medical wastes".

Here 15% to 20% medical waste is very dangerous for the human life. When they through these type of waste into the municipal waste in the open land, then it can create the dangerous health hazards for the city people.

Solid wastes and polyethylene have create three ways problems –

Bad effect on human health, environmental pollution, block the flows of drainage system.

Plastics are very cheap and available in markets, for that the people don't want to reuse it. They throw it here and there.An Inception Report on Control & Management of Polyethylene bags in Bangladesh shows - that people of Dhaka City alone use 600 million bags a day.

All types of plastics in Dhaka city create the barriers inside the drain, for that in the rainy season the water cannot pass through the pipe line then huge flood is appeared.

Natural process cannot decompose the Polyethylene and Plastic materials and they are not bio-degradable. It creates the barriers of the flow of mineral or nutrient elements to the soil. There are some useful bacteria inside the soil, plastic also destroy this type of bacteria. After a long time period plastics are able to affected on the physical infrastructures.[2]

Our government are very much conscious to pay money for the inadequate and unplanned waste management practices Specially in the urban areas. Because they realized that Lack of proper management caused long term damage in the environment. And high collection of plastic components has a higher income of the people. Plastic consumption has increased significantly in the urban areas – from 5.56 kg per person in 2005 to 14.9 kg per person in 2014 (Waste Concern, 2014).

Gradual increase of plastics consumption also increased the plastic wastes.

The share of plastic waste in Dhaka city has increased from 1.74 per cent in overall landfills in 1992 to 4.1 per cent in 2005 and to 6.5 per cent in 2014 (Waste Concern, 2014).[3]
If we compare our Bangladesh with the neighbor developing and developed countries, then we can see that Bangladesh stay very far from the waste management. Many countries have their own policy, framework, structure to generate the waste in the municipal areas. Already Bangladesh also has taken some necessary steps to establish the proper legal frame work, and structure.

This paper focus on the solid waste management, provide the suggestion to reduce the municipal solid wastes.

The per capita consumption of plastic in 2014 was 3.5 kg (Waste Concern, 2014), national consumption of plastic in Bangladesh amounted to be about 545,300 tones. According to a study, total plastic waste which was available for recycling was about 50,213 tones (Waste Concern, 2014). This indicates that only 9.2 percent of total plastic consumed in the country was available for recycling in 2014. Then the huge amount of landfill plastics causes damages to the environment. Lack of waste management creates the environmental concern in our country. For Bangladesh, the waste management is very early stage of development. Commercially waste management are appeared many private company try to recycling the plastic wastes from the municipal areas.Plastics wastes are collected from the end users such as hospitals, industries, households etc. some people are collected the plastics individually from the landfills, dumping areas and traded to the middlemen which is send for recycling.Two types of plastics are seen, big in size, have weights, easy to collect have their more commercial value for recycling.Another one is light weight, difficult to collect have their less commercial value for recycling.[3]

## 1.1 Project objectives

The main objectives of our project are:

i) To enhance the resource conversion and reduce the greenhouse gases.
ii) To establish the plastic recycling process and implement it.
iii) To development the environmentally sound technology.
iv) To reduce the dependency on the fossil fuels.
v) To expand the economical growth of the country.
vi) To encourage the people conversion of the plastics wastes into diesel fuel , generating and marketing it at a cheaper rates more than the diesel oil in the markets.[4]

When the reactor is filled with Waste mixture of Plastic and catalysts , it has to be checked there is no oxygen as it may cause serious fire when the temperature will be risen to 450°C. So Two ways to eliminate oxygen-

1. Vacuum Pumping
2. Before closing the reactor set fire inside the reactor and then close the reactors with all the valves closed and when all the oxygen with in the cylinder is burn out fire will be stopped.

### General objectives of plastic waste policy:

The most important objective of waste policy is to reduce the harmful effect on health and undesirable environmental impacts of waste. To attain this purpose, we have to ensure that:

i) To reduce the production of plastic wastes.
ii) To enhance the reuse of plastics waste.
iii) Enhance the recycling of the material.
iv) Enhance the energy use of plastic waste.
v) Ensure that the treatment and disposal of plastic waste cannot create any harmful impacts.

## 1.2 Project Methodology

We will get two types of facilities to by converting the plastics into oil, gas and coal.

i) The oil, gas, coal which are produced from the plastics – we can use it in the industrial and automobile sector.
ii) Different types of environmental pollution which are occurred by waste plastics possible to minimize.

If we follow the plastic industries, then it appeared that plastics are produced from the natural gas (i.e. ethane). For that we can also able to converted the wastes plastic into its gaseous form. We will select a machine which is able to provide the heat to the plastics in a certain temperature so that it can be melt but does not burns.

The main purpose of our project is to extract out the diesel or plastic oil from the wastes plastics, which we named it as a "PLASTIC PYROLYZED OIL".

### Methodology

i) At first we have to identify the types of the waste plastics
Such as – PE/PP/PS/HDPE/LDPE.
ii) Put down or prepare the waste plastics for the pyrolysis process.
iii) When the waste plastic meting and produce the gases, then condensate these gas to attain the raw fuel.
iv) Then purifying the raw fuel , as a result we will get the oil which characteristics is as like as diesel fuel.[4]

## 2 Plastics

Plastics are synthetic organic materials which are produced by polymerization. Which are generally high molecular mass, these type of polymers can be molded or extruded into desired shapes.

There are two main types of plastics: **thermoplastics** and **thermosetting polymers.**

- ✓ **Thermoplastics**: This type of plastic is soft and melt if enough heat is applied and hardened on cooling, so that they can be made into new plastics products.

**Examples**: polyethylene, polystyrene and polyvinyl chloride etc.

- ✓ **Thermosets or thermosetting: it also can** melt and take shape only one time. This type of plastics are unable for repeated heat treatments; after one time melting it stay in solid phase , and cannot convert it into liquid phase again.

