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## Conversion of LDPE and HDPE into Fuels using Nano-Cobalt Carbonate through Pyrolytic Cracking

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### Abstract

Non-biodegradable waste represents a critical ecological test because of its long decay period and unfavourable effect on biological systems. The essential target of this exploration is to examine the possibility of changing over non-biodegradable waste into significant results like petroleum and diesel through synergist processes. Changing over plastic waste into significant fuels adds to asset recovery and diminishes the reliance on limited non-renewable energy sources. The possible advantages, including decreased natural effect, asset recuperation and monetary maintainability, highlight the significance of this imaginative way to deal with plastic waste administration. Various catalysts have been investigated for the process over the years. However, there exists a need for better and more efficient techniques. Thus, we have utilized Nano-Cobalt carbonate for conversion of LDPE and HDPE into fuels, for production of fuel in higher yield owing to the increased surface area to the catalyst. As the world wrestles with a rising measure of plastic waste, this exploration shows a promising way towards a more economical way to deal with the roundabout economy of plastic waste.

**Keyword:** Nano-metal carbonate, LDPE, HDPE, Pyrolytic cracking, Fuel

### 1. Introduction

Non-biodegradable plastics signify a significant danger to ecosystems and human well-being because of their persistence and restricted reusing options. Ordinary waste management strategies, such as landfilling and burning, have demonstrated inconvenience, prompting soil and water pollution, greenhouse gas emissions, and resource consumption [1]. Investigation into overseeing non-biodegradable plastic waste, including LDPE, HDPE, PP and PS, and changing over it into important powers, for example, raw petroleum and diesel faces key ecological and asset challenges. The writing survey reveals insight into the arising worldwide plastic waste emergency and highlights the dire need to foster practical waste administration frameworks. Specialists feature the difficulties of conventional plastic removal strategies and the requirement for inventive methodologies, for example, pyrolysis to moderate the ecological harm brought about by plastic aggregation. The scientist looks at changed pyrolysis strategies, including slow and quick pyrolysis, microwave-helped pyrolysis and synergist pyrolysis, with their separate benefits and restrictions. They elude to past investigations that analyzed the impact of various boundaries, for example, temperature, warming rate and impetuses on the pyrolysis interaction and hence impact the item yield and piece. The survey shed light on arising advances in the field and exhibited the potential for coordinating pyrolysis with different cycles, for example, gasification and burning to further

develop energy recuperation and asset use. Researchers underline the significance of figuring out the substance synthesis of pyrolysis items and their applications in fuel creation and modern cycles. This exploration is essential for the critical worldwide need to handle plastic contamination, increment asset proficiency and accomplish supportable energy advancement. It goes past conventional waste administration practices and offers an answer for the future that joins squander the executives and energy age. In a review named "Pyrolysis of non-biodegradable polymer squander for energy recuperation", the examination of pyrolysis as a technique for handling non-biodegradable polymer squander features the reality of the plastic waste emergency and its ecological effect. Specialists' advantage in pyrolysis, a warm decay process, exhibits its true capacity for separating complex polymers into important items like gases and fluids. This mirrors the developing worry about the removal of plastic waste and its effect on the climate.

Researchers bring up the meaning of learning the compound structure of pyrolysis items and their applications in fuel creation and modern cycles. Their reference to past examinations, which analyzed the effect of different boundaries, for example, temperature, warming rate and impetuses on the pyrolysis cycle and its effect on the exhibition and creation of the product, highlights the significance of expanding on existing information and investigating new boondocks in pyrolysis research. A concentrate by Nguyen et al. in 2023 addresses the difficulties of pyrolysis and stresses the significance of reactor plan and item detachment to accomplish positive outcomes. Studies also depicts the use of the pyrolysis plant in the production of paraffin from different types of plastic waste catalysis. The shortage of energy is a major problem that the plastic industry has been facing nowadays. Based on the report of "The World Energy Council" in the year 1970, the satisfaction of demand for energy is fulfilled by fossil fuels. But it causes the emission of excessive greenhouse gas. Thus it affects the atmosphere and changes the global climate. So, research has been started to analyze alternative sources of generating energy in the laboratory. Conversion of plastics into fuel those are usable is one kind of process to generate alternative resources of energy.

The authors start by emphasizing the global plastic waste crisis and its impacts on biological systems and human health. The traditional disposal techniques like landfilling of the pyrolysis process lead to pollution and decrease the waste materials from the earth. They also have researched alternative approaches to plastic-to-fuel advancements. The research focuses on pyrolysis, gasification, and liquefaction. Pyrolysis includes the thermal decomposition of plastics in the absence of oxygen, bringing about the formation of gases, and fluids. Gasification is the process that uses a controlled amount of oxygen to create gas that can refined into valuable fuels. Liquefaction is the process the converting plastics into fluid hydrocarbons utilizing a catalyst and heat.

