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CONVERSION OF PLASTIC WASTE TO LIQUID FUEL

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Abstract: **Municipal solid waste management (MSWM) constitutes one of the most crucial health and environmental problems facing authorities in the Khartoum State (Sudan). The analysis showed that Khartoum State produced around 1,040,250 tons of solid municipal waste annually 12.7% of it plastic which is 132,112 tons. Studies say that the liquid (oil) yield of thermal pyrolysis of plastic waste is between 80-90%. Modification made by Aspen Hysys program for thermofuel process to improve the efficiency of the process.**

***Key words*— PYROLYSIS, PLASTIC WASTE, FUEL, and ENVIROMENTAL PROBLEMS.**

I. INTRODUCTION

Plastic is a high molecular weight material that was invented by Alexander Parkes in 1862. [1] Plastics are originally composed of polymers. The term polymer means a molecule made up by repetition of simple unit.

Plastics are a generic group of synthetic or natural materials, composed of high-molecular chains whose sole or major element is carbon. In common usage the terms plastics, polymers and resins are roughly equivalent. A plastic material is 'any one of a large group of materials consisting wholly or in part of combinations of carbon with oxygen, hydrogen, nitrogen, and other organic or inorganic elements which, while solid in the finished state, at some stage in its manufacture is made liquid, and thus capable of being formed into various shapes, most usually through the application, either singly or together, of heat and pressure.'. [2]

Plastics are light-weight, durable, and versatile, allowing their incorporation into a diverse range of applications. The consumption of plastic is growing every day due to the differences of uses of it. Thus the plastic waste is also increase daily

From 2009 to 2010 the global production of plastics increased by 15 million tonnes (6%) to 265 million tonnes, confirming the long term trend of plastics production growth of almost 5% per year over the past 20 years. In 2010 Europe accounted for 57 million tonnes (21.5%) of the global production and China overtook Europe as the biggest production region at 23.5%.[3]

II. SCENARIOS OF PLASTIC WASTE MANAGEMENT

Due to population increase, the demand for plastic products has steadily increased over the last 40 years. Since plastics are non-biodegradable, they cannot be easily returned to the natural carbon cycle; hence the life cycle of plastic materials ends at waste disposal facilities [4]. There are several methods for disposal of municipal and industrial plastic waste, i.e. landfill, incineration (energy recovery), true material recycling (similar recycled product or monomer recovery), and chemical recovery [5]. The suitable treatment of plastic wastes is one of the key questions of the waste management and is important from energetic, environmental, economical and political aspects [6].

In most developed societies domestic organic waste, including plastics packaging, is disposed of in sanitary land filled or by incineration. During early 2000, the largest amount of plastic wastes is disposed of by land filling (65–70%), and incineration (20–25%). Recycling is only about 10% [7].

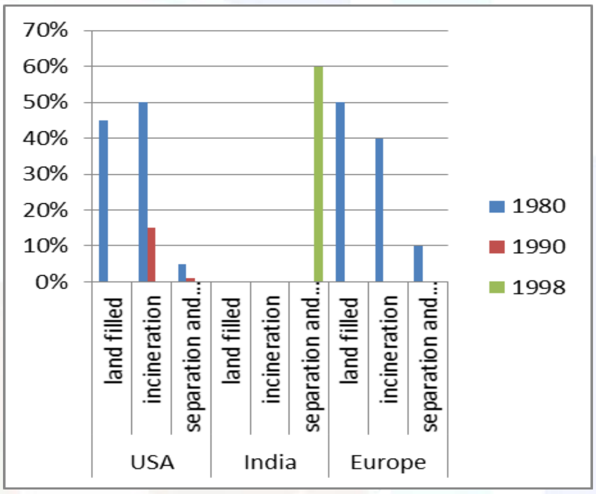

Fig 1: Scenarios of plastic waste management

This figure varies from country to country, however they are approximately nearer to it with some exception. In Japan, the percentage of municipal plastic wastes, as a fraction of MSW, that was land filled in the early 1980s was estimated to be 45%, incineration was 50%, and the other 5% was subjected to separation and recycling. In the USA, more than 15% of the total MSW was incinerated in 1990; only about 1% of post-consumer plastics were recycled. In India, during 1998 around 800,000 tonnes representing 60% of plastic wastes generated in India was recycled involving 2000 units. This level of recycling is the highest in the world. The corresponding figure for Europe is 7%, Japan 12%, China 10%, and South Africa 16%. In Europe 2006 marks a milestone as the first year when recovery and disposal rates of used plastic were equal. The recovery rate of post-consumer end of life plastics now stands at 50% and disposal stands at 50%. The recycling rate for post -consumer plastics has increased to 19.7% up from 18% in 2005 and energy recovery has increased to 30.3% up from 29% in 2005. Of the 11.5 million tonnes recovered 4.5 million tonnes were recycled as material and feedstock and 7.0 million tonnes were recovered as energy. The overall material recycling rate of post-consumer plastics in 2006 was 19.7%, with mechanical recycling at 19.1% (up 2.5% point over 2005) and feedstock recycling at 0.6% (down 1% from 2005). The energy recovery rate was up by 1.5% from 2005 to 30.3%, reflecting the stricter legislation on landfill in several Member States [8]. From the above recent data it is clear that there is an increase in the recycling operation (material and energy) compared land filling due to strict regulations and growing awareness.