**Examples**: phenol formaldehyde and urea formaldehyde

## Table: Product types of some plastics pyrolysis

| Main products | Type of plastics | As a feedstock of liquid fuel |
|---|---|---|
| Liquid hydrocarbons | Polyethylene (PE)<br>Polypropylene (PP)<br>Polystyrene (PS)<br>Polymethyl metacrylate (PMMA) | Allowed.<br>Allowed.<br>Allowed.<br>Allowed. |
| Liquid hydrocarbons | Acrylonitrile-Butadiene-Styrene copolymer (ABS) | Allowed. But not suitable. Nitrogen-containing fuel is obtained. Special attention required to cyanide in oil. |
| No hydrocarbons suitable for fuel | Polyvinyl alcohol (PVA)<br>Polyoxymethylene (POM) | Not suitable. Formation of water and alcohol.<br>Not suitable. Formation of formaldehyde. |
| Solid products | Polyethylene terephthalate (PET) | Not suitable. Formation of terephthalic acid and benzoic acid. |
| Carbonous products | Polyurethane (PUR)<br>Phenol resin (PF) | Not suitable.<br>Not suitable. |
| Hydrogen chloride and carbonous products | Polyvinyl chloride (PVC)<br>Polyvinylidene chloride (PVDC) | Not allowed.<br>Not allowed. |

$CH_2=CH_2$ + $CH_2=CH_2$ $\rightarrow$-$CH_2$-$CH_2$-$CH_2$-$CH_2$-$CH_2$-$CH_2$-

ethene ethene polyethene segment

**Table 3.1: Heating values of various fuels and wastes**

| Fuel or waste | Typical heating value (kcal/kg) |
|---|---|
| **RDF** | **4000 – 5000*[1]** |
| **RPF** | **6000 – 8000*[2]** |
| Coal | 6000 – 8000*[3] |
| Heavy oil | 9500 |
| Wood/paper | 4300 |
| Plastics (polyethylene) | 11000 |
| Typical municipal wastes | 1000 – 1500*[1] |

RDF= Refuse Derived Fuel

RPF= Refuse-derived Paper and Plastic Fuel

# 3 Limitation and scopes

My thesis paper mainly focused on the recycling the plastic to utilized it for our domestic purpose. Bangladesh government have no concern about that issue, for that there are no complete data view in Dhaka city regarding the waste plastics. Some author, researcher, private company they collect the data on it and I used the data for my thesis purpose. There are some data content of "Dhaka city corporation" I also followed it. Population of the Dhaka city is increasing day by day and a large number of plastic wastes get every day , collected it by the poor people , if we recycling it then will be very helpful in different ways.[7]

# 4 Outline of the study

Here We discussed the present plastic recycling situation in Bangladesh, plastic waste recycling process (collecting, sorting, cleaning, drying, shredding) and finally pyrolysis process. Literature survey is described before the starting of pyrolysis process. Then production method included here. Discussed the performance of characteristics of produced liquid fuel from the plastic wastes. Physical properties of the diesel grade of waste plastics. Emission characteristics of the waste plastic pyrolized oil. Overall result and discussion, Application of project and future work.

# 5 PLASTIC RECYCLING IN BANGLADESH

Here we can define the Recycling as- it is one kind of reprocessing of the used materials into a new form.

**Methods of the study**

There are no available data about plastic recycling, for that the plastic industries they are not interested in plastic recycling. The responsible authority of the Dhaka city plastic waste management is "Dhaka City Corporation". They have the total overview of wastes but that is not particularly for the plastic wastes.

Some rules and regulations were taken from the "Ministry of Environment and Forest". Most of the diagram, photo, and content are collected from the Dhaka City Corporation website and from various Bangladeshi organizational website.

**Plastic Background in Bangladesh**

As a engineering materials, plastic has a domestic demand in our country. At this time, the plastic industries are growing up day by day. It has a important impact on our industrial sector.

Plastic industry was first introduced in Bangladesh in 1960. At that time they produced the plastic toys, photo frame, and some plastics parts for the jute mills spare parts. They made this type of plastic product by hand plastic molding.

After few years, In 1970, manufacturing machines was introduced, and they made the plastic jugs, plastic plates and glass etc.

In 1980, film blowing machines also introduced and made plastic bags.

Actually, the plastic recycling idea took place in 2000 through the injection and extruder process. And many other company use the rotational molding process machine produced plastic chairs, tables, water tank etc.

At present, there are around 2997 plastic factories in Bangladesh , where 1965 factories are small , 980 are medium and remaining 52 are the large factories which are extending globally.

It is noted that most of the plastic industries are placed in Dhaka and some industries stay in Chittagong. And a few number of factories in Narayan gang city.[8]

Plastic Consumption Rate in Dhaka City Corporation

When the plastics are starting to get popularity in the Bangladeshi market then plastic factories required to import the polymer.

Before 1987, factories imported the polymer 10,000 tons every year.

From 1987-2007, during this time – every year they imported 287,000 tons polymer. But it imported rate are increasing day by day. At present, the total plastics are used 750,000 tons every year.

That is the 5kg per capita per year and the globally 30kg per capita per year. Now we get opportunity to export the plastic product in the world market such as India, Sri Lanka and Nepal.

Increase of plastic product is related with the population growth. At present, 30 million people living im Dhaka city. For that, every day the disposal rate of plastic also increasing.

According to Dhaka City Corporation, every day the total waste is produced 3315tons/day. Where 4.15% of the total waste is the plastic waste.[9]

Waste concern consultants published a waste data scenario of Bangladesh –

The collected plastic for recycling 50,213 tons/year and 34,646 tons/year is soiled where 69% of total plastic are able to recycling.