In order to increase reaction speeds and product yields, catalysts are crucial. In order to purify waste particles into energizers, catalysts break them down into less complicated hydrocarbons [2]. This helps with the problem of trash removal, increases the production of energy, and decreases the need of petroleum-based products. Zeolites, metal oxides, and mixed metal catalysts are only a few examples of the various types of catalysts used in waste-to-fuel conversion [3]. The choice of catalysts is influenced by things like how the waste feedstock is organized and the desired end results. The catalysts function on the production of significant energizes while also affecting the item conveyance and accelerating the reaction. Utilizing diverse waste products as potential fuel is one of the many advantages of catalytic conversion. It is possible to convert solid waste, plastic trash, agricultural deposits, and even sewage mud into useful energy. This provides a workable answer to the energy demand by reducing the weight of landfills [4]. Numerous catalysts have been utilized, including MCM-

41 [5], ZSM-5 zeolite [3], clinoptilolite [6], and silica-alumina [7]. Catalyst utilization has a crucial role in accelerating the synthetic responses anticipated for a waste transformation. The study aims to reduce the weight on landfills and prevent ecological contamination by working with the conversion of waste materials into useful support by using the right catalyst [8].

However, using nano metal carbonate catalysts has more benefits than using conventional catalysts, such as large surface area, improved synergist movement, and tunable selectivity[9,10]. These catalysts assist in the conversion of waste plastic into hydrocarbon-rich fuels mimicking gasoline and diesel by dissolving complicated polymer structures into smaller hydrocarbon molecules. This procedure lessens the buildup of plastic and offers a creative method for supplying optional fuels, improving energy sustainability and lowering greenhouse gas emissions[11]. Utilizing nanometal carbonate catalysts adds a novel dimension to the management of plastic waste, preparing it for effective waste-to-fuel conversion technologies. The urgent need to address plastic contamination, resource consumption, and energy sustainability is the driving force behind the scientific justification for non-biodegradable plastic waste management and their conversion into significant petroleum and diesel alternatives employing nano-metal carbonate catalysts[12].

The point of this study is to utilize Nano-metal carbonate impetuses to change over non-biodegradable plastics into significant fluid powers in a review, consequently easing strain on petroleum product holds and giving a harmless to the ecosystem garbage removal strategy. The nano-cobalt carbonate impetuses offer benefits like high surface region, higher synergist action, and tunable selectivity. By separating the perplexing polymer structures into more modest hydrocarbon particles, these impetuses assist with changing over plastic waste into hydrocarbon-rich energizes like unrefined petroleum and diesel. This cycle decreases the amassing of plastic, yet in addition offers a creative way to deal with the development of elective powers, hence adding to feasible energy advancement. The utilization of carbonate-based nano-metallic impetuses opens up another aspect in plastic waste administration and makes them reasonable for use in proficient waste-to-fuel advances. The examination reasoning for overseeing non-biodegradable plastic waste and changing over it into significant oil and diesel substitutes utilizing nano-metal carbonate impetuses originates from the earnest need to address plastic contamination, asset consumption and energy supportability.

The research on waste management of non-biodegradable plastics like LDPE, HDPE, PP, and PS, alongside their conversion into important by-products like petroleum and diesel using nano metal carbonate catalysts, addresses basic ecological and resource challenges. By utilizing nano-metal carbonate catalysts, this study seeks to change over non-biodegradable plastics into significant fluid fuels, decreasing the weight on fossil fuel reserves and giving an eco-accommodating waste disposal strategy. This research aims to give a sustainable solution by successfully overseeing plastic waste and producing useful fuels. The reasoning for this research lies in the pressing need to check plastic contamination and upgrade resource effectiveness.

## 2. Materials and Methods

### • **Materials**

Waste feedstock is collected from the university campus area. Collected waste feedstock will be cleaned (2-3) times and then dried for 6-7 hours. The collected material will be ground with the help of a grinding machine which helps to increase the feasibility of the reaction by increasing the surface area of the collected substance. Pyrolysis of the waste feedstock using a Nano-Cobalt carbonate catalyst gives the desired product.

### • **Pyrolytic cracking of HDPE and LDPE using Nano CoCO<sub>3</sub>**

The experiment was conducted inside a muffle furnace (4400 W) attached with a temperature controller. The feed material is placed inside the pyrolytic batch reactor made of mild steel with an internal reactor volume of 2 litres, height of 15 cm and inner diameter 16.5 cm. Ultra cryostat of 5 litres capacity is used to maintain the temperature of water at 20°C. Submersible pump (3.6 W) with a flow rate of 320 litre/hr is placed inside the cryostat to supply the cooling water to the condenser unit. The vapors that have evolved during pyrolysis reaction are condensed in a Cell condenser and the Fuel is collected in the Fuel collector.

### • **Characterisation**

#### • **Thermogravimetric analysis**

The thermal decomposition behavior of plastic wastes was studied by TGA Q50 instrument (TA Instruments, USA). These observations were made under a heating rate of “20 °C per minute”. The pyrolysis process began at an initial temperature of around 22 °C and subsequently terminated at a “final temperature of 390 °C”.

#### • **Rheological analysis**

##### **Melt Flow Index (MFI)**

The melt flow rates of the specimen samples were determined by the procedure of ASTM Method D1238-00. Standard test condition 190/2.16 was used. The flow rate was determined at 190°C using a load of 2.16 kg. The flow rate of the melt was measured by a manually operated extrusion plastometer manufactured by the Tinius-Olsen Testing Machine Co.

