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Waste plastic between estimation and pyrolysis.

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ABSTRACT

Solid waste plastic is a source of fuel and biodiesel, so we studied the amount of waste plastic in Fayoum and different cities in the world. Also, different techniques of pyrolysis of waste plastic catalytically and non-catalytically and the resultant valuable gases and liquids have been discussed.

Keywords: waste plastic, pyrolysis.

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INTRODUCTION

BACKGROUND

Solid waste is one of the most natural issues at present time everywhere throughout the world. It's created by different human activities, with the expanding populace, rising way of life and industrial advance. It is unsafe for the general wellbeing as well as for social and financial angles. Proper disposal is the principle issue we are confronting. This issue is extremely destructive to human wellbeing and safety, environment and natural sources too. Municipal solid waste differ relies on the level of earning of the consumer, attributes and conditions of the group and human conduct. The higher pay they have the more it produces waste than those with less level of wage. In territories with low earning fall produces solid waste by up to under 0.3 kg/capita/day. In regions with high wages they create more than 1kg/capita/day and not as much as the extent of organic waste to the detriment of recoverable materials, for example, glass, plastic, paper, metal and others [1]. Subsequently, it is imperative to have tenets, controls and rules for the waste management. The advancement of coordinated management framework for the waste has turned out to be more critical. With a specific end goal to accomplish one objective in dispensing with this issue in management waste transfer, the utilization of present day strategies and methods ought to be produced. Egypt's delivered solid waste of 18-25 million tons in a year. In Egypt there's a major contrast between produced amounts of waste and quantity. Rubbish heaping up in the avenues, the municipal solid waste is a burden to the general public; it is exceptionally hurtful in the parts of wellbeing, environment and economic [2].

ECONOMIC VALUE TO THE COMMUNITY

Primitive methods are still prevalent now in dealing with this waste in Arab countries. Modern methods were developed in the treatment of waste. Through which can be converted from the source of contamination to an economic commodity. Solid waste is considered a national treasure, if managed properly, because of recycling. The use of most components, elimination of random materials can be of economic value rather than having negative effects on the environment and health [2]. Department in charge of the waste management should find a solution for this solid waste problem. They should find a way to integrate solid waste management. Deal with the quantities of waste generated previously and current. Also, the burning of solid waste became a major environmental problem. The management system should comprise of proper collection process, proper treatment, and proper daily disposal. The Ministry of Local Administration and its executive play an important role in this kind of problem. In the process of public hygiene, waste should be disposed safely all over the country which relies primarily on the right governmental procedures. Generation of plastic waste all over the world is increasing continuously due to industrial growth and changed in consumption and production patterns. Rapid urbanization and economic development have been resultant as increment in plastic consumption in Arab countries, particularly Egypt due to high population growth rate. Waste plastic and its management has become a major problem. Cities having low economic growth are also participating as the largest producer of waste plastic in the form of plastic packaging material, poly shopping bags, polyethylene terephthalate (PET) bottles and other house hold items containing major percentage of plastic material, so it is necessary to find the alternative ways for the disposal of mixed waste plastic.

THE PYROLYSIS OF PLASTIC

After such a large number of research and studies, it has been found that properties of unrefined petroleum got from waste plastic are like the current hydrocarbons and it can be utilized as a part of diesel motors or for energy creation. Plastics are manufactured natural material and essentially created by polymerization. With substantial utilization of fossil energy and powers, the world will be confronted with deficiency of energy and natural worries sooner rather than later if there are no other options. Then again, sustainable power sources and waste streams can be handled for generation of energy and powers. Pyrolysis of waste plastic is an efficient technique to take care of waste plastic issue and to create quality fluid fuel which can have comparative properties to the generally utilized petroleum fuels. Plastic molecular mass is high and it is conceivable that to enhance the quality and execution. Polymers of plastic are tremendously diminished and can be expelled into the required shapes. Plastics are manufactured polymers that can be shaped by pressure or heat. There are two main types of plastics, which are thermoplastic and thermoses. Approximately 85 to 90% of plastic from our daily life can be recycled or can be used for the production of synthetic fuel [3,4].

OBJECTIVES OF THE INVESTIGATION

- 1- Study of the present circumstance for the management of waste (municipal solid) in Fayoum governorate.
- 2- Study fruitful universal encounters in the management of waste, for example, (China, UAE/Abu Dhabi and Japan).
- 3- Work for the change and rebuilding of the present framework in the city solid waste management.
- 4- Work to accomplish the sound managing of metropolitan solid waste to be advantageous to all.
- 5- Proposal of how to find source to support the metropolitan solid waste management.
- 6- Illustrate the significance of reusing civil solid waste.
- 7- Achievability of processing municipal waste with an emphasis on the practicality of the creation of diesel from plastic waste and private financial comes back from the generation of diesel from plastic waste.
- 8- Investigation of producing diesel from plastic waste by using a catalyst.

LITERATURE REVIEW ON PLASTIC PYROLYSIS

Wastes are defined as all materials that are not utilized by the proprietor, but rather it are conceivable that I need to use by another individual through reuse or reusing or transfer. Municipal solid waste may be defined as the waste from home and commercial places, and the cleanliness of the lanes, trash containers and most of which is not hazard, for example(paper, plastic, metal and glass) and a little part chance, including (electronic waste, batteries and compartments of paints), etc.

Integrated waste management

It is a coordinated procedure managing appropriate waste collection, exchange and legitimate disposal. By and large intends to approach the perfect case which is to research general wellbeing insurance and defilement of the encompassing, environment and the greater part of its components for the protection of natural resources. Components of the integrated system for waste management are:

Reduced waste from source

A program is composed basically to reduce the quantity of waste left by the person from home to work and his whereabouts. Hence lessen the amount of waste that goes to the site for waste treatment.

Re-use

Reuse is the action of using the objectives again and again for their original purpose or another different function.

Waste recycling

One of the strategies utilized generally in many developing as well as developed countries, the craft of solid waste reusing and usage.

Heat treatment

The craft of consuming waste exceptional plastic to lessen the volume of wastes and decrease their amount, in addition to the production of energy can be used in several areas.

Healthy backfill waste

Adopted all over the world for a long period of time, the art of backfill health waste is a way to get rid of waste because of the expansion of urbanization and growth population, depends on the space available for reclamation, which made them think that the treatment of such waste could give good economic returns [5].



Fig (1): Hierarchy of solid waste management

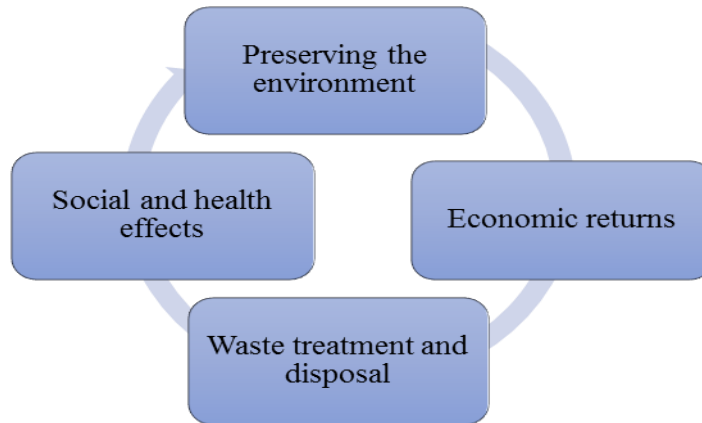


Fig (2): Components of the integrated system for waste management.

Municipal solid waste problem in Egypt

The despicable transfer and consuming of solid waste speaks to a noteworthy environmental issue. Expanding quantity of strong waste every day needs fundamental legitimate treatment, preparing and transfer. Solid waste has turned into a worldwide problem. It requires persistent collaboration and coordination between partners, government officials, business analysts and professionals. The factors as a result of the continuously growing solid waste are population development, change in way of life, advance in the generation, techniques in enhancing bundling and promoting, building new urban areas, lack of environmental mindfulness among the group, lack of data spread, absence of joining and coordination in the organization, inability to take after fitting approaches to manage solid waste, lack of conceivable outcomes, poor plant and equipment support, and finally, lack of information [6].

Table (1): Solid waste generated in Egypt in 2010 [2].

TYPE OF WASTE	QUANTITY GENERATED/TONS
Municipality solid waste	13,806,269
Construction and demolition waste	41,748,603
Agricultural waste	30,000,000
Industrial waste	2,906,895
Medical waste	3,146,254
Cleansing waterways waste	3,58,509
Total	94,936,530

Municipal waste collection systems in Egypt

Municipal solid waste composed of organic (56%), paper (10%), plastic (13%), glass (4%), scrap (2%) and other (15%). However, there are two waste collection systems in Egypt: the traditional and the modern systems.