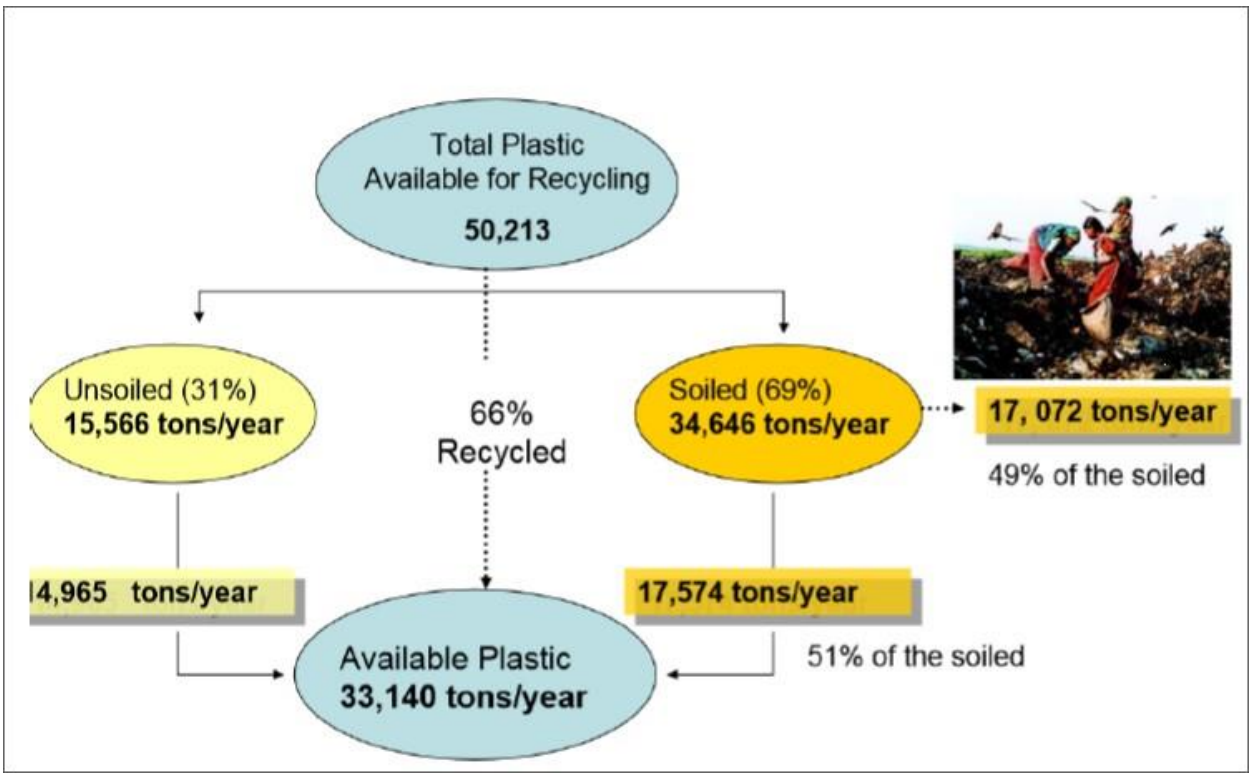



Figure: Plastic waste recycling In Dhaka.

Source: waste Database of Bangladesh, Waste concern consultants.

## 5.1 Plastic Waste Recycling Process

Plastic recycling is not highly used in Bangladesh yet. Recycling machine is not available here. There are small number of industries who have some extruder and shredder machines. In Bangladesh, labor cost is very low, for that plastic collecting, cleaning, sorting is done manually. Labor cost is 200taka per day for that owner of the companies are interested to do it manually.

Now I want to show the total process of recycling before starting the pyrolysis process.[10]

## 5.2 Collecting

Bangladesh has no technological method to collect the waste, the people's throw the plastic here and there, and the collector to whom we named as a TOKAI -they collect the plastic bottles and many others plastic wastes from the dustbin, drain, and street and sell it to the plastic waste collector in a low price rate . Dhaka City Corporation is the responsible for collecting the plastic waste, according to their data- 42% of the solid wastes collected from the Dhaka city in 2007. And remaining uncollected plastic stay in the open place. There are two types of plastic waste collector in Dhaka city, primary waste collector and the secondary waste collector. Tokai is the primary collector and the DCC is the secondary plastic waste collector.[10]

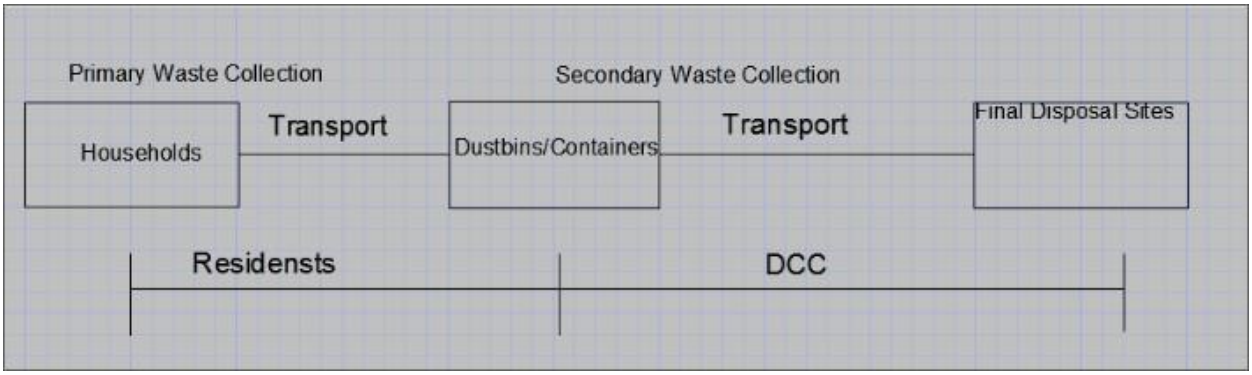



**Figure : Waste Collection System in Dhaka City.**

Here are some pictures of plastics collection in Bangladesh.

Figure: Tokai; collecting plastic wastes Taken by B, M Mahibul Islam Sabab Accessed on 19.11.2014

**Figure : Collecting Plastic wastes (Demotix.com, accessed on 19.11.2014)**

## 5.3 Sorting

When the small buyers collect the plastic wastes and sort it according to their own choice. There are no sorting machine for that it's occurring manually. Only the worker sorted the plastic following the plastic codes, such as the 1 is PET and 3 is PVC.

**Figure: Sorting of plastic (Shimo, 2014)**

Figure: Sorting of plastic (Shimo, 2014)

## 5.4 Cleaning and Drying

Cleaning the plastic is an important thing to clean after sorting process. All the cleaning process is conduct manually, normally in river or pond.

Figure : Cleaning the Flakes (Martin, R (2014). Plastic recycling workers in Bangladesh, Ranak Martin blog, 17.11.2014)

Figure: Drying the flakes (Martin, R (2014). Plastic recycling workers in Bangladesh, Ranak Martin blog, 17.11.2014)

## 5.5 Shredding

To cut the plastic in their small particle. Before putting the plastic into the shredder, it's essential to cut the big size plastic wastes. Inside the shredder, there is a rotating blade that cut the plastics into the small particles. Then we can prepared for the pyrolysis process. Benefits of utilizing the waste plastics if the pyrolysis process done systematically, then whole benefits can be attain from the three ways- social, economical and environmental.[10]

Figure: Plastic flakes (Shimo, 2014)

# 6 LITERATURE SURVEY

**According to M.fAli** , liquid fuels can be extract out from the plastic waste at the temperature range 100℃ - 480℃ . But the produced gas obtained with a small amount of heavy oils, and some other insoluble material such as coal dust gums etc.

As a result, from the plastic wastes we can convert into liquefied coal products and petroleum oil.

**According to Miskolczi,** He observed the pyrolysis process of waste plastics , he used a horizontal tube reactor at the 520℃ temperature in presence and absence of ZSM-5 catalyst. And it appears that gasoline and light oil is increased in the presence of catalyst. He found that plastic wastes converted into gasoline (20-48%) and light oil (17-36%) which is mainly depends on the used parameters.