#### • **Fourier Transform Infrared spectrophotometer**

The catalyst was characterized using FTIR spectroscopy for the presence of the characteristic functional groups with a Perkin-Elmer Spectrum 100 spectrometer in the range 4000 to 500 cm<sup>-1</sup> over 16 scans with a Universal ATR; the spectra were recorded with a resolution of 4 cm<sup>-1</sup>.

#### • **Pyrolytic Yield**

The different yields of pyrolytic products such as fuel oil, solid residue and pyrolytic gas were calculated as follows.

$$\text{Fuel oil yield, \%} = (\text{Weight of fuel oil} / \text{Weight of plastic wastes used}) \times 100 \quad (1)$$

$$\text{Solid residue yield, \%} = (\text{Weight of solid residue} / \text{Weight of plastic wastes used}) \times 100 \quad (2)$$

The yield of pyrolytic gas was determined by subtracting the sum of fuel oil yield (%) and solid residue yield (%) from 100.

- **Gas composition**

The composition of pyrolytic gas at different operating temperature analysed using multi gas analyser.

- **Elemental Composition**

Elemental composition analysis by CHNS analyzer using ASTM D-5291-96.

- **Octane number**

The octane number of test samples was determined using octane number analyser (Zeltex, USA).

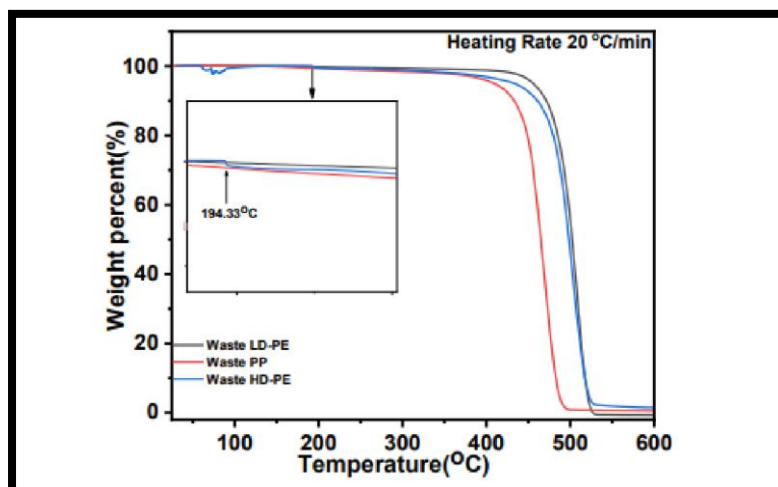
- **Gas Chromatography–Mass Spectroscopy model (GCMS)**

The condensed liquids were analyzed by a Shimadzu Gas Chromatography–Mass Spectroscopy model (GCMS) GCMS-QP 2010s using helium as the mobile phase.

## 2. Result and discussion

- **Thermogravimetric analysis**

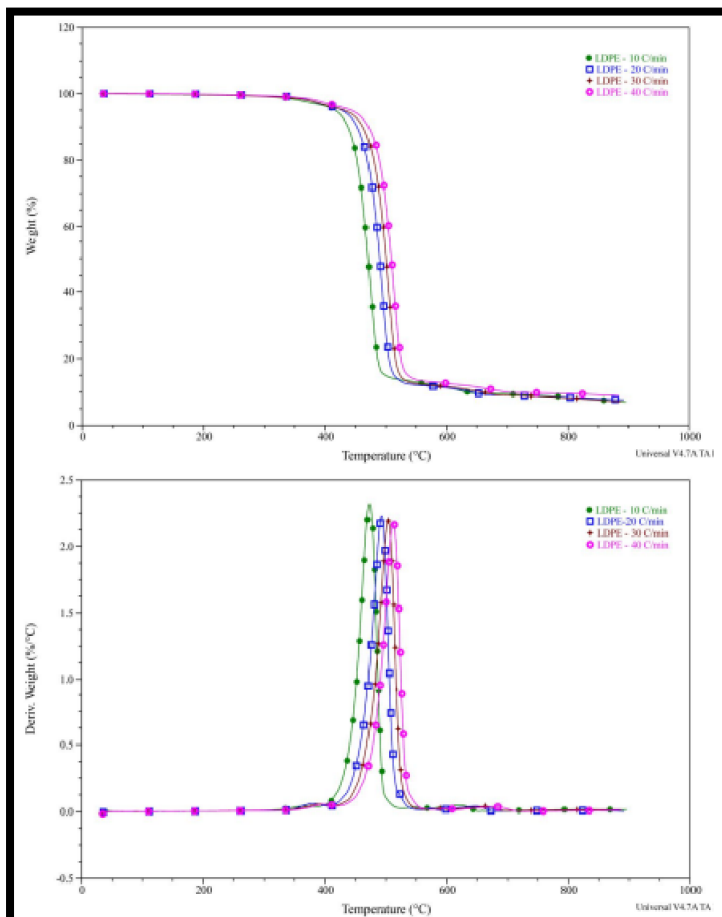
The thermal stability of different polyolefin wastes was assessed using thermogravimetric analysis (TGA)”, as seen in the accompanying figure 1. The temperature ranges at which the degradation of waste “LD-PE and HD-PE” occurs were seen to be “30 °C to 515 °C, 30 °C to 510 °C, 30 °C to 475 °C, and 30 °C to 500 °C”, respectively. The attribute of thermal stability is highly sought after in pyrolysis feedstock due to its capacity to maintain compatibility with the required pyrolysis temperature[13].