The traditional system

Combining the wastes by scavengers, the separation process accomplished by the families of scavengers

Modern system

Wastes are collected by companies, then transferred to the separation in the collection stations

Facts about the collection and recycling of municipal solid waste in Egypt

- Ten cleaning companies are contracting with the provinces of Alexandria, Matrouh, Algharbia, North Sinai, South Sinai, Port Said and Suez) local 8 - foreign 2.
- Civil association 621 is involved in waste collection.
- Number of scavengers in greater Cairo is about 175,000, according to the report of the Ministry of State for Environmental affairs.

Table (2): Municipal solid waste generated daily in 2012.

Governorate	Generated waste(t\ d)	Waste collection proportion (%)	Accumulated waste (kg/m2)
Cairo	15000	70	500000
Giza	4500	60	3000000
Alexandria	4000	65	344830
Qalyoubia	3500	60	2000000
Dakahlia	4500	50	1800000
Algharbea	3500	47	750000
Menoufia	2500	40	280000
Albheria	3500	50	60000
Kafr El-Sheikh	2500	50	227000
Alsharkia	2200	45	510000
Damietta	1100	55	100000
Ismailia	600	60	35000
Port Said	650	70	650
Suez	400	40	459040
Fayoum	720	65	292500
Beni-Suef	800	62	150000
Minya	1300	55	500000
Asyut	700	65	250000
Sohag	1100	60	281845
Qena	1080	60	258480
Aswan	800	70	385240
Luxor	470	75	107022
AlbahrAlahmar	450	60	500000
Matrouh	300	60	146429
North Sinai	250	60	140000
South Sinai	500	70	512000
Alwady Algaded	100	40	60
Total	57020		

The collection of municipal solid waste is not covered efficiently resulting in:

- Accumulation of waste on the get together/compartment focuses.
- Presence of unlawful open dumps which may be consumed or burned in the slums.
- Tossing the solid waste metropolitan landfills in the open to environmental and wellbeing dangers.
- Decomposition of organic matter prompts the exit of methane start flames and tainting of groundwater.

As shown in Table (3), there are five areas allocated for waste sorting, recycling and disposal.

Site	Allocated space (acre)
West of Belbais road	714
East Belbais	715
Mountain Al Ryahyat Valley	1197
Mount Hay	1236
Karetgandy	1477

2.5 The actual situation or problem of municipal solid waste in Fayoum

Fayoum is considered as one of the cities which are experiencing the issue of solid waste management. Inappropriate transfer of solid waste expands the creation of more waste. Absence of dumpsites or area for waste is another problem. Solid waste heaping were initiated in the city, which turned into a place for creepy crawlies, rodents and different creatures. Burning of waste on the streets added to the environmental contamination rate. The governorate daily production of waste is 720 ton, with accumulation of 295.500 Mt. The only waste recycling plant was closed recently. Also, there is no presence of clean landfill. Table (4) shows the municipal solid waste generated in each city of Fayoum governorate [2], according to the last update of 2017 report.

Table (4): Amount of municipal solid waste and population in Fayoum governorate cites (2012)

City	Population(Capita)	Municipal solid waste generated (Ton)
Fayoum	805,902	77,015
Itsa	588,780	15,330
Tamiya	373,324	29,200
Ibshway	345,695	6,935
Snurs	508,953	47,450
Yusuf al Siddiq	323,918	7,300
Total	2,946,572	183,230

Table (5): The annual revenue for the management of municipal solid waste in Fayoum.

City	Conservative allocations	Governmental allocations	Service fees
Fayoum	425,000	350,000	699,332
Ibshway	Nil	Nil	85,000
Yusuf al Siddiq	Nil	Nil	35,000
Tamiya	Nil	Nil	123,432
Itsa	Nil	Nil	48,000
Snurs	Nil	Nil	242,000
Total	545,000	350,000	1,232,764
Total revenue =			2,127,764

Table (6): The annual expenses for the management of municipal solid waste in Fayoum.

City	Waste collection expenses\ creation of new facilities	Annual depreciation expenses	New equipment and trucks	Operating and Maintenance	Total annual wages and benefits
Fayoum	350,000	Nil	3,050,000	620,190	3,326,144
Ibshway	300,000	250,000	1,000,000	500,000	1,440,000
Yusuf al Siddiq	200,000	150,000	400,000	150,000	150,000
Tamiya	20,000	Nil	Nil	240,020	394,295
Itsa	Nil	Nil	670,000	8,000	Nil
Snurs	190,000	Nil	Nil	4,002,000	6,012,000
Total	1,060,000	400,000	2,070,000	5,520,210	11,322,439

Total expenses =20,372,649 EGP

Table (7): Cost estimation of services needed to be developed in Fayoum municipal solid waste management.

Service needed to be develop	Probably estimated cost (M EGP)
Accumulations removing	4.5
Improving of collection and transport facilities	20
Establishment of recycling centers	5
Establishment of sanitary landfills	30
Total	59.5

China

With China's rising purchasing power of individuals, the municipal solid waste in 2003 reached 148 million tons while the industrial waste was about 1 billion tons. Industrial solid waste in 2010 was about 4.2 billion and municipal solid waste rose to 160 tons. Burial of 90% of municipal solid waste and a small percentage turned into compost, also, rapid development in the construction of cemeteries and the number of 495 burials landfill in 2008. Recyclable waste collection by the poor is considered a source of income for them, rest tend to recycle waste in the municipal system [7-9].

UAE Abu Dhabi

The Abu Dhabi Center for Waste Management (TADWEER) is the body in charge of directing all exercises identified with the procedure of waste administration in Abu Dhabi.

Strategy of Waste Management Center in Abu Dhabi

- Development of an integrated waste management system in Abu Dhabi, according to the Abu Dhabi 2030 plan.
- Use of the latest and best technologies in the field of waste management.
- Preserving the environment and contributing to sustainable development.
- Encourage producers to reduce waste and re-use or recycle.
- Public awareness to be an active partner in waste management.
- Provide a distinctive and comprehensive service for waste management services sector.
- Application of an integrated system to regulate the process of collection and transportation of waste to the landfill.
- Involve waste producers in the application of waste management systems, and highlight the role of the community in creating a healthy environment and the introduction of waste activities and services.
- Application of an integrated system of supervision and inspection.
- Build a database to provide indicators and basic statistical data, which in turn helps to the development of strategic plans and decision support.
- Encourage enterprises producing various types of waste to adopt policies and technologies aimed to reduce waste from processing waste and various commercial activities.
- Encourage enterprises producing various types of waste to deal with commercial waste as a source and additional economic return.
- Creation of economic investment in the field of waste

Fees on waste producers

- The burden of levies on waste makers comes surprisingly close to Abu Dhabi waste management strategy to lessen waste generation in Abu Dhabi in line with the vision of the government in 2030 to be among the best five governments at the level of the world and for a sustainable environment.

-Targeted impose tariffs on waste producers system in all establishments of assorted types (business, mechanical, expert, and development and craftsmanship and so on) of government and semi-government and private working in the Emirate of Abu Dhabi.

Classifications included the burden of non-tax framework on waste makers who working in the zones of waste management services (accumulation, transportation, treatment, transfer, control, cleaning ... and so

on), where will be liable to permit expenses, licenses and endorsements for practicing the profession. The ascertained tax was estimated in view of the generation rate of established waste (metric tons) every year, as indicated by the sort of movement and the created span. Approved tariff raised 225 dirhams for every ton of waste every year (comparable to 45% of the actual cost brought about by an Emirate for each ton to discard squander every year).The most extreme yearly gross value of the tariff has been distinguished to 50,000 dirhams and at least of 225 dirhams for every year.

Facilities can work to decrease the estimation of the tariff through the commitment to execute projects to diminish waste creation taking after:

- 1- Recycling of waste through an agreement with specific organizations for recycling.
- 2- Waste separation from the source of production.
- 3-Application of green eco-accommodating innovations to decrease the volume of waste produced.
- 4- Contract with the affirmed organizations with the center for the exchange of waste to reusing spots and places disposal environmentally friendly ways.
- 5-Suggest any different methodology with a specific end goal to decrease the generation of waste facility [10].

Achievements rotate in2013

- Application of the electronic framework declined to screen holder areas and weights and application system development following tanker autos waste.
- Exempt organizations from the new tariffs on the waste in the first year to support speculation.
- Adoption of the show framework for the exchange of a wide range of wastes exchange approach to determine the size and sort of waste and full session of the development of the waste item to the transporter to the last treatment plants and landfills.
- Establishment of database on the size and nature of waste happen month to month.

Japan

Incorporated system for the managing of solid waste in Japan is viewed as the predominant system covers all parts of waste generation and division, transport, sorting, preparing and transfers with the capacity to accomplish the most extreme effectiveness of the utilization of the benefits of this system which are: clean and safe neighborhoods, high productivity of resource utilizes and lower expenses of waste managing accordingly of lower phases of waste transfer.

- Decline industrial waste up to 403.7 Mt(48.1 Mt of non-industrial waste and 79.2 % of MSW) in 2008 in contrasted with 421.7 Mt (52.7 Mt of non-industrial waste and 77.4% of MSW) in 2005 [11,12].