**According to F murfyk**, that is the current literature, converting of wastes plastic to the fuel oil is a current research topic, waste plastic oil produced from the thermal pyrolysis process, when we get some residues , analysis the viscosity and density of it and conducting the performance test on oil.[4]

## 7 PYROLYSIS

It is a process where the plastic is converted into mixed oil in an inert atmosphere where oxygen is absent. This process used to produce fuel oil which is similar with the diesel fuel properties. Such as higher cetane value and the lower sulphur content than the traditional diesel.
In the pyrolysis process, when providing the heat in plastic waste in the absence of oxygen then the macromolecular structures of polymers are broken down into smaller molecules. The reaction will be thermal and catalytic pyrolysis.[6]

### i) Physical process:

When the pyrolysis process is occurring then the plastics starts to melting and gaseous phase is appeared. By the help of condensation process, we separate the liquid oil from the mixtures of gases. After condensation, inside the water jar layer of oil will be appeared which is connected with the melting zone.

### ii ) chemical process:

Plastic to fuel conversation depends on the catalytic thermal depolymerization process.Plastics molecules increases when the temperature is increasing. And at an optimum temperature the bond of plastic molecule is divided or split and converted into gaseous form.

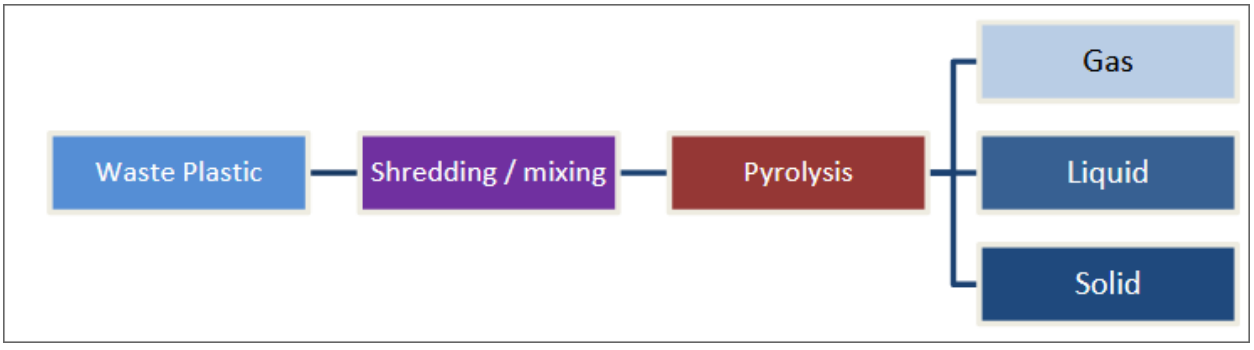



Figure: Waste plastic feedstock[5]

## GAS

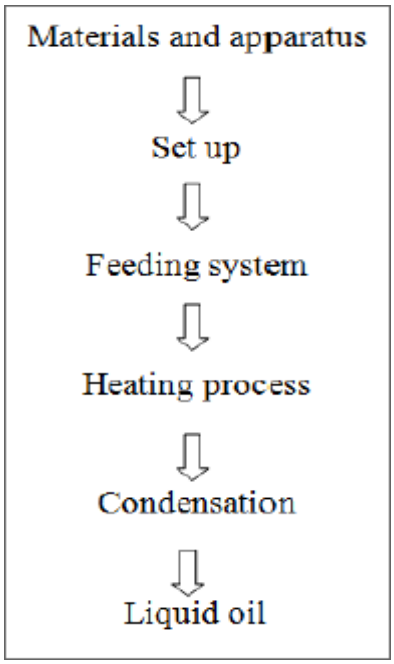
The three types of output products, gas is one of them. Here gas will be produced that cannot be condensed into liquid products. There are some light fuel gases or non- condensable gases (i.e. methane, ethane, propane) only 10-15% of the mass of processed plastics. This type of gases also combustible, which properties is as like as natural gas. This gas we can use for the pyrolysis melting process also and the other works.

## LIQUID

The main product of our pyrolysis process that is liquid fuel. The fuel is the main revenue for every plant and it is stored and contained before use in an appropriate fuel application.

## SOLIDS

From the process, the solid product is char or carbon that's mean coal (co-product) pure coal without ash used in different ways. Such as in photocopy machine, ink of printer, use in battery industry etc.



# 8 Production method

The gasification process includes a series of steps such as pretreatment, gasification, gas cleaning and storage.

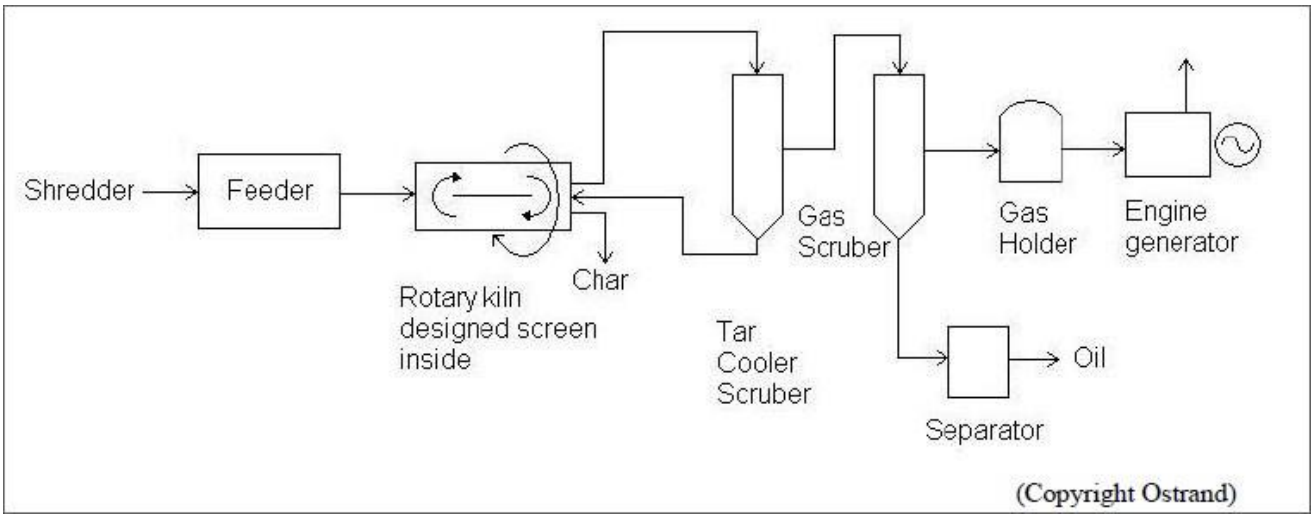



**Figure: Schematic diagram of a production plant of plastics-derived gaseous fuel**

## 8.1 Altis's commercial plant for liquid fuel production.

| Main features | |
|---|---|
| Feed | Mainly mixed plastics; current commercial operation is for medical waste |
| Processes | Pyrolysis |
| Main equipment | Tank reactor |
| Special features | Removable inner reactor vessel |
| Main product | Hydrocarbon oil |

## 8.2 Technical description

A schematic diagram of a typical plant is shown in Figure.