**Figure 1: Waste analysed with TGA**

The figure 2, illustrates the “thermogravimetric (TG)” curves corresponding to “high density polyethylene (HDPE)” specimens subjected to varying heating rates inside an inert atmosphere. The weight loss curve obtained under testing conditions exhibited three distinct stages of disintegration for each heating rate. The experiments were performed throughout a temperature range spanning from ambient temperature to 900°C. It was observed that, for certain heating rates, “the thermogravimetric (TG)” curves exhibited a high degree of similarity[14]. The findings of the study suggest that the heating rate plays a crucial role in the liberation of volatile components from the HDPE waste under investigation. Specifically, it was observed that the temperature range associated with the active pyrolysis zone expanded as the heating rate rose. The observed phenomenon of slower breakdown rates and higher

decomposition temperatures in the tested plastic samples may be attributed to the limited time available for polymer molecules to dissipate heat as the heating rates rise. The solid residue obtained at a temperature of 800°C had values that were in closer proximity. The experimental results indicate that the conversion rate of “5% HDPE” waste was seen to be low when subjected to a heating rate of “10°C” per minute at a temperature of 413°C. Conversely, the conversion rate was found to be at its highest when the heating rate was increased to “40°C per minute”. A like trend was seen in the case of “HDPE's 95% conversion”. Two distinct peaks were seen on the DTG curves for the HDPE samples. In comparison to alternative heating rates, the peak temperature was seen to have shifted towards higher temperature values. The “maximum rate of weight loss”, which was found to be “1.532 percent per degree Celsius”, was identified and shown to increase with increased rates of heating[15].

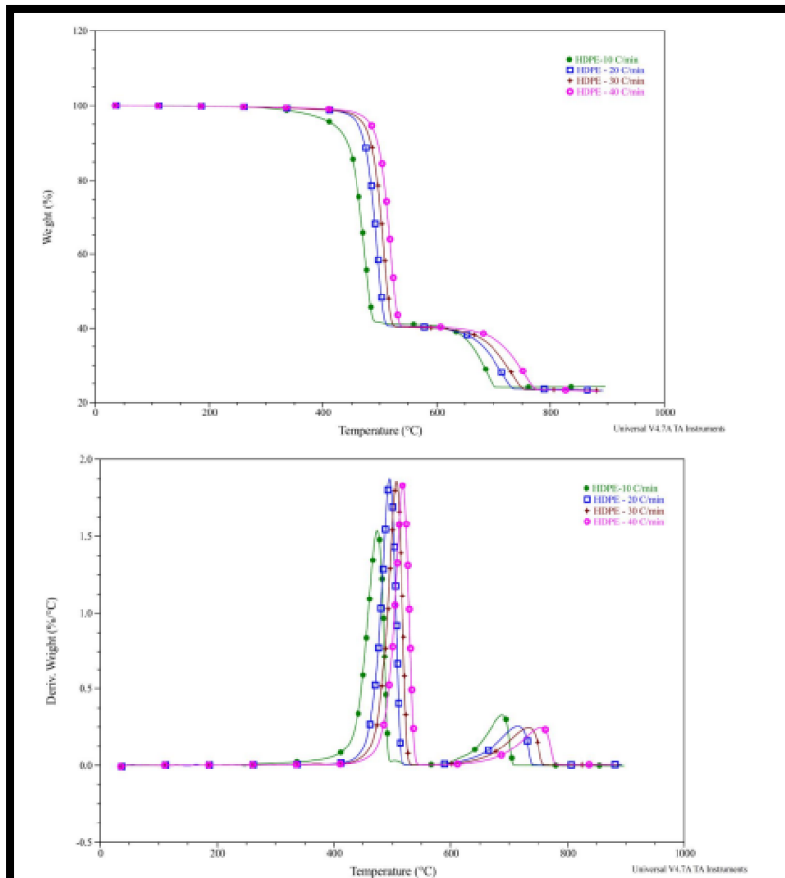


**Figure 2: Weight loss curves for HDPE wastes**

The figure 3, displays “the thermal gravimetric (TG)” curves for four distinct heating speeds. The study observed that LDPE waste conversion rates of “5% and 95%” were associated with the lowest and highest temperatures recorded at “429°C and 602°C”, respectively. The findings of the research indicate that there is a reduction in the temperature range of the pyrolysis zone when the heating rates are increased. This observation demonstrates that both condensable and non-condensable vapours have the potential to be discharged within a reduced period of retention.

Based on the findings of the study, it was observed that a range of “8.20 to 9.56” percent (by weight) of solid residue remained at a temperature of 800°C. Irrespective of the heating rates used, it was seen that the temperature of the active pyrolysis zone was responsible for over 91% of the weight reduction observed throughout the course of the experiment. When subjected to a nonreactive environment, “the thermogravimetric (TG)” curves exhibit a

persistent and singular inflection point. Each of “the differential thermogravimetric (DTG)” curves exhibited a solitary and unequivocal peak, which may be attributed to the prevailing pyrolysis mechanism. The observed peak temperatures in the “differential thermogravimetric (DTG)” curves exhibited a range of “473 to 512°C” across all heating rates. It was observed that the peak temperature had an upward trend as the heating rate rose. The experimental results showed that, across all examined heating rates, the highest observed weight reduction ranged from “2.171 to 2.310” percent per degree Celsius. It is noteworthy to observe that higher heating rates resulted in an increase in the initial temperature at which “LDPE deterioration occurs”. The completion of the degrading process for LDPE wastes exhibited a comparable temperature trend [16].