United Kingdom

The process of waste generation in the UK consists of three sections: demolition and development of business, industrial waste and waste gathered by nearby experts. The total waste decreased form 288.6 million tons in 2008 in comparison to 307.1 million tons in 2006 and 325.3 in 2004.57% of the nationals of England are re-utilizing some of the things, for example, papers and plastics, etc. [13].

United State of America

Villa Delfina program reward to recycling

Program logo display that if the inhabitants know more about how they recycling their part in maintaining the cleanliness of the city and the environment, the program offers rewards and discounts and gift cards for Everyone recycles waste [14]. Clarification of international experience in the field of waste collection and recycling of the importance of the put integrated system in Egypt to deal with the waste problem.

Wisconsin and Connecticut

Applied the law in the state divisions to alter the techniques for buy needs Government to dishearten the buy of items that are utilized for one-time just To support the buy of items can be utilized for different circumstances.

What's more, recognized the US objectives for diminishment program demonstrates the discount rate to be accomplished in certain years, and the advancement steps or ways to gauge or to evaluate the advance of the lessening program, and distinguish an offered year to begin (WFP). The nine states in the northeastern piece of America framed council to decrease waste involving individuals from the industrial sector and government and some non-benefit associations of the board, the council sets up the objectives and benchmarks for the program and the advancement of an organized instructive program and the arrangements of devices to empower the diminishment of waste. The council likewise created uncommon bundling rules and item bundling, select needs for preparation without filling, low assembly, jugs can be returned or utilization or repackaged, can be reused bottles, compartments made of reused materials.

Applied the law in the state divisions to alter the techniques for buy needs Government to dishearten the buy of items that are utilized for one-time just To support the buy of items can be utilized for different circumstances.

Production of diesel from plastic waste using a catalyst

People start producing fuel by using waste plastic. Only 8% of waste plastic is reused in the U.S., 15% in Western Europe, and much less in developing nations, this recycle of plastic can potentially keep large quantities of plastic out of landfills and out of the oceans. More than 500 billion pounds of new plastic is fabricated each year and approximately 33% of that is used for one time and thrown away. As so little amount of plastic is reused, the waste of plastic need to be reframed as an underused resource vs. landfill destined. According to the United Nations Environment Program, global plastic consuming has gone from 5.5 Mt in the 1950s to 110 Mt in 2009. Due to the technological limitations or improperness of recycling, only a fraction of that material resurfaces in new plastic products. Energy production by incineration can be considered the second most attractive option for waste plastic using. This process can decrease the amount of waste by more than 90%. But sometimes it is highly criticized due to the lack of recovery of raw materials, low efficiency of energy and high expenses of gas [15].

Factors affecting Plastic pyrolysis

The major factors that influencing the process of plastic pyrolysis and pyrolysis product molecular distribution are chemical composition of the feedstock, cracking temperature and heating rate, operation pressure, reactor type, residence time and utilization of catalyst. These factors are mentioned in this part as follows.

Chemical composition of feedstock

Products of pyrolysis process are depending on the chemical structure and composition of the plastics to be pyrolyzed. In addition, the chemical structure of the used plastic also has an effect on the whole processes of pyrolysis. In the fact, waste plastics may be polluted before reusing or recycling process that could also has effects on the pyrolysis process and its yield. Plastic has a large molecular weight that was invented by Alexander Parkes in 1862. Plastics are also named polymers. The term polymer refers to a molecule created by repetition of monomer.

The most components of the total plastic content of MSW, plastics have a high calorific value (i.e., polyethylene 43 MJ/ kg, polypropylene 44 MJ/kg, polyvinyl chloride 20 MJ/kg), extensively, classification of plastics has high-density polyethylene, low-density polyethylene (LDPE), polypropylene and polystyrene. Likewise, plastics are categorized by their chemical composition of the polymer's backbone and side chains. Some major groups in this categorization are the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastics can likewise be grouped by the chemical procedure utilized as a part of their synthesis, for example, condensation, poly addition, and cross-linkage. Low-density polyethylene (LDPE) is

utilized for its strength, adaptability, and relative straight or hardness. It is utilized to make bottles that require additional adaptability. To exploit its quality and durability, it is utilized to deliver basic supply sacks and junk packs, squeezable containers, recoil wrap, extend movies, and covering for drain containers. It can likewise be found in toys, holder tops, and bundling. Polypropylene (PP) is known for its high dissolving point, which makes it perfect for holding hot fluids that cool in the jugs (for instance, ketchup and syrup). It can be produced to be adaptable or unbending. It is utilized to make holders for yogurt, margarine, takeout dinners, and store nourishments. It is additionally use for pharmaceutical bottles, bottle tops, and some family unit things [16-18].


Symbol	Short Name	Scientific Name	Used In
	PET	Polyethylene Terephthalate	Water bottles, PET Bottles, etc.
	HDPE	High Density Polyethylene	Milk/detergent Bags, Carry bags, Container etc
	PVC	Polyvinyl Chloride	Cables, Pipes, Floorings etc
	LDPE	Low Density Polyethylene	Carry bags, films
	PP	Polypropylene	Medicine bottles, cereal liners, Packaging films etc
	PS	Polystyrene	Foam Packaing, Tea Cups, ice cream cups, etc
	O	Others	Thermoset plastics, Multilayer & Laminated Plastics, PUF, Bakelite, Polycarbonate, Melamine, Nylon etc.

Fig (3): Classification of plastics according to the compound structure and applications.

Cracking temperature and heating rate

Temperature is a standout amongst the most vital working variables, since the temperature commands the cracking reaction of the polymer materials. Not the greater part of the polymer materials can be split by expanding the temperature. Van der Waals drive is compelling between the molecules, which pulls in particles together and prevents the collapse of particles. At the point when the vibration of particles is sufficiently awesome, the molecules will evaporate from the surface of the object [19]. So, the carbon chain will be broken if energy induced by Van der Waals force along the polymer chains is higher than the enthalpy of the C-C bond in the chain [20]. This is the motivation behind why high molecular weight polymer is disintegrated as opposed to be bubbled when it is warmed. In principle, the temperature of the C-C bonds thermal breaking ought to be steady for a given kind of plastic. However, this temperature has been found to contrast in various studies. For instance, the temperature when PP begins cracking was accounted for at 380 °C in Ciliz et al.'s [21] results but it is measured to be 650 °C in Demirbas's results [22]. The two utilized similar batch process reactor and thermo gravimetric analysis. As indicated by gave plans, the in all likelihood reason is the distinction in the temperature estimation area where the temperature sensors were found. There was critical temperature slope along the mechanical assembly in which the dissolved plastic at the base of a settle bed cluster reactor had much lower temperature than that on the top surface of the reactor. It was likewise found that the space temperature in the pyrolyzer was emphatically impacted by the item vapor. Distinctive areas of the temperature sensors in various reviews are accepted to be a standout amongst the most imperative components on the diverse breaking temperature detailed, researched the temperature profile along a tube warmed by external furnace [23]. Large temperature variation was observed between the ends and the center of the tube (Fig. 4). Clearly, there was significant heat loss at both ends of the tube reactor.

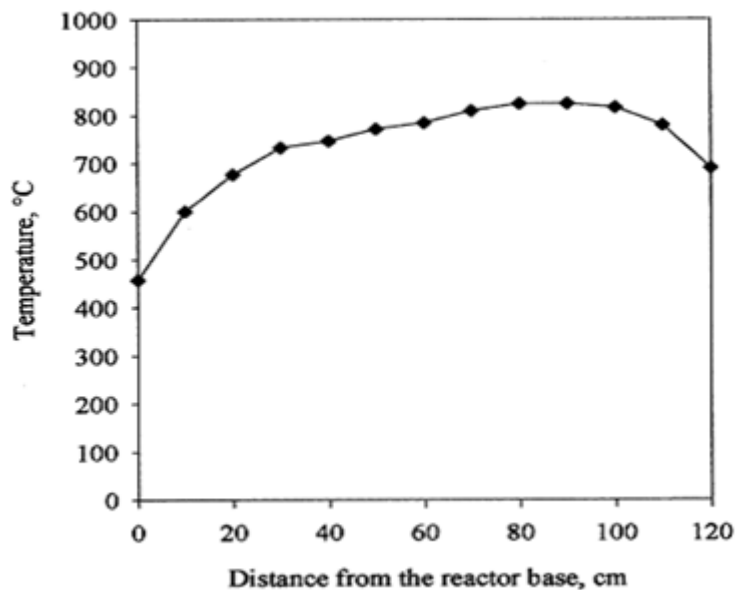


Fig (4): The relation between temperature and distance from the base of the reactor

The non-catalytic or thermal pyrolysis of polyolefin is a high energy, endothermic process requiring temperatures of at least 350–500 °C. In some studies, high temperature as 700–900 °C is essential in achieving decent product yields. 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. In addition, reactor design also plays a fundamental role, as it has to overcome problems related to the low thermal conductivity and high viscosity of the molten polymers. Several types of reactors have been reported in the literature, the most frequent being fluidized bed reactors, batch reactors and screw kiln reactors. Characteristics of thermal degradation of heavy hydrocarbons can be described with the following points;

- High production of C1s and C2s in the gas product.
- Olefins are less branched.
- Some olefins are made at high temperature
- Gasoline selectivity is poor; i.e. oil products are a wide distribution of molecular weight.
- Gas and coke products are high.
- Reactions are slow compared with catalytic reactions.