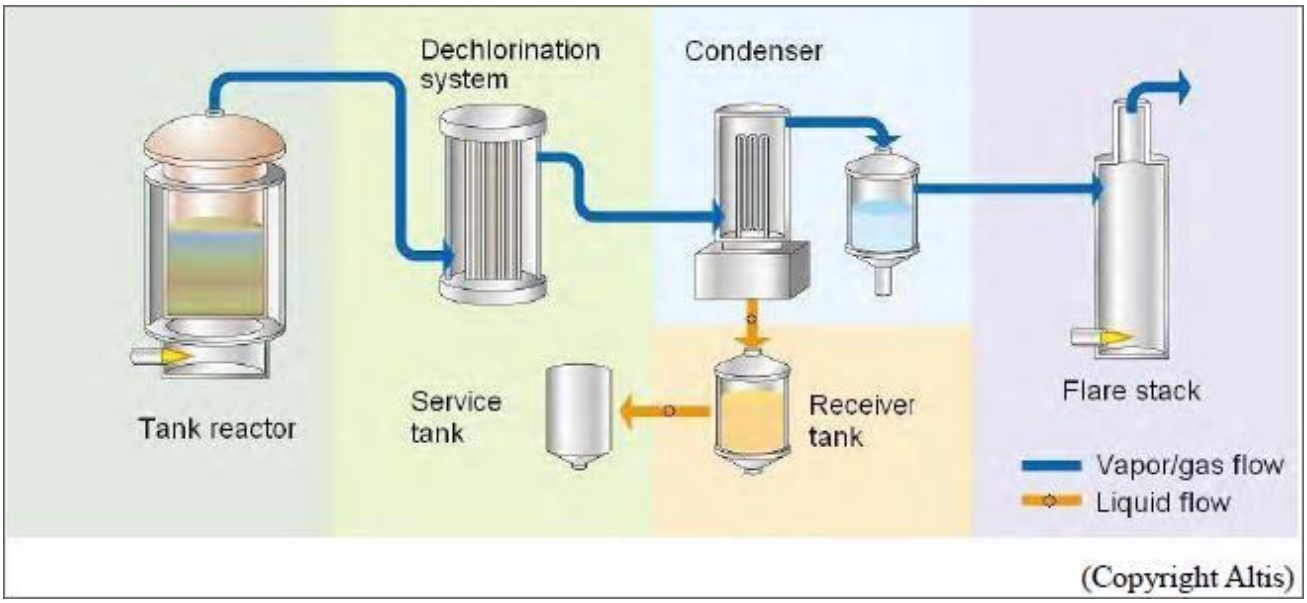



**Figure : Schematic diagram of a plant for medical wastes**

If we pyrolysing the chlorine-containing plastics of the medical waste plastics, hydrocarbons and hydrogen chloride are formed. After removal of hydrogen chloride in a de-chlorination system, volatized hydrocarbons are condensed inside condenser. The resulting liquid hydrocarbons are stored in a service tank for use. Produced Gas collected in a flare stack as flue gas without hydrocarbon.

## 8.3 PHYSICAL PROPERTIES OF DIESEL GRADE OF WASTE PLASTIC

Shown in below

| Sl no. | Characteristics | Diesel Grade Fuel |
|---|---|---|
| 1 | Flash point in $^{o}C$ | 87 |
| 2 | Fire point $^{o}C$ | 92 |
| 3 | Viscosity @40 $^{o}C$ | 3.8 |
| 4 | Density $kg/m^3$ | 800 |
| 5 | Calorific value kj/kg | 46988 |

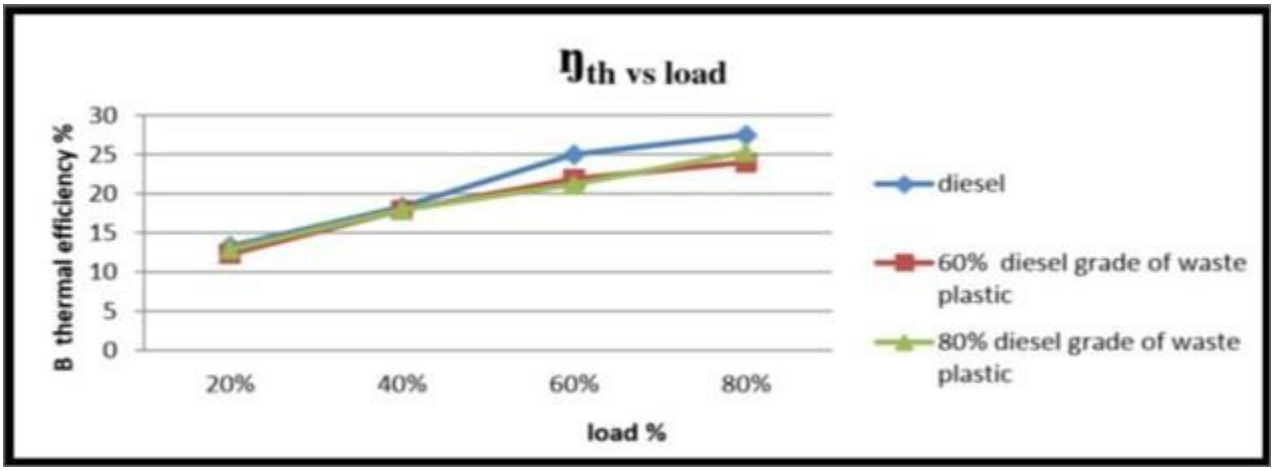
# PART-02

# 9 Performance characteristics:

## 9.1 Brake thermal efficiency:

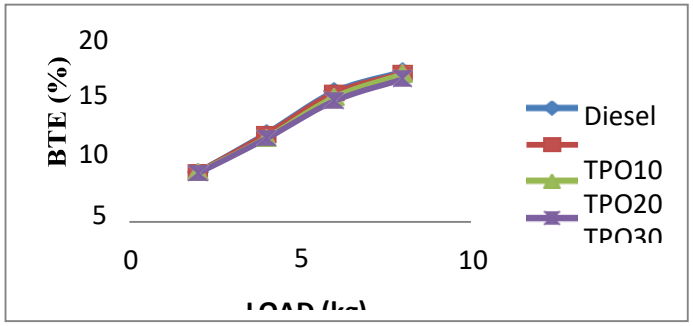
The experimental study on a single cylinder, four stroke, air cooled DI diesel engine and air- cooled spark ignition engine with waste plastic oil, At full load, the efficiency is higher for diesel and petrol fuel. This is due to the fact that at full load, the exhaust gas temperature diesel and petrol fuel. This is due to the fact that at full load, the exhaust gas temperature and the heat release rate are marginally higher for waste plastic Graph shows that an experimental study on waste plastic oil and diesel fuel blends in compression ignition engine proved that the thermal efficiency is 27.5% at full load.