III. THERMAL PYROLYSIS

Traditional treatments for post-consumed plastics were recycled, landfilled or incinerated. However, landfill of the post-consumed plastics has potential problems because of limited land resource and high durability of plastics. Incomplete incineration may generate poisonous substances and causes serious health problems. Other methods like gasification and bioconversion are mainly used for organic materials. Therefore, significant amount of energy can be produced by converting plastic waste to oil. This could be an alternative energy resource for substituting fossil fuels. This conversion process called thermolysis (pyrolysis).

Pyrolysis, also termed thermolysis (Greek: pur = fire; thermos = warm; luo = loosen), is a process of chemical and thermal decomposition, generally leading to smaller molecules. Semantically, the term thermolysis is more appropriate than pyrolysis, since fire implies the presence of oxygen and hence of reactive and oxygen-bearing intermediates. In most pyrolysis processes, however, air is excluded, for reasons of safety, product quality, and yield. [3]

The first report of turning plastic wastes into oil came in 2001 from the People’s Daily, China’s English language newspaper. An oil refinery in Hunan province had succeeded in processing 30, 000 tonnes of plastic wastes into 20,000 tonnes of gasoline and diesel oil that satisfied the provincial standards. Wang Xu, who built the refinery in 1999, started experimenting with waste plastic processing in the 1980s, and later teamed up with Hunan University doctoral tutor Zeng Guangming who gave him scientific advice on decomposing plastic wastes. In the 1980s, Illinois microbiologist Paul Baskis in the United States modified the process to produce lighter, cleaner oil, but failed to convince investors until 1996, when a company called Changing World Technologies began development with Baskis to make the process commercially viable. Again, the plants with a capacity of 1000 tonnes/annum have been running nearby many cities in China [9]. Thermal cracking or Pyrolysis, involves the degradation of the polymeric materials by heating in the absence of oxygen. The process is usually conducted at temperatures between 350 °C and 900 °C and results in the formation of a carbonized char (solid residues) and a volatile fraction that may be separated into condensable hydrocarbon oil consisting of paraffins, isoparaffins, olefins, naphthenes and aromatics, and a noncondensable high calorific value gas. The proportion of each fraction and their precise composition depends primarily on the nature of the plastic waste but also on process conditions. The extent and the nature of these reactions depend both on the reaction temperature and also on the residence of the products in the reaction zone, an aspect that is primarily affected by the reactor design. However, the thermal degradation of polymers to low molecular weight materials requires high temperatures and has a major drawback in that a very broad product range is obtained.

IV. PROBLEM STATEMENT

The amount of plastic waste collected daily at Khartoum is about 362 ton daily.

Table 1: the waste type and composition in Khartoum state

	Waste Type	Percent %
1	Paper and cardboard	11.8
2	Plastic	12.7
3	Organic Matter	49.5
4	Dust and ash	13.4
5	Metals	1.7
6	Woods	0.2
7	Leathers	0.4
8	Glass	3.5
9	Cotton and jute	4.6
10	Couch	0.3
11	others	1.9
Total		100

Source: supervisory authority for cleaning Khartoum state (2011)

Table 2: Volume of Khartoum state daily tonnage of waste generated and collected in 2005 - 2011.

year	Average tonnage generated/day	Average tonnage collected/day
2005	1650	1450-1500
2006	1815	1600-1650
2007	2005	1800-1850
2008	2250	2000-2105
2009	2500	2300-2400
2010	2700	2500-2550
2011	2850	2600-2700

Source: supervisory authority for cleaning Khartoum state (2011)

It is noticed that the increase in the amount of waste from 1500 to 2700 ton per day within seven years. This indicates that in the coming few years the waste amount will still enlarge to an extent that might cause disaster, so there should be ways and means to get rid of these huge waste amounts and transform it into useful and highly demanded applications.

V. Solution Approach and Methodology

Let discuss some commercial methods that produce fuel from plastic waste.