The plastics were initially pyrolyzed at 600°C producing condensable oils and non-condensable gases. The non-condensable gases were further heated in a second reactor either at 500 or 800°C. Heating at 800°C caused decomposition of the gases to intermediate products (methane, ethylene and condensable oils), which were converted over a nickel-based catalyst into multi-walled carbon nanotubes (MWCNT) with similar yields and properties regardless of the plastic feedstock. Heating at 500°C had no effect on the composition of non-condensable pyrolysis gases. However, the carbon materials produced over the catalyst had different yields and structures implying the influence of plastic feedstock on the properties of materials were more pronounced at lower synthesis temperature. At 500 °C, the mixture of plastics (MP) non-condensable pyrolysis gases were converted into carbon Nano cages and MWCNTs having higher graphitization degree compared to carbon materials from PP and LDPE, which were mainly MWCNTs. Furthermore, the carbon yield was the highest using PP followed by LDPE and MP samples (32%, 21% and 3%, respectively). The lower carbon yield using LDPE compared to PP was attributed to the lower concentration of unsaturated hydrocarbons in the pyrolysis gas, while the low yield using MP was caused by the presence of PET in the plastic mixture, decreasing the reactivity of hydrocarbon gases over the catalyst [24].

Thermal pyrolysis of both virgin and waste plastics as well as other hydro-carbonaceous sources has been studied extensively in the past. A good number of these thermal cracking studies are on polyethylene, polypropylene and polystyrene. On the other hand, only a few have worked on the thermal decomposition of

other common plastics such as polyvinylchloride, poly methyl methacrylate, poly urethane and polyethylene terephthalate. Mostly, thermal cracking outcomes in liquids with low octane value and higher deposit substance at normal temperatures, therefore an inefficient procedure for delivering gasoline range fuels. The gaseous production acquired by thermal pyrolysis are not reasonable for use as fuel product, requiring further refining to be upgrades to useable fuel products. A few scientists have looked to enhance thermal pyrolysis of waste polyolefin without utilizing the using of catalysts; however these progressions either yielded insignificant changes or included another level of complexity and expenses to the system [16].

The differ in the temperature at first surface of touch with the plastic and the temperature of the plastic near the surface was calculated by Karaduman, A., *et al.* for comparison, which is measured generally minor and constant in this researching study. Thus, the temperature at the reacting surface is chosen for observing the cracking temperature of plastics. In Shah et al., blend of post-consumed plastics of PE, PP and PS was pyrolyzed in a fixed-bed batch reactor at various temperatures for 60 minutes [25]. It was found that higher reaction temperature benefit the gas production and generation of highly molecular weight products in the liquid (Figures5&6).

Figure 5 shows the gas chromatography (GC) analysis resulting from the liquid products with the temperature on the bends demonstrating the cracking temperature. It showed that the liquids generate at high cracking temperatures have low flash-off percentage at the exactly same GC throughout the analysis. This shows larger amount of high molecular weight constituents in the liquid [25,26]. Similar conclusion was also founded in other researches using pure plastics and fluidized-bed, semi-batch reactor [25].

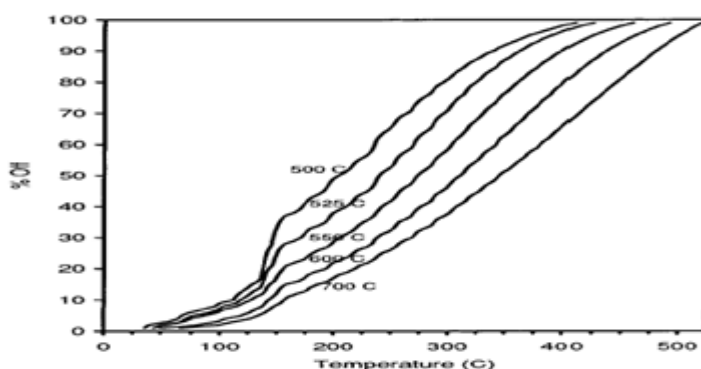


Fig (5): GC analysis results of liquid plastic pyrolysis.

In any case, the general gas proportion of the gas production become greater with the raising of cracking process temperature up to 730°C while the liquid production proportion become smaller with the cracking temperature in the full range of the using temperature [27], as shown in Fig. (6).

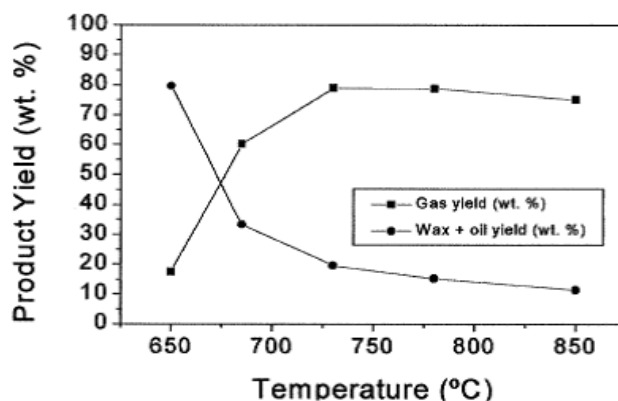


Fig (6): Influence of temperature on product distribution

Plastic feedstock was heated to the cracking temperature. The temperature stand relatively constant till all feedstock has been pyrolyzed. For that reason, heating rate is typically applied as the temperature indicator as an alternative reaction temperature in a slowly pyrolysis operation. It was found that the heating rate is typically changed from 10 to 100 °C/m in a previous pyrolysis researches [28,29]. In Saha and Ghoshal's [30] study on pyrolysis of Coca Cola drink PET bottles. Effect of the heating rate in reaction process was analyzed by using thermo gravimetric analysis (TGA) as shown in Figure 7.

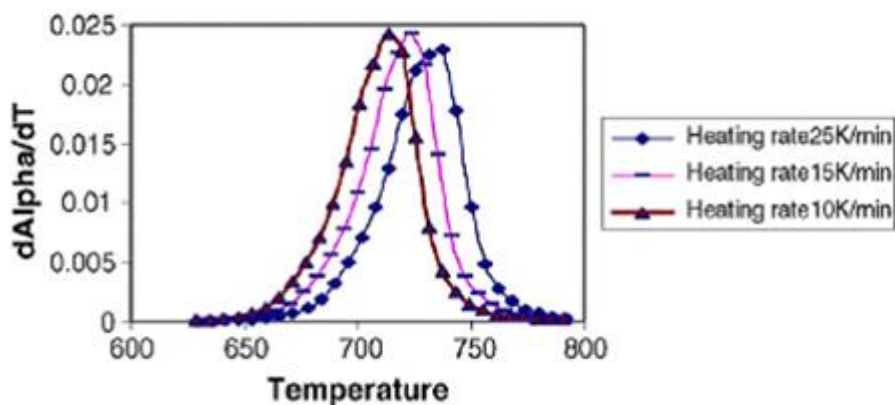


Fig (7): Reaction rate as a function of temperature and heating rate in pyrolysis of CocaCola soft drink PET bottle

Temperatures effect on fuel oil. 1Kg polyethylene was cracked in the reactor and differences in the reaction time are noted. At various temperatures the production of gases is also vary. At 180°C, gas and residues separation is starts and after 205°C the product of gas is 50.5 % and residues is 48.5%. At 210°C gas production is about 52% and residue is 46.8%. At final temperatureof250°C, the residue is approximately 44.9% and the gas product is 53%.

The measuring quantity (1Kg) of plastic material is heated to the reactor with variety of temperatures and the crude oil produced throughout the process is collected. Residue remain through the reaction is also isolated at the end of the process. The temperatures effect on oil product from high density Polyethylene. In the beginning, oil production is increased with temperature and after a specific temperature, oil production became constant. At temperature 178°C, the gas produced was 62% and proceed with certain increment up to 250°C at which the percentage of gas production is 62.72%. At a temperature of 300°C the percentage of the gas production is 56.2% [31,32].

Pressure

Operating pressure has a specific effect on both the pyrolysis process and the products. Boiling points of pyrolysis products become greater under a high pressure, thus, under pressurized environment heavy hydrocarbons are further pyrolyzed instead of vaporized at the giving process temperature. Figure 8 shows effect of pressure on the hydrocarbon number and their fractions in pyrolysis productions of PE. In effect, under pressurized pyrolysis, further energy is needed for more hydrocarbon cracking. Also it was found that high pressure increases the yield of non-condensable gas and decreases the yield of liquid productions (Fig. 9). The usual molecular weight of gases production also decreases with the increasing of pressure. The effect of pressure on the concentration of double bond, C=C, of the liquid production was not specific as reported by Murata et al. [33] In summary, pressure has major influence on the pyrolysis reaction and the distribution of PE pyrolysis productions, but has a minor influence on the double bond components. Thermal cracking of PE is known to continue via free radical system taking after random scission. At first on heating polyethylene breaks to create a few long radical chains, which stay in the liquid phase [34].