It is observed that the engine fuelled WPO60 and WPO80 of diesel grade gives brake thermal efficiency of 24 %and 25.3% respectively at full load. The total heat release for each WPO- DF blends is lesser than diesel. Hence, the brake thermal efficiency is lower for the WPO-DF blends than diesel.



## 9.2 Brake specific fuel consumption:

Brake specific fuel consumption measures how efficiently an engine is using the fuel supplied to produce work. It is inversely proportional to thermal efficiency as shown in the graph below.




The Fig. shows the variation of the brake thermal efficiency versus load for compression ratio of 16.5 for different blends of distilled tire pyrolysis oil respectively.
It is observed that the thermal efficiency is gradually increased with increase in load. The thermal efficiencies of the blends decrease with the increase in TPO of the blend. This may be due to the lower heating value of DTPO.

## 9.3 Brake specific Fuel consumption*:*

*The* variation of brake specific fuel consumption for different engine load conditions and for compression ratio 16.5 as shown in the fig.

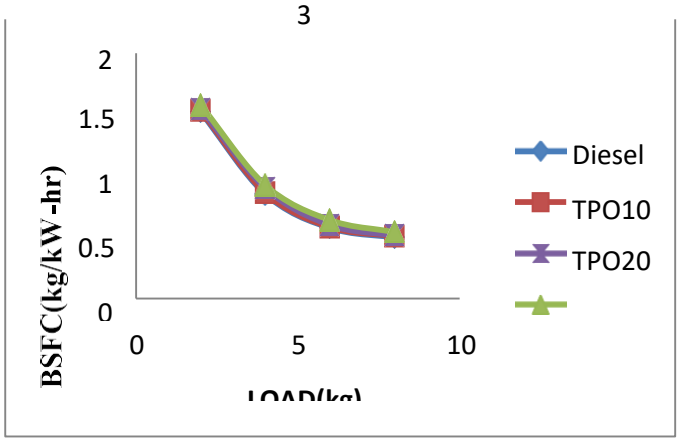



Fig.3 Variation of Brake Specific Fuel Consumption versus Load

Fig.3 shows the variation of brake specific fuel consumption for different blends of distilled tire pyrolysis oil respectively. It is observed that the BSFC is gradually decrease with increases in the load condition. At the same time it also shows that BSFC increases with the increase in the concentration of DTPO in diesel. This behavior is obvious since the engine will consume more fuel with DTPO diesel blends than diesel, to gain the same power output owing to the lower calorific value of DTPO.

# 10 Emission characteristics:

## 10.1 Effect of Emission of Hydrocarbons at Different Brake Power:

The Figure 9 shows variation of HC with the brake power. At the brake power of 3.27 kW diesels give value of 28 while B5 at CR17 and B5 at CR 16 show 30 and 32 respectively. The value of B5 at CR 17 is greater than diesel at CR17 at max power comparing with the start where the diesel leads the B5 fuel at CR 17. The B5 fuel emits more HC than diesel.

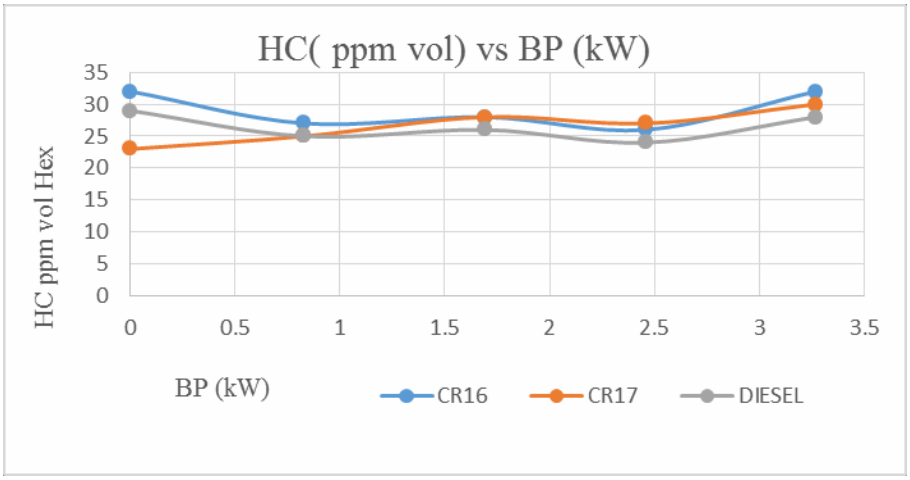



Fig: Variation of HC with the brake power

## 10.2 Effect of Emission of Oxides of Nitrogen (NOX) at Different Brake Power:

The Figure 10 indicates the variation of $NO_X$ with BP. From the graph it is seen that at BP of 3.27 kW. The $NO_X$ emission is 1200 ppm volume for B5 fuel and shows the same characteristics as that of diesel.

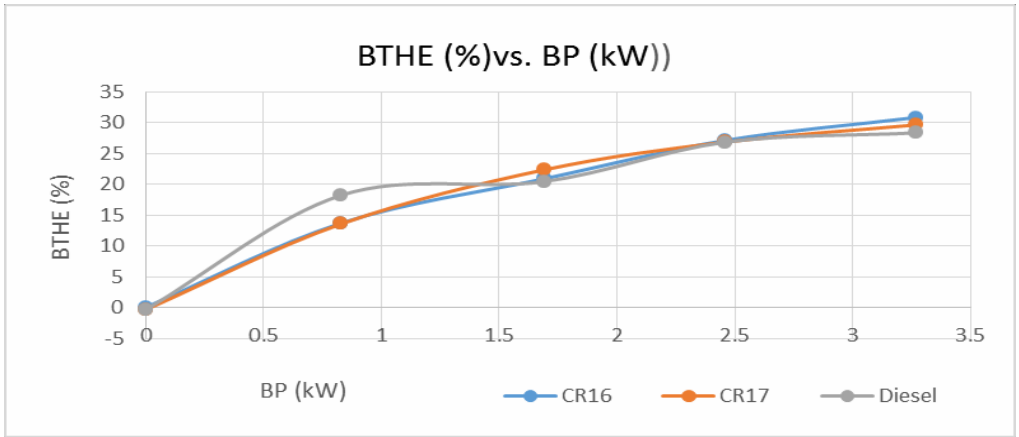



**Fig 10: Variation of oxides of nitrogen with the brake power**

## 10.3 Effect of Emission Carbon monoxide at Different Brake Power:

The figure 12 indicates the variation of emission of carbon monoxide with Brake Power. Diesel and B5 fuel CR17 emit the same amount of carbon monoxide i.e. 0.06% vol at a BP of 3.27 kW. It is Cleary seen from the graph that the emission of carbon monoxide reduces with increase in BP. The formation of the carbon monoxide is due the incomplete combustion of the fuel.