**Figure 3: Weight loss curves for LDPE wastes**

- **Melt Flow Index**

The ease with which the melted thermoplastic polymer flowed was measure by the MFI (melt Flow Index). The mass of polymer that flows in ten minutes through a capillary with a certain diameter and length under pressure from different stipulated gravimetric weights at different prescribed temperatures is what is meant by the definition. High melt flow rate of plastics corresponds to low molecular weight and vice versa. It was an indirect method of evaluating molecular weight. In the given conditions, the viscosity of the melt has an inverse relationship with the melt flow rate[17].

Type of Plastic waste	MFI (g/10 minutes)
HDPE	0.95
LDPE	2.69

**Table 1: MFI of plastic wastes**

- **Analysis of the Pyrolytic products**

Under various test conditions, the yields of fuel oil, solid residue, and pyrolytic gas from the pyrolysis of HDPE wastes varied from 35.8 to 57.2 percent, 3.2 to 10.6 percent, and 38.2 to 56.4 percent, respectively. HDPE wastes had a residence duration that varied from 42 to 61 minutes. The highest production of fuel oil (57.2%) was produced at 500°C for 47 minutes of residence time. Under various test conditions, the yields of fuel oil, solid residue, and pyrolytic gas from the pyrolysis of LDPE wastes varied from 37.6 to 60.5 percent, 4.7 to 11.7 percent, and 33.4 to 50.7%, respectively. The fuel oil yield result was comparable to reported results [18]. The evaluated plastic trash sample residence times were observed to be between 39 and 58 minutes. The highest output of fuel oil (60.5%) was produced at 500 degree Celsius for 44 minutes of residence time [19].

Types of plastic wastes	Temperature. Degree Celsius	Fuel Oil	Solid residue, %	Pyrolytic gas, %	Residence time, min
HDPE	450	22.3	7.5	78.6	65
	400	25.6	5.3	56.3	56
	550	15.6	2.3	65.2	52
	500	52.6	9.6	45.3	25
LDPE	450	68.6	8.5	79.8	45
	400	29.8	7.9	55.3	85
	550	56.3	6.7	26.1	75
	500	32.3	5.5	25.9	59

**Table 2: Details of pyrolytic products using batch pyrolytic reactor**

Run	Factor 1 A: Temperature	Factor 2 B: Nitrogen Flow rate ml/min	factor 3 C: Feed rate, kg/h	Response 1 Oil yield, %	Response 2 Solid residue, %	Response 3 Gas Yield, %
1	450	5.5	0.231	55.33	10.23	25.23
2	251	10.3	0.365	56.45	5.63	8.47
3	562	10.3	0.325	52.36	5.24	8.47
4	238	10.2	1.236	57.99	6.35	45.32
5	567	10.3	0.891	54.36	6.24	8.48
6	581	20.6	0.871	56.89	7.32	36.4
7	259	25.3	0.698	58.31	7.96	19.31
8	589	23.6	0.635	46.23	8.65	40.23
9	563	32.1	1.894	45.89	5.43	10.65
10	354	33.6	0.698	46.88	5.63	16.23
11	236	25.9	1.981	45.36	5.32	8.47
12	256	35.6	0.456	45.96	5.98	22.31
13	357	56.1	1.238	45.76	7.32	14.56
14	314	46.1	0.685	44.33	4.65	56.23
15	385	37.9	1.287	79.36	9.35	54.21
16	456	61.3	0.653	46.32	2.56	23.25
17	596	52.3	1.526	98.65	5.65	14.26



**Table 3: Optimized results of product yields on pyrolysis of HDPE wastes**

All experimental runs were carried out in accordance with the specified run, and each run was operated under the prescribed process parameters. The three-dimensional diagram helped to analyze how each variable affected the answer. Maximum oil yield, solid residue yield, and gas yield were all calculated as response variables for each run.

Run	Factor 1	Factor 2	factor 3	Response 1	Response 2	Response 3
	A: Temperature	B: Nitrogen Flow rate ml/min	C: Feed rate, kg/h	Oil yield, %	Solid residue, %	Gas Yield, %
1	560	15.5	0.231	23.33	10.23	23.1
2	251	10.3	0.365	86.45	5.63	22.3
3	562	36.5	0.325	52.36	5.24	8.47
4	438	10.2	1.236	97.99	12.3	25.6
5	567	10.3	0.891	45.36	23	8.48
6	681	41.3	0.871	57.89	5.64	32.1
7	259	25.3	0.698	18.31	8.65	21.3
8	589	23.6	0.635	45.32	8.67	56.4
9	263	32.1	1.894	25.64	5.32	10.65
10	354	45.1	0.698	23.14	2.36	25.8
11	456	25.9	1.981	58.65	2.54	8.47
12	256	35.6	0.456	89.31	5.98	14.3
13	654	56.1	1.238	54.65	2.89	14.56
14	314	46.1	0.685	87.65	4.65	26.7
15	657	37.9	1.287	89.23	5.65	54.21
16	456	61.3	0.653	45.65	5.36	23.25
17	365	45.3	1.526	56.23	5.56	14.26