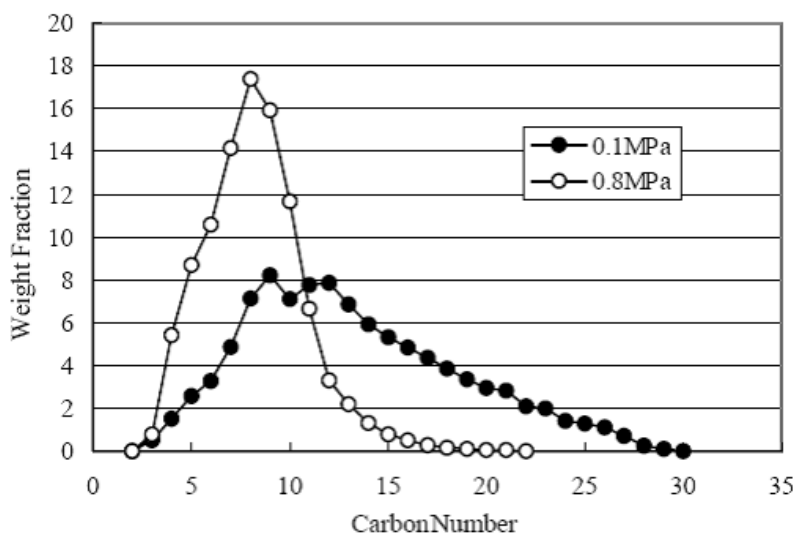


Fig (8): Effect of pressure on the distribution of PE pyrolysis products.

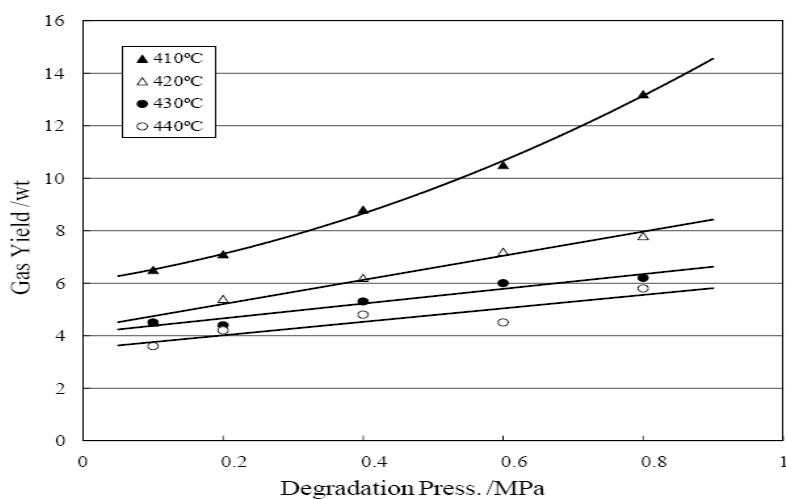


Fig (9): Effect of pressure on the yield of gas at different temperature.

Arbitrary scission creates short chain length radicals who are vaporous and go into gas phase. These radicals may extract hydrogen to create the corresponding alkanes or go through beta-scission to shape an olefin and a radical of smaller molecular weight. The raising in pressure from 1 to 6 bar could be credited to upgraded cracking on account of higher residence time creating a smaller molecules, which is reflected by the increasing in gas yield. In a more residence time the pressure raise up to 36 bar in around 12 m and from that point stays constant, however the yield of liquid increases progressively showing occurrence of some parallel recombination reactions. The sudden decrease in olefins combined with increase in paraffin with the expansion in pressure from 1 to 6 bars can be credited because of recombination of olefins. However on further increment in pressure from 6 to 36 bar the relative rate of the all paraffin and olefins remains about the same, yet there is specific difference in the diverse sorts of paraffin and olefins e.g. the relative dissemination of n-paraffin, iso-paraffin and cyclo-paraffin in the group paraffin and the relative distribution of alpha-olefins and different olefins in the group olefins.

Reactor configuration

The kind of reactor for plastic pyrolysis significantly effects on the heat transfer rate, blending of plastics pyrolysis products, residence time and the reflux level of the initial products [17]. According to the feeding and product removal procedures, the pyrolysis reactor is classified into (batch, semi batch and continuous reactors). The materials are fed to the reactor in batches [35] for pyrolysis either toward begin of

the procedure or after the majority of the fed materials are handled. Secondary pyrolysis may happen in semi-batch reactors and does not happen in batch reactors. Semi-batch reactor separate the pyrolysis productions continuously immediately when they are proceed but the feed materials are attached initially before the pyrolysis procedure begin. Some semi-batch method utilizes inert bearer gas to help remove the pyrolysis products. Batch and semi-batch reactors are mostly connected on research [28,36]. Abbas-Abadiet *al.* [37] directed the PP pyrolysis in semi-batch reactor utilizing Fluid Catalytic Cracking (FCC) catalyst at 450°C. From the experiments, they found that high liquid yield of 92.3 wt. % was gotten. A portion of the batch and semi-batch reactors were likewise equipped with stirrer that running at various speed relies upon the required setting. In continuous reactor [38-42], the feed materials are inserting from one part and the productions are driven out from the other part of the reactor.

Residence time

The meaning of residence time contrasts in different reviews. In quick pyrolysis or continuous pyrolysis procedure, it refers to the contact time of the plastic on the hot surface all through the reactor. However in slowly pyrolysis and batch procedure, the residence time implies the duration from the time when feedstock plastic begin to heat to the time when the productions are isolated. The long residence time supports a further transformation of the primary productions along these lines yielding more thermal stable productions, as, light molecular weight hydrocarbons, non-condensable petroleum gases [26,43,44]. Perkin Elmer Gas Chromatography and Mass Spectrometer (GC/MS) analysis of polypropylene waste plastic to naphtha (2nd fractional) fuel (Fig. 5) in accordance with the different retention times and trace masses diverse sorts of hydrocarbon compounds are showed up in the analysis result index (Table 8). Many compounds are raised on the analysis of carbon range from C4 to C20, based on the retention time and trace mass following hydrocarbon compounds [45]. In slowly pyrolysis, the longer residence time encourages the carbonization process and produces more tar and char in the productions [46,47], the pyrolysis conditions, residence time and target products are given in Table 8.

Table (8): Pyrolysis processes classification.

Process	Heating rate	Residence time	Temperature (°C)	Target Products
Slow carbonization	Very low	Days	450-600	Charcoal
Slow pyrolysis	10-100K/m	10-60 m	450-600	Gas, oil, char
Fast pyrolysis	Up to 1000K/s	0.5-5 s	550-650	Gas, oil, char
Flash pyrolysis	Up to 10000K/s	<1 s	450-900	Gas, oil, char

Transition temperature range in the catalytic pyrolysis (Fig. 10) is lower than the thermal pyrolysis (Fig. 11) which is the reason that the rate of oil creation is more likewise. It was watched that, measure of gasses and wax delivered through pyrolysis is inversely proportional to the amount of fuel oil created.

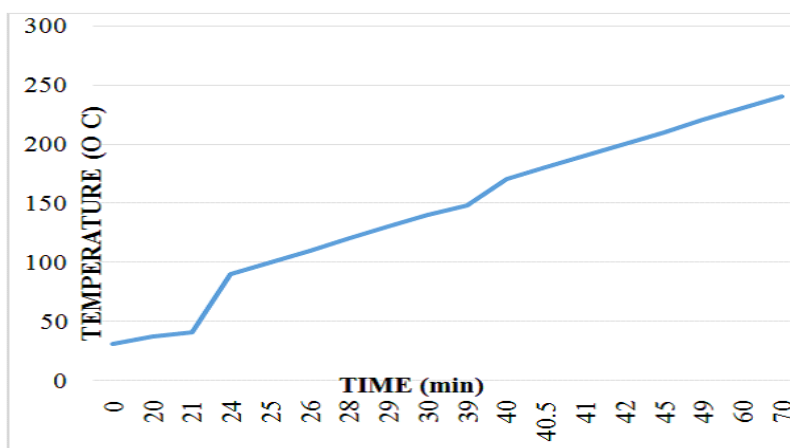


Fig (10): Time temperature graph for catalytic pyrolysis.