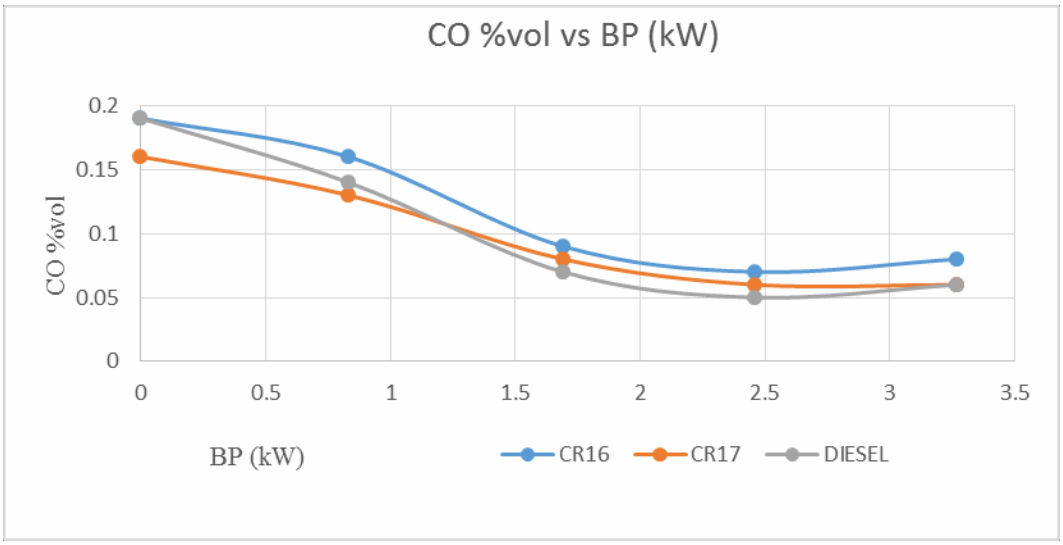
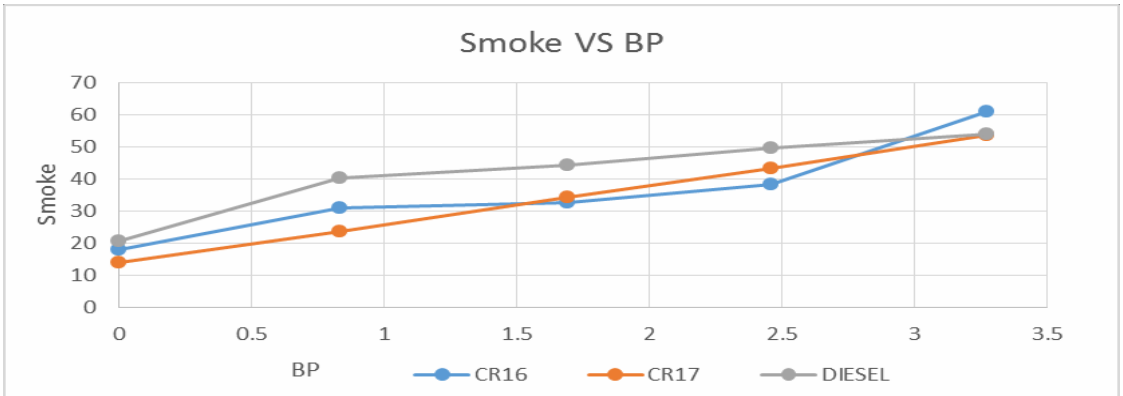



**Fig 12: Variation of CO with the brake power**

## 10.4 Effect of Emission of Smoke at Different Brake Power: Emission of Smoke is harmful for human beings and also the atmosphere. Figure 14 shows emission of smoke increase as power increases for the three set of fuel B5 at CR 17 emits lesser amount of smoke than diesel at same compression ratio. The increase in emission of smoke for B5 at CR 17 is from 14.2 at the start to 53.7 at maximum power whereas for diesel it is from 20.9 at the start to 53.9 at maximum power. It shows B5 at CR 17 is better than diesel in the smoke aspect.



# 11 Pre-processing:

In all pyrolysis technologies, pre-processing is required to shred the waste plastics to a reduced size to increase surface area, remove contamination as far as possible, ensure better heat transfer and homogenize the material. In pyrolysis, the treated plastic feedstock is often transferred into the pyrolysis reactor by means of a feed screw or a plug, to ensure oxygen is excluded.

## 11.1 Cracking (de –polymerization):

Plastics are made up of long chain organic compounds, and in order to produce liquid fuels these long chains need to be broken into shorter ones. This breaking of these polymers, or de-polymerization or cracking, can be achieved with either heat (often pyrolysis) or the use of a catalyst.

11.2 Products: The three main products produced are gas, a liquid product and a solid. The solid product is often simply a carbon rich waste and will probably not offer any value and may need to be disposed appropriately following classification. The gas will be a mixture of the lightest organics formed and is often recirculated back into the process to produce heat. The liquid phase will be a crude liquid fuel and will always require a further distillation stage in order to produce a quality transport fuel such as petrol or diesel.

Fuels produced from clean plastic feedstock will demonstrate low sulphur levels when compared to conventional fuels. Sulphur levels can be under 10 ppm compared to sulphur levels of other fuels in the region of < 35-50 ppm. A higher Cetane value can also mean that synthetic diesel from pyrolysis and hydrothermal processes demonstrate lower engine emissions of hydrocarbons and $CO_2$ due the increased efficiency of the fuel. Synthetic diesel also has higher lubricity, potentially reducing wear on Engine Company.

# 12 Recycling Technologies:

Recycling Technologies has developed an advanced fluidized bed reactor, the RT7000, that uses thermal depolymerisation to convert residual plastic waste from material recycling facilities (MRFs) and other sources into a valuable low sulphur hydrocarbon they call Plaxx™. Plaxx™ is a hydrocarbon product that can be used as; a low sulphur alternative to heavy fuel oil (HFO), slack wax or as a feedstock for more plastic.

Plaxx™ has been granted ‘end of waste’ status by the Environment Agency of England on the basis that:

- The product is commonly used for specific purposes;
- There is an existing market or demand for the substance or object;
- The use is lawful i.e. the product fulfils the technical requirements for the specific purpose

  and meets the existing legislation and standards applicable to products; and
- The use will not lead to overall adverse environmental or human health impacts.