**Table 4: Optimized results of product yields on pyrolysis of LDPE wastes**

Run Order	Oil yield, %		Solid residue yield, %		Gas Yield, %	
	Actual Value	Predicted Value	Actual Value	Predicted Value	Actual Value	Predicted Value
1	55.23	55.2	10.23	10.25	33.36	33.56
2	83.67	83.67	5.36	5.35	8.95	8.95
3	83.67	83.67	5.36	5.35	8.95	8.95
4	49.36	49.32	9.4	9.5	42.65	42.65
5	89.63	89.63	5.36	5.35	8.95	8.95
6	86.32	86.88	8.25	8.25	45.65	45.56
7	63.24	63.22	6.94	6.95	6.23	6.23
8	65.21	65.23	8.57	8.56	65.23	65.61
9	76.63	76.63	7.12	7.12	12.32	12.35
10	45.65	45.6	5.36	5.35	16.35	16.52
11	94.32	94.3	2.36	2.35	15.34	12.37

12	96.35	96.3	5.68	5.65	19.37	20
13	65.32	65.3	3.65	3.66	16.67	16.65
14	25.66	25.5	3.69	3.69	6.35	6.39
15	54.32	54.3	5.36	5.35	3.37	3.37
16	34.65	34.56	4.65	4.65	3.36	3.35
17	23.21	23.3	5.65	5.65	6.35	6.34

**Table 5: Predicted and actual values of product yields on pyrolysis of HDPE Wastes**

The figure is showing that the actual value of oil yield is around 64.71% and the predicted value is 63.99%. The actual value of gas yield is around 4.49% and the predicted value is 4.66%. The actual value of solid residue yield is 30.8 in order to number 1 run order.

Run Order	Oil yield, %		Solid residue yield, %		Gas Yield, %	
	Actual Value	Predicted Value	Actual Value	Predicted Value	Actual Value	Predicted Value
1	65.23	23.65	10.23	10.96	33.33	33.56
2	83.67	83.67	5.36	5.65	8.95	8.95
3	83.67	83.67	5.36	5.35	8.95	8.95
4	49.36	49.32	9.4	9.5	23.36	23.35
5	89.63	89.63	5.36	5.35	8.95	8.95
6	86.32	86.88	8.25	8.25	23.32	23.32
7	23.65	23.65	6.94	6.95	6.23	6.23
8	65.21	65.23	8.57	8.56	55.65	55.65
9	76.63	76.63	7.12	5.65	12.32	12.35
10	45.65	45.6	5.36	5.35	16.35	16.52
11	94.32	94.3	2.36	2.35	12.35	12.37
12	99.65	96.3	5.68	5.65	19.37	20
13	65.32	65.3	3.65	3.66	16.67	16.65
14	25.66	23.67	3.69	3.69	6.35	6.39
15	54.32	54.3	5.36	5.35	3.37	3.37
16	45.68	34.56	4.65	4.65	3.36	3.35
17	23.65	65.65	2.65	2.65	2.65	5.63

**Table 5: Predicted and actual values of product yields on pyrolysis of LDPE Wastes**

- **Gas Composition of Pyrolytic Wastes**

The above figure is about gas composition of pyrolytic. The 400 degree Celsius get gas composition of 8.2% CO<sub>2</sub>.

Plastic wastes	Temperature, degree Celsius	Gas composition, %				
		CO	CH <sub>4</sub>	C <sub>n</sub> H <sub>n</sub>	H <sub>2</sub>	CO <sub>2</sub>
HDPE	450	14.6	22.6	7.8	1.6	8.9
	470	9.3	30.6	10.5	4.2	5.6
	500	6.2	35.2	15.6	6.2	3.9
LDPE	450	12.3	36.3	5.65	2.32	5.6
	470	13.6	56.2	2.68	2.56	2.6
	500	5.23	45.6	6.65	4.32	9.6
PP	450	2.36	32.3	9.68	5.29	3.7
	470	5.65	65.6	5.65	6.27	6.9
	500	9.56	9.56	9.51	2.97	9.3

**Table 6: Gas composition of pyrolytic gas**  
• **Elemental Composition of Fuel oil**

The elements that makeup fuel oil, wastes made of "High-Density Polyethylene (HDPE)", "Low-Density Polyethylene (LDPE)", and wastes made of "Polypropylene (PP)" are listed in the table. HDPE wastes have a carbon content of 82.16%, LDPE wastes have a carbon content of 83.52% [20]. Additionally, the composition contains the proportions of hydrogen, nitrogen, and sulfur for each kind of waste. 12.58% Hydrogen, 0.26% Nitrogen, and 0.43% Sulfur are all present in HDPE. 13.16% Hydrogen, 0.35% Nitrogen, and 0.38% Sulfur are all present in LDPE. 12.17% Hydrogen, 0.14% Nitrogen, and 0.31% Sulfur are all present in PP. Understanding the chemical composition of these substances, which may affect their combustion characteristics and potential environmental effects when used as fuel, is vital [21].