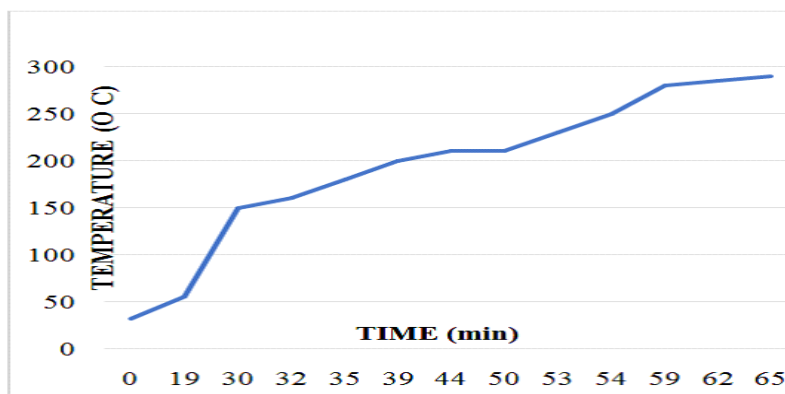


Fig (11): Time temperature graph for thermal pyrolysis

The GC/MS analysis of the plastic oil get out with pyrolysis without catalyst was carried out and the results are summarized which is given in the following Table (9).

Table (9): GC/MS analysis of plastic oil.

Retention time (m)	% Area	Name of Compound	Molecular Formula
2.6	3.467	Cyclohexane,1-Methyl	C ₇ H ₁₂
2.783	8.393	Trans-2-Methyl-4-NButylthiane, S,S-Dioxide	C ₁₀ H ₂₀ O ₂ S
2.88	7.913	Dodecane,1-Fluoro-	C ₁₂ H ₂₅ F
4.06	7.27	Trans-2-Methyl-4-NPentylthiane, S,S-Dioxide	C ₁₁ H ₂₂ O ₂ S
4.2	8.452	Dodecane,1-Fluoro-	C ₁₂ H ₂₅ F
5.65	8.569	Trans-2-Methyl-4-NButylthiane, S,S-Dioxide	C ₁₀ H ₂₀ O ₂ S
5.78	6.639	Dodecane,1-Fluoro-	C ₁₂ H ₂₅ F
7.24	4.804	Trans-2-Methyl-4-NPentylthiane, S,S-Dioxide	C ₁₁ H ₂₂ O ₂ S
7.39	4.646	Henriacontane	C ₃₁ H ₆₄
8.79	2.497	Trans-2-Methyl-4-NButylthiane, S,S-Dioxide	C ₁₀ H ₂₀ O ₂ S
8.91	2.848	Tridecane,6-Methyl-	C ₁₄ H ₃₀
10.23	1.401	Trans-2-Methyl-4-NButylthiane, S,S-Dioxide	C ₁₀ H ₂₀ O ₂ S
10.35	1.791	Henriacontane	C ₃₁ H ₆₄
11.6	1.013	Trans-2-Methyl-4-NPentylthiane, S,S-Dioxide	C ₁₁ H ₂₂ O ₂ S
11.7	1.131	Henriacontane	C ₃₁ H ₆₄
12.87	0.512	Trans-2-Methyl-4-NPentylthiane, S,S-Dioxide	C ₁₁ H ₂₂ O ₂ S

From the GC/MS analysis of the LDPE plastic oil sample, it is observed that the carbon number present in the oil is in the range of C₇ to C₃₁ with a retention time (RT) ranging from 2 to 13m [48]. With the exception of the batch reactor for pyrolysis in a closed system, residence time is hard to be controlled straightforwardly however can be balanced by modifying other operation parameters, for example; feeding rate, bearer gas flow rate and production discharge rate. Residence time was then, calculated for these controllable operation parameters. Secondary pyrolysis cracking happens when residence time is sufficiently long, which upgrades the yield of gases product. Higher value of V/m speaks to longer residence time in Figure (12). The Y axis is the

change of HDPE to gaseous product [47]. There is a huge impact on the transformation when the residence time differs in a specific range through the non-catalyst thermal reaction [44,49].

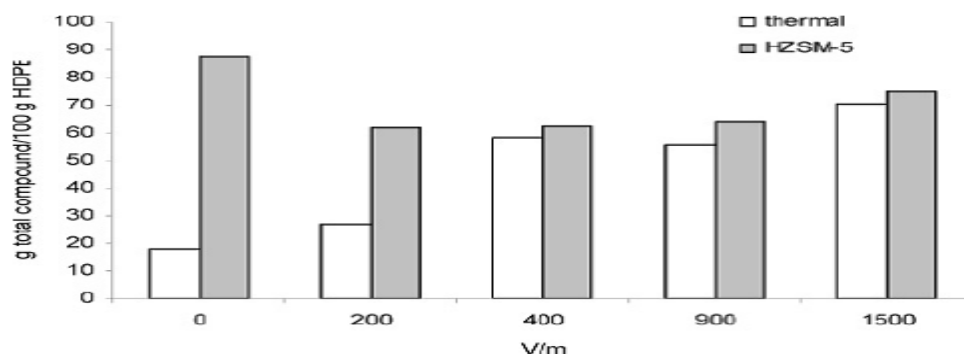


Fig (12): Influence of residence time on the production of gaseous product of HDPE thermal and catalytic cracking

Use of catalyst

Keeping in mind the end goal to improve plastic pyrolysis reactions and change the dispersion of pyrolysis products, catalysts are generally utilized as a part of research and industrial pyrolysis forms. For example, thermal degradation with nickel silica catalytic cracking of high and low density polyethylene, polypropylene and polystyrene blend movement was observed. GC/MS analysis is demonstrating first carbon crest at C5. Adding nickel silica catalyst during the production, very nearly 8% of gas products were framed from HDPE, LDPE, PP and PS cracking with hydrocarbons (C1-C4) with a high extent of olefins. In the polypropylene and polystyrene degradation, the request of movement is strongly adjusted contrasted with the low and high density polyethylene plastics. The product distribution of the polypropylene and polystyrene cracking over these impetuses is subjectively like those of HDPE and LDPE with liquid hydrocarbon blends as predominant products. Polypropylene has a CH₃ group and polystyrene has a benzene ring compound. All analysis results demonstrate that blend sample material with promising catalytic properties for the transformation of polymeric wastes to liquid feedstock for refinery was produced. The greatest yield of the transformation fuel and the least deposit acquired at 400 °C, which is likewise the temperature comparing to the most extreme cracking rate of poly olefins. The created fuel has a high concentration of aromatics, and the gasses are chiefly methane, ethane propylene and butanes [50]. The ideal conditions considered for this work were: at 430°C under 950 psi (6.5 Mpa) H₂ pressure for the length of 2 h. The dechlorination procedure of PVC demonstrates that the evolved HCl gas could be quantitatively isolated from the degradation results of the plastics at lower temperatures. The influence of various catalysts on the product distribution for PVC and Vacuum Gas Oil (VGO) systems were evaluated and the outcomes were looked at. The presence of VGO expanded the general transformation in the binary co-processing reactions contrasted with the single component reaction. The rate of change in the co-processing system relied on the chemistry and composition of the PVC, VGO and catalyst materials. It demonstrates that the catalytic co-processing of PVC with VGO is an achievable procedure by which PVC and VGO materials can be changed over into transportation fuels at bench scale [51]. Conical spouted bed reactor is a reasonable technology for in situ catalytic pyrolysis of waste tires, without issues of stability, isolation, or bed agglomeration. FCC catalyst significantly effects on product circulation and composition, expanding the yield of diesel portion, from 9 % wt at non catalytic pyrolysis to 50% wt. An exceedingly aromatic +C11 liquid is gotten, at the expense of gasoline non-aromatic fraction, because of the alkylation and condensation reactions that support the arrangement of naphthalene derivate compounds. Accordingly, in order to meet the commercial fuel standards, the liquid ought to be subjected to hydro treatment processes [52]. Fly ash-derived amorphous silica–alumina catalysts for LDPE pyrolysis were combined effectively and economically by the fusion of fly ash with NaOH, trailed by enactment by co-precipitation. Synthesis parameters, for example, the NaOH/fly ash weight ratio and activation time had impacts on the execution accomplished by the catalysts. Fly ash-derived silica–alumina (FSA) catalyst (1.2-8) synthesized with a NaOH/fly ash weight ratio of 1.2 and an activation time of 8h demonstrated the best execution terms of catalytic activity and generation cost. Catalytic performance of FSA (1.2-8) was comparable with that of commercial catalysts and it was presumed that FSA could be a decent possibility for catalytic use in the reusing of waste plastics [53]. Bentonite can be utilized for the procedure as a catalyst. It is a permeable made out of aluminum phyllosilicate, basically unclean clay comprising generally of montmorillonite. There are