12.1 Global Renewables: The Global Renewables (GRE) technology uses a pyrolytic thermal depolymerisation process to reduce and convert material such as plastics into light crude oil. The conversion of plastics to fuel occurs in an oxygen free environment to create an emission free process, using the same science as is be adopted by FOY.

GRE has one fully permitted and commercially operational facility in the United States, producing a renewable liquid fuels and syngas product. The plant has an output of between 1.5-3 million gallons of liquid fuel per year with a waste plastics feedstock.

Thus, the global pyrolysis reaction that takes place into a reactor can be described in the following manner:

Tire wastes $\rightarrow$ volatile hydrocarbon + gases + solid residues

- Tire wastes, fed into the pyrolysis reactor undergoes a thermal cracking, by cleaving itself into volatile hydrocarbon, gases and solid residue.
- Volatile hydrocarbon can be cooled and condensed into a liquid fraction Gaseous fraction remains uncondensed during quenching
- Solid residues wait in the reactor chamber for their removal

Normally, the process provides:

- A gaseous fraction (10 – 15 wt%) essentially composed of $CH_4$, and higher hydrocarbons $C_mH_n$, $H_2$, $CO_2$, CO etc.

A liquid fraction (40 – 45 wt%), composed of water, tar and oils (organic compounds);
Solid residues containing steel cord (10 – 12 wt%) and char (30 – 35 wt%), containing fixed carbon and ashes (metals, oxides and inert matter).
Thermal decomposition (pyrolysis) behavior for a typical solid tire waste at two different heating rates are presented in Fig. 2. The TG and DTG curves show that the volatile fraction completely decomposed within the reactor temperature below 500 $^{o}$C and the decomposition rate is maximum around 400 $^{o}$C.

# 13 Benefits of Recycled Plastics:

Recycling of plastic has many benefits for the country if the recycling is done systematically. The whole benefit of the recycling process can be figured in three sector, social, economic and environmental. The three beneficial sectors described below:

## 13.1 ADVANTAGES:

1. Problem of disposal waste plastic can be solved.
2. Waste plastic is converted into the high value of fuels.
3. Industrial and automobile fuel requirement shall be fulfilled to some extent at lower price.

4. No pollutants during cracking of plastic.
5. The crude oil can be used for generation of electricity.
6. Volume of waste is significantly reduced.
7. Storable/transportable fuel or chemical feed stock is obtained.
8. Desirable process as energy is obtained from renewable sources like municipal solid waste or sewage sludge.
9. Reduce environment effects.
10. Reduce importing of petroleum products.

## 13.2 Social Benefits:

To make a society clean, beautiful and healthy place to live recycling is one of the most important things to focus on. People throw their wastes on the rood or dustbin and plastic wastes litter the streets and bind the water removal system in the drain which causes mosquitos and flies. As Bangladesh is a densely populated country there is not much suitable land for disposal and not any secured place for disposal of hazardous waste. To have a clean and safe place to live, recycling of wastes is the best option. Modeling examples from other nations our leaders want to apply the systematic way of developing the country and in the process make it more beautiful. Better management of wastes is an important part of it.

### 13.3 Environmental benefits:

Modern waste management reduces the environmental impact and will save resources. Bangladesh used to have very fertile lands in the world but because of non-biodegradable wastes it is losing its fertility. There are some kind of wastes which can be turned into composts, a viable source of energy but the plastic wastes like polyethylene, PET bottle are non-biodegradable and can cause many impacts on the environment.

Plastic is manufactured from crude oil and the energy used for recycling is less than the energy use of the production of virgin products. And producing virgin plastics cause the emission of carbon-di-oxide and sulfur-di-oxide in the atmosphere where the recycling of plastic can decease the emission and protect global warming.

Recycling also protects water from pollution, as plastic is non-biodegradable, since the wastes which is made by polymer can leach chemical both the surface and under water and decrease the fertility of soil, recycling can protect that.

### 13.4 Economic benefits**:**

Most of the companies manufacture plastic from raw materials in Bangladesh. If they start using recycle plastic that can save their money and the price of the products will be less than the virgin products. So the companies will eventually get more consumers and the consumer also can afford to buy more plastic products which are necessary.

And by starting recycling plastic companies can create more job opportunities than before. They don't need much education for recycling and can earn their livelihood easily.

### 13.4 Economic consideration**:** When it's about pyrolysis process, economic benefits play an important role. A company that recycles plastic has to follow the market rule, and has to find the consumers for their products. And for that they have to face some challenges like:

- Are they getting enough pyrolysis raw materials for their products?
- Are they able to keep the quality of the products compared to the virgin one?
- Are they able to follow the plastic products standards?
- Public attitude about recycled products.

## 14 Application of project and future work:

1. The obtain fuel could be utilized in diesel generators, vehicles such as tractor and also passenger vehicle as such as car.
2. The fuel has to be refined at the industrial establishments based on the results of which small scale industry can be established.
3. As there is a high demand of crude oil and due to its sky reaching prices we could take up this project to setup large or small scale industries and produce the fuel locally at much cheaper rates directly benefiting the national economy.
4. The application of this project help in reducing the dependency on the gulf countries and promote asset towards innovation.

# 14 Results and discussions:

1. Through our experimentation we concluded that about 600to 750ml of diesel fuel could be obtained by burning 1kg of plastic .burning 1kg of plastic in an open environment produces 3kg of co2, whereas by converting it into fuel and burning it reduces 80% of co2 emission which results in to be environmentally friendly.
2. Lesser emission of unburnt hydrocarbons in waste plastic pyrolysis oil compared to that of diesel.
3. The diesel or oil thus obtained has a higher efficiency with around 30to 40% low production cost compared to that available in the market.
4.

# 15 Limitations:

1. High carbo9n monoxide emissions compared to that of currently available diesel in the market.
2. High emissions at lesser loads compared to that of higher load working engines.
3. For efficient use of diesel grade fuel of waste plastic blending it with normal diesel is necessary.

## 16 Conclusion:

The aim of this study was to document and asses the plastic wastes management state in Bangladesh. The result is that this study has produced a set of suggestions and pointed observations regarding the current state of plastic industry in Bangladesh.
The early chapters on the elementary principles of plastics sciences served as a guide throughout the research. That is because since the plastic waste management in Bangladesh is still quite manually done, the basic principles were enough to make sense out of them.
For the empirical research the interviews suggests that large companies are still not very active in starting their own recycling operations whereas the smaller ones are quite the opposite- their business model is based on recycled plastics.

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