Fuel oil	Elemental composition, %			
	Carbon	Hydrogen	Nitrogen	Sulphur
HDPE wastes	85.36	12.32	0.32	0.45
LDPE wastes	86.36	13.56	0.35	0.39

**Table 7: Elemental composition of fuel oil**

- **Octane number of fuel oil produced from various plastic wastes**

The table lists the fuel oils' octane ratings made from various types of plastic trash. Higher values indicate superior anti-knock qualities. Octane levels are indicators of a fuel's performance in internal combustion engines. The "Research Octane Number (RON)" of the fuel oil made from "High-Density Polyethylene (HDPE)" wastes is 93.1, which indicates how resistant it is to knocking under controlled circumstances [22]. Its "Motor Octane Number (MON)" of 82.4 indicates how it will behave when operating engines under more challenging conditions. Fuel oil made from "Low-density polyethylene (LDPE)" waste has a RON of 83.1 and a MON of 85.1 [23].

Fuel oil	Research octane number, min	Motor octane number, min
HDPE wastes	95.6	82.4
LDPE wastes	94.2	84.5

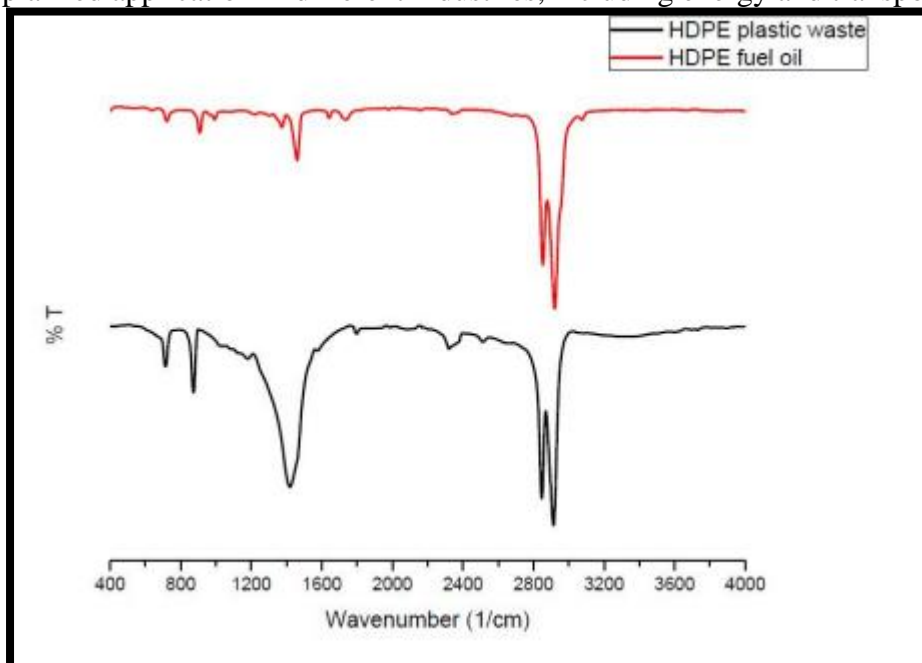
**Table 8: Octane number of fuel oil produced from various plastic wastes**

- **FT-IR analysis of fuel oil**

Various functional characteristics of fuel oil can be characterized with the implementation of FTIR (“Fourier Transform Infrared Spectroscopy”).

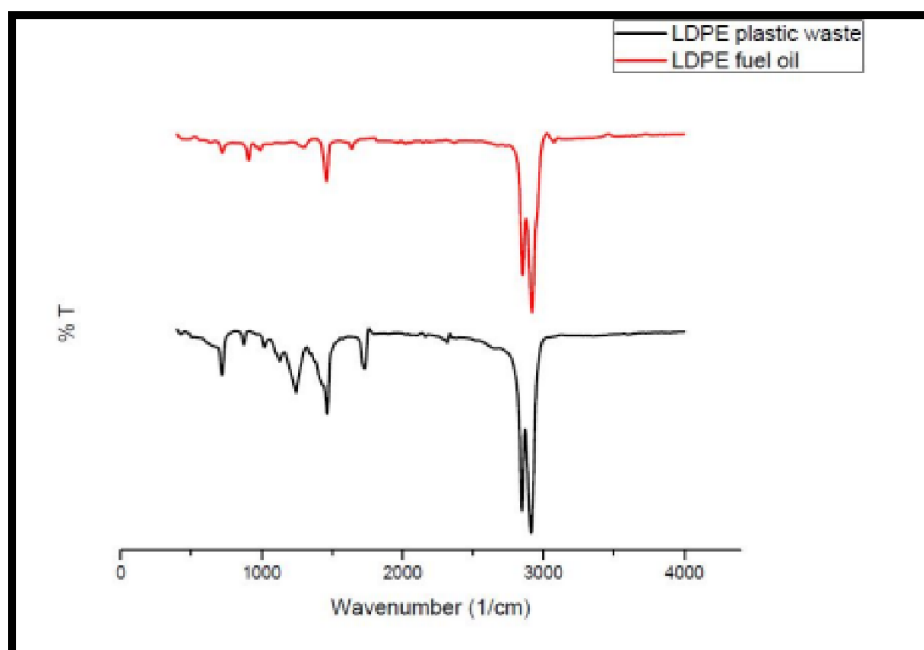
The figure 4 is the FT-IR spectra of the HDPE plastic wastes and fuel oil. The graph is obtained as %T vs Wavenumber ( $\text{cm}^{-1}$ ). The red portion shows the FTIR spectra of HDPE plastic wastes. The black portion shows the FTIR spectra of HDPE fuel oil[20]. From the above FTIR spectra, the O-H stretching frequency is observed at  $3306.36 \text{ cm}^{-1}$ . The stretching frequency for C-H is observed at  $2913.91 \text{ cm}^{-1}$  and also it is observed at  $2853.17 \text{ cm}^{-1}$ . The frequency graph at  $1735.62 \text{ cm}^{-1}$  is observed for the C=O bond[21].