diverse sorts of bentonite, each named after the individual dominant element, for example, potassium (K), sodium (Na), calcium (Ca), and aluminum (Al) [54]. Waste plastics blends with ZnO catalyst (20%) to recoups fuel effectively in the batch procedure. Transformation rate was 87.19% including liquid and light gas and rest of rate was dark solid residue. It is hard enough to be used for street or rooftop covering. Liquid product analysis indicated C3-C36 carbon length. Product fuel has aromatic group compounds, for example, Benzene, Toluene, Ethylbenzene, Styrene, (1-methylethyl)- Benzene, propyl-Benzene, α -Methyl styrene, 2-propenyl-Benzene, 3-butenyl-Benzene, bis-1,1'- (1,3-propanediyl)Benzene and so on. Benzene group compounds showed up from polystyrene plastic has aromatic compounds. Fuel shading is light yellow and fuel scent is plastic and benzene smell. The vast majority of the aliphatic compounds are available in product fuel including alkane, alkene, and alkyl gathering. Fuel can be utilized in internal combustion motors and deliver power utilizing extensive generator since product fuel has long chain hydrocarbon. Utilizing this procedure can change over every waste plastic into liquid fuel and save environment waste plastic problem at a certain time. Waste plastics are making natural issue, for example, land fill, dumping and incineration issues [55]. Sequential changing pyrolysis and catalytic procedure in a nonstop system has been effectively tried for the transformation of HDPE and PS into liquid and gaseous fuels utilizing Hydrogen HY-zeolite catalyst for the catalytic improving of pyrolysis gas produced in a pyrolyzer. The impact of the reforming temperature and weight hourly space velocity (WHSV) on the product yields; the liquid attributes and the gaseous creation have been researched for both HDPE and PS samples. There were huge impacts of the changing temperature and WHSV on the products yields for both HDPE and PS. Expanding the changing temperature and decreasing WHSV have brought about an expansion of gaseous and solid products while the liquid product decreased. The most extreme oil creation for HDPE (70.0 % wt) and PS (88.1% wt) were acquired at the pyrolysis temperature of 450°C and WHSV of 4. Valuable aromatic, C2, C3 and C4+ gasses (>75 % mole) and branched species in the light oil extend (C5-C15, >70 %wt.) were the principle components of the gaseous and liquid products for HDPE, which were attributed to the molecule structure of HDPE, the generally direct acidity and the huge opening size of the HY-zeolite catalyst. In the case of PS, C2 and C3 gasses (>65 mole %) were the fundamental components of the gaseous product, the amount of gaseous products was low to serve in as a fuel gas either for motor or for the SPCR procedure. Also, the liquid products of PS consisted of the most part monocyclic aromatic hydrocarbon, for example, styrene and benzene, and lower concentrations of possibly hurtful polycyclic aromatic hydrocarbons. High quality gaseous product can be utilized as a fuel either to drive gas motors or for dual-fuel diesel motors. It can likewise be utilized as a heating source for the pyrolysis reactor [56]. Pyrolysis of HDPE waste utilized as a part of the type of carry bags gives yield as liquid fuel, gas and waxy residue. In pyrolysis, the temperature range 450-550 °C gives greatest percent of oil and less yield of wax. At a temperature around 500 °C, the rate of oil got is quick. By utilizing catalyst in pyrolysis process, the response time can be limited upto an hour for 200-300 gm of plastic waste. The percent of oil can be expanded and wax amount can be diminished with the assistance of catalyst. The oil acquired by catalytic pyrolysis has higher calorific value (33,494 to 36,425KJ/Kg) when contrasted with pyrolysis without catalyst (30,145-30,563KJ/Kg). Subsequent to examining pyrolysis by utilizing characteristic zeolite and alumina catalysts, it is concluded that as yield acquired with alumina is higher than that of normal zeolite and calorific value decided with alumina is additionally higher so alumina is a better as catalyst. The oil acquired without catalyst and with alumina and common zeolite has hydrocarbon portions from C4 to C37. Oil got with alumina has extensive variety of hydrocarbons and shows nearness of gasoline, kerosene and diesel fractions [57]. Polystyrene and polypropylene waste plastic blend to light review fraction fuel was recuperation with 5% ferric oxide catalyst and 65 °C fractional tower temperatures. Two sorts of temperature was use in the experiment, one was solid waste plastics liquefaction and another temperature profile was light grade portion fuel collection. Collected light grade fraction fuel recuperate rate was 14% and fuel density was 0.72 g/ml. Fuel shading is light yellow, fuel is straightforward and touch off capable. Fuel was examination by GC/MS (Perkin Elmer display Cluras 500) and fuel analysis chromatogram demonstrated carbon chain length C4 to C15. Product fuel has short chain hydrocarbon including alkane, alkene, alkyl, aromatic group, oxygen, and alcoholic group.

Fuel can utilize internal combustion motors and its can deliver power utilizing gas generator. This technology can change over all PP and PS squander plastic into evaluating energizes. Using the technology can remove all waste plastics issue from environment and convert it to light review portion fuel has fragrant aromatic group compounds on the grounds that underlying crude materials have benzene mixes. Fuel can utilize internal combustion motors and its can deliver power utilizing gas generator. This technology can change over all PP and PS squander plastic into evaluating energizes. Using the technology can remove all waste plastics issue from environment and convert it to helpful hydrocarbon fuels [58]. In this procedure, PVC waste plastic changing over significant hydrocarbon compounds fuel and delivered fuel transformation rate

very nearly 71%. In thermal degradation procedure performed with ZnO and initiated carbon to decrease some chlorine rate, fuel was treated with silver nitrate solution for expel chlorine rate. The results deliver fuel carbon anchor begins from C4 to C26 and mixes was benzene derivatives, halogenated, alcoholic, hydrocarbon gathering, oxygen and nitrogen -containing compounds. Fuel has chlorine compound thus deliver fuel can be utilized as a feed stock refinery for further change. The technology can change over liquid halogenated group related hydrocarbon compound fuel and expel PVC squander plastic from spare condition to come to people. PVC waste plastic can stay long period into land fill and discharging toxic gas. The proposed technology can take care of PVC waste plastic issue and deliver hydrocarbon fuel for petroleum refinery and boost up energy sector for not so distant future [59].

Petroleum based fuel has been delivered from waste plastic (polythene)

The ideal catalyst and reactions for catalytic pyrolysis of polythene have been found in view of the yield and thermo physical properties, the mix of silica alumina and zeolite 1 (pore estimate ~4Å) was chosen as the ideal catalyst. The properties of the plastic oil and its chemical composition have been analyzed. The normal chemical formula was observed to be C_{13.18}H_{23.56}, and consequently the execution examination was done in a CI motor. In the execution investigation in motor, despite the fact that the plastic oil indicates inferior comes about when contrasted with diesel, the lower mixes rate oils demonstrate comes about close with that of diesel (B10, B20, and B30). This makes it a strong competitor in the region of exchange fuels. Likewise the mix B20 has low CO emissions than for diesel. Emissions are higher for B20. (v) 64.15% of the creation cost is represented the cost of catalysts. On the off chance that less expensive catalysts can be utilized, the creation cost can be decreased significantly. If the gaseous products and solid can be utilized, then the successful cost will down significantly further. As opposed to thinking of it as similarly and alternate fuel, the useful significance of this method in waste plastic administration includes its value as a substitute fuel, Table (10) shows the optimum properties of plastic oil using different catalysts [60].

Table (10): The optimum properties of plastic oil using different catalysts.

Catalyst	None	BaCO ₃	Z1	SA1	SA2	SA1 + Z1	Z2
Temp.(°C)	450	450	450	425	450	425	450
Liquid collected (mL)	80	50	110	145	130	130	100
After filtration (mL)	60	40	100	130	120	120	90
Calorific value (MJ/kg)	41.35	36.61	45.15	41.36	36.83	44.57	42.24
Viscosity (×10 ⁻³ Ns/m ²)	1.269	1.6534	1.189	1.286	1.199	1.2066	1.2245
Density (g/cc)	0.858	0.9745	0.863	0.947	0.910	0.9265	0.8785
Flash point (°C)	<32	—	<32	<32	<32	<32	<32
Fire point (°C)	≤32	—	36	34	36	35	34
Cloud point (°C)	-3	—	-2	-34	-3	-2	-2
Pour point (°C)	-13	—	-12	-12	-13	-13	-12

Comparison of pyrolysis products and petroleum fuels qualities

Comparison of diesel with plastic derived fuels

Crude oil from waste plastic has made by blended organic compounds. At the point when contrasted and diesel plastic oils sulfur and calorific value is low. **Waste plastic oil (W.P.O.)** will produced consist of a around 70-75% liquid hydrocarbons which included petrol, diesel and kerosene, little measure of residue coke and L.P.G. Table 11 is demonstrating the properties of W.P.O. and diesel. Pawar Harshal1 et al. did review on pyrolysis process for transformation of waste plastic into fuel without oxygen. The procedure inferred that, engine can keep running with full proficiency by fuel produced using waste plastic, Engine fueled with W.P.O. indicates thermal effectiveness up to 75% of the rated power and Brake thermal productivity of the motor with retarded injection timing is observed to be higher. Infusion timing comes the thermal proficiency about 28.2% at full load for standard infusion timing and 32.25% for the retarded infusion timing of the waste plastic oil, appeared in Figure (13) [31].