1- Thermofuel process

In the Thermofuel process, plastic waste is first converted to the molten state and then ‘cracked’ in a stainless steel chamber at temperatures in the range 350–425°C under inert gas The hot pyrolytic gases are condensed in a specially designed two-stage condenser system to yield a hydrocarbon distillate comprising straight- and branched-chain aliphatics, cyclic aliphatics and aromatic hydrocarbons. The resulting mixture is essentially equivalent to regular diesel.

The essential steps in the Thermofuel pyrolysis of plastics involve:

- Uniformly heating the plastic within a narrow temperature range without excessive temperature variations;
- Ensuring the plastic is homogeneous and stirred to prevent hot-spots;

- Excluding oxygen from pyrolysis chamber, yet at the same time allowing rapid egress of the hot pyrolytic vapours;
- Constantly removing the carbonaceous char by-product before it builds up on the pyrolysis chamber walls and acts as a thermal insulator, thereby lowering the heat transfer to the plastic;
- Reactive distillation, which means the hot pyrolytic vapours can condense and be returned to the main pyrolysis chamber until the correct carbon chain length is achieved;
- Careful condensation and fractionation of the pyrolysis vapours to produce diesel of good quality and consistency.

2- SMUDA PROCESS

Smuda Process is a continuous process where the mixed plastic feedstock is fed from an extruder into a stirred and heated pyrolysis chamber The extruder acts as an airlock to exclude oxygen and also to preheat and melt the polymer, so less energy input is required in the main chamber. The pyrolysis vessel operates at a constant level of 60% and the headspace is purged with nitrogen gas. A layered silicate catalyst (5–10% by vol) is added to the plastic melt to give a catalytic cracking reaction . The fuel from the Smuda process is both transportation-grade diesel (85%) and gasoline (15%). The gasoline produced by the process is used in a cogenerator to produce electricity for the process. The diesel has an average olefin content of 10%, a flash point of 70◦C and a pour point of −40◦C. Since the diesel produced catalytic cracking contains approximately 10% olefin.[10]

3- HITACHI PROCESS:-

Hitachi Zosen has developed a stirred tank/kettle pyrolysis process for waste plastic that is characterized by the following features:

- The ability to handle mixed plastic waste;
- A relatively low pyrolysis temperature;
- The automatic removal of char and extraneous matter;
- Double (or triple) condensers;
- Production of kerosene and gasoline fractions.[2]

Study made to modify by Aspen HYSYS program to the thermofuel method as follows:

1- Add screw conveyer with heaters to melt the feed.

2- Use the uncondensed gases in the mentioned heaters.

3- Plastic waste enter the screw conveyer at 30 ◦C. With molecular weight 55.7 ,with composition (polypropylene 0.3, polystyrene 0.3 and polyethylene 0.4) and heated to 220◦C.

4- Heated in the rector to 425-450◦C.

5- The reaction equation is:

$$(C_8H_8)_n + (C_3H_5)_n + (C_2H_4)_n + N_2 \xrightarrow{Heat}$$
$$H_2 + CH_4 + C_2H_6 + C_2H_4 + C_3H_6 + C_3H_8 +$$
$$C_4H_{10} + C_8H_{16} + C_{16}H_{32} + C_{28}H_{56} + C + N_2$$

6- Collect the vapour and cool it in the first cooler to 300 ◦C then the first separator to separate the vapour and the liquid.

7- Then the vapour enters the second cooler which is cool to 175◦C. Then to the second separator to separate the liquid and the uncondensed gases.

8- Add screw conveyer to carry out the residual in the main chamber.

9- Liquid produced is hydrocarbons (C to)

Aspen HYSYS used as simulating program.it gives the following results

Production capacity (plastic) 250kg/h

Yield of the process 82%

Carbon black 3%

Uncondensed gases 13%

The benefit of adding screw conveyers is to provide a continuous process with melted (semi liquid) feed stock which safe time and energy by using the uncondensed gases as preheating the feed stock changing from solid to melted state which reduce the energy used in the reactor and the reaction time.

V. CONCLUSIONS AND FUTURE WORK

It could be concluded, that thermal pyrolysis of plastic waste leads to the production of fuel oil, valuable resource recovery and reduction of waste problem. Thermal pyrolysis of waste plastic waste has also several advantages over other alternative recycling methods. It has been shown that the conversion at lower temperature in the presence of catalyst into liquid is a feasible process. An important difference is that the oil obtained relatively with greater volume and low boiling range in the presence of catalyst as compared to pyrolysis in the absence of catalyst. The total pyrolytic oil can be blended with the gasoline or kerosene. Consequently, evaluation of plastic waste by catalytic pyrolysis is very important from economic and environmental point of view. However, further studies are necessary to utilize pyrolytic oil as liquid fuel or feedback.

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