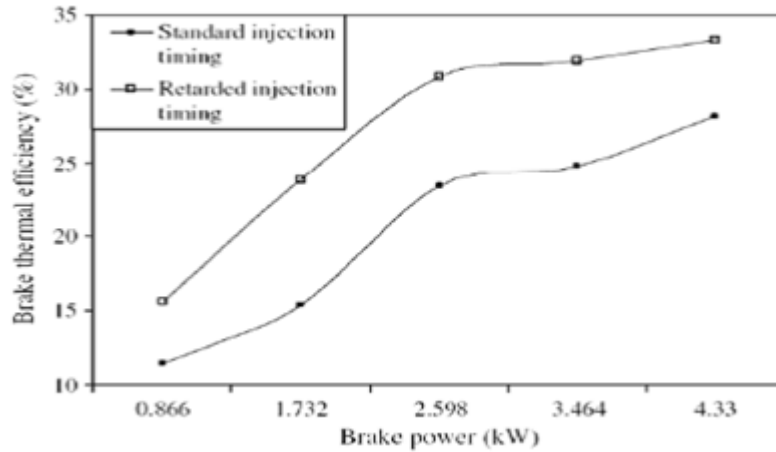


Fig (13): Variation of brake thermal efficiency with brake power

Comparison of waste plastic oil, waste plastic pyrolysis oil and diesel properties are represented in Tables (11&12) [61].

Table (11): Comparison of waste plastic pyrolysis oil and diesel properties.

No.	Properties	W.P.O.	Diesel
1	Colour	Yellow	Orange
2	Density(kg/m ³)	793	850
3	Ash content (%)	<1.01	0.045
4	Calorific value(kJ/kg)	41,800	42,000
5	Kinematic viscosity at 40°C	2.149	3.05
6	Cetane number	51	55
7	Flash point (°C)	40	50
8	Fire point (°C)	45	56
9	Carbon residue (%)	0.01	0.20
10	Sulphur content (%)	<0.002	<0.035
11	Pour point (°C)	-4	3-15

Table (12): Comparison of fuel properties from waste plastic oil and diesel fuel

Property	Waste plastic oil	Diesel
Density (gm/cc) at 30°C	0.8355	0.840
Ash content (%)	0.00023	0.045
Gross calorific value (kJ/Kg)	44.340	46.500
Kinematic viscosity (Cst) at 40°C	2.52	2.0
Cetane number	51	55
Flash point(°C)	42	50
Fire point(°C)	45	56
Carbone residue(%)	82.49	26
Sulphur content (%)	0.030	0.045
Distillation temperature (°C) at 58%	344	328
Distillation temperature(°C) at 95%	362	340

Comparison of diesel from waste plastic pyrolysis oil resulted from pyrolysis process and fresh diesel properties are shown in Table (13) [62].

Table (13): Comparison of diesel from plastic pyrolysis oil and fresh diesel

Properties	Diesel	Plastic pyrolysis oil
Heating value(kJ/Kg)	45814.74	46199.12
C(%)	87	83.79
H(%)	13	11.36
O(%)	-	2
Cl(%)	-	0.03
S(%)	-	-
Density (g/cc) at 30 °C	0.7994	0.8147
Viscosity (cp) at 40 °C	1-4.11	2.49
Flash point(°C)	70	100

Products from the thermal pyrolysis of plastics

Plastics (LDPE, HDPE, PP, PS, and PET) in general and PVC in particular is a major thermoplastic material used in a very wide variety of applications and products. Studies were performed to establish the solubility properties of model materials each available plastic used in this study was pyrolyzed individually at the optimum reaction conditions obtained earlier. Table (14) shows the product distributions obtained from the thermal pyrolysis of the plastics and petroleum residue [4].

Table (14): Products distribution from the thermal pyrolysis of plastics

Material	Gas	Hexane Soluble	Toluene Soluble	THF Soluble	IOM	Soluble (%)	Recovery (%)
HDPE	2.6	11.0	6.5	3.5	76.4	23.6	99.3
LDPE	1.9	15.4	6.5	5.7	70.5	29.5	98.1
PS	5.0	71.2	13.8	0.0	10.0	90.0	99.3
PP	2.1	30.6	14.7	19.2	33.4	66.6	98.4
PVC	51.3	3.6	9.7	4.5	30.9	69.1	97.9
Petroleum Residue	10.3	61.5	15.2	7.9	5.1	94.9	99.0

% Conversion = conversion of plastics/petroleum residue into gases and pyrolysis oils.

The change of municipal waste plastics to liquid hydrocarbon fuel was completed in thermal corruption handle with/without catalyst. Exclusively the experiment was run on waste plastics, for example, HDPE-2, LDPE-4, PP-5 and PS-6. Each of those experiment processes are looked after indistinguishably, every 10 minutes of interval experiment was observed and found during the condensation time changes of individual waste plastics outer conduct distinctive in view of their diverse physical and chemical properties. Essentially, another experiment was run with 2kg of blend of waste plastics in stainless steel reactor. Starting temperature is 350 °C for speedy liquefying and ideal temperature is 305 °C. For glass reactor each examination temperature was kept up by variac meter, when investigation began variac percent was 90% (Tem-405 °C) for brisk liquefying, after dissolved variac percent decreased to 70% (Tem-315 °C) because of smoke arrangement. Normal (ideal) utilized variac percent in this analysis 75% (337.5 °C) Step by step temperature range was kept up by variac meter with legitimate observing. In fractional distillation process we isolated distinctive class of fuel, for example, gas, naphtha, stream fuel, diesel and fuel oil as per their breaking point temperature profile [63].

Table (15): Individual Fuel Production Yield Percentage

Waste Plastic Name	Fuel Yield %	Light Gas %	Residue %
HDPE-2	89.354	5.345	5.299
LDPE-4	87.972	5.806	6.221
PP-5	91.981	2.073	5.944
PS-6	85.331	4.995	9.674
HDPE,LDPE,PP&PS	90	5	5

Table (16): Individual Plastic to Fuel Properties

Name of Waste Plastic Fuel	Fuel Density gm/ml	Specific Gravity	Fuel Color	Fuel Appearance
LDPE-4	0.771	0.7702	Yellow, light transparent	Little bit wax and ash content
HDPE-2	0.782	0.7812	Yellow, no transparent	Wax, cloudy and little bit ash content
PP-5	0.759	0.7582	Light brown, Light transparent	Little bit wax and ash content
PS-6	0.916	0.9150	Light yellow, not transparent	Wax, cloudy and little bit ash content
Mixed Plastic to Fuel	0.775	0.7742	Yellow light transparent	Ash contain present

By-products of the plastic pyrolysis

Pyrolysis of plastics also produces char and gas as by-products. The proportion of by-product in pyrolysis strongly depends on several parameters such as temperature, heating rate, pressure and residence time. Some information about the by-products generated discussed below [64].

Char

Generally, slow heating rate at very low temperature and long residence time maximizes the char formation in pyrolysis process. Even though the char formation in fast pyrolysis process is commonly low, it is worth noting the properties and usage of the char to fully maximize the potential of plastic pyrolysis.

Jamradloedluk et al. [65] analyzed the char properties obtained from the pyrolysis of HDPE plastic waste. From the proximate analysis, volatile matter and fixed carbon were found to be the main components of the char (>97 wt%) while moisture and ash were the minorities. These components were closely related to the proximate analysis of the raw plastic showing that most plastics were composed from almost 99 wt% of volatile matter. The calorific value of the char was about 18.84 MJ/kg. Furthermore, the low sulfur content made it suitable to be used as fuel, for instance in combustion with coal or other wastes.

Gas

The main components of produced gases from pyrolysis of different types of plastic are methane, hydrogen, propane, propene, ethane, ethene, butane and butane [66]. Increase in process temperature increases the production of gases [67,68]. It is reported that 1 kg of plastic feedstock produces around 13 to 26.9% gases by weight. The produced gases from plastic waste have high calorific values.

Miskolczi et al [69] reported that gases produced from agriculture plastic waste have 45.9 and 46.6 MJ/kg HHV. In addition, gases produced from PP and PE has HHV of 50 and 42 MJ/kg respectively [70]. Moreover, similar results for HHV of waste tires (45 MJ/kg) were also reported [71]. The produced gases have high HHV and hence showing potential to be used for energy generation. Additionally, the produced gases can be used in boiler for heating or in gas turbine for the generation of electricity without any flue gas treatment [72]. Moreover on the basis of their composition, 1-butene and isoprene can be recovered through condensation and can be used in tires production [71]. While, after separation from other gases, propene and ethane can be used as chemical feed stocks to produce poly olefins [64].

CONCLUSION

From all above papers in the review for amount of waste plastic in all the world daily (PP, PS, PVC, etc.) and on the other hand the methods used for recycling by catalytic and non-catalytic pyrolysis producing different useful bio-diesel and sources of energy, it is concluded that the waste plastic pyrolysis represents a good alternative fuel and therefore must be taken into consideration in the future. There are also many

successful experiments in the waste management field. These experiments should be used according to local conditions and dealing with waste as an economic resource that should not be wasted.

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