Fourier-Transform Infrared (FTIR) spectroscopy is a strong insightful method used to look at the substance organization of materials, including HDPE fuel oil. In FTIR examination, an example is presented to infrared radiation, and the subsequent retention range gives significant data about its sub-atomic construction. On account of HDPE fuel oil, FTIR can recognize trademark peaks related with its parts. HDPE is a polymer comprising basically of carbon and hydrogen reinforced together in lengthy chains [24]. In the FTIR range, hope to see noticeable peaks in the  $2800\text{-}3000 \text{ cm}^{-1}$  area, relating to C-H extending vibrations[25]. These prototypes demonstrate the presence of hydrocarbon chains in HDPE. FTIR can recognize practical gatherings or pollutants in the fuel oil. The presence of oxygen-containing groups like carbonyl (C=O) or hydroxyl gatherings might propose oxidation. This data is significant for quality control, investigating, and guaranteeing the fuel oil’s suitability for its planned application in different industries, including energy and transportation[24,26].



**Figure 4: FT-IR spectra of HDPE wastes and fuel oil**

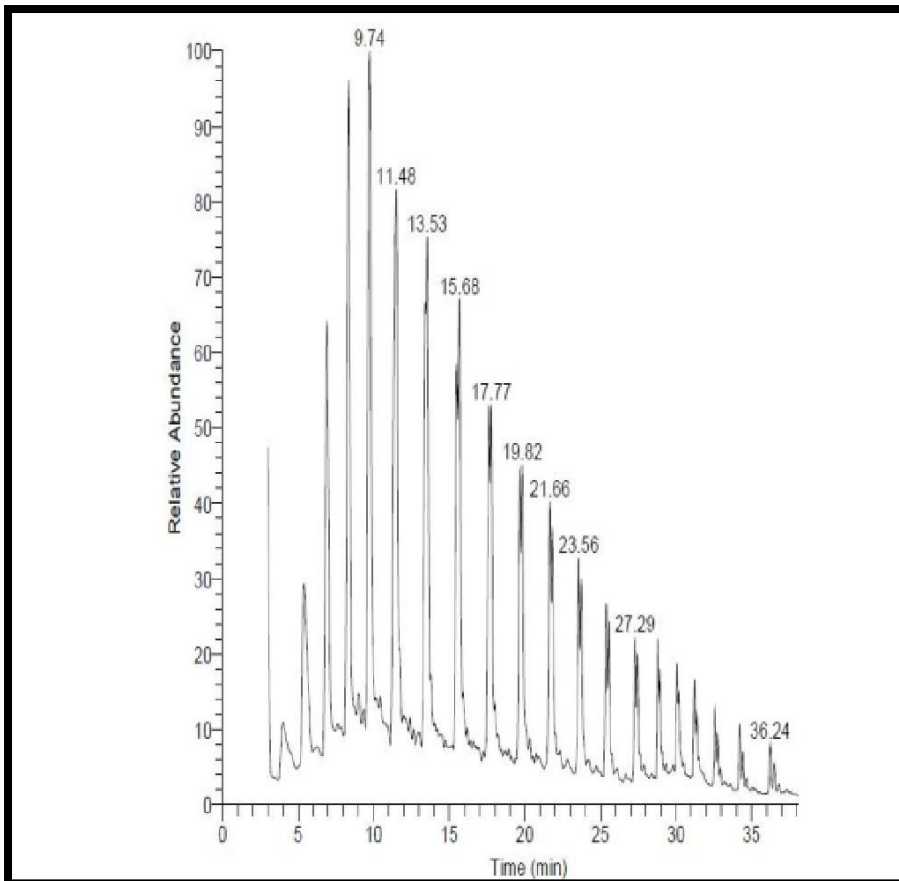
FTIR is an important scientific strategy used to portray the substance synthesis of materials, including LDPE (Low-Density Polyethylene) plastic wastes. LDPE is a typical plastic known for its adaptability and protection. In a FTIR range of LDPE plastic waste, a few key elements can be noticed. At around  $2916\text{ cm}^{-1}$  and  $2849\text{ cm}^{-1}$  compare to  $\text{CH}_2$  uneven and symmetric extending vibrations, individually[24,27]. These show the presence of the polyethylene spine. The area between  $1470\text{ cm}^{-1}$  and  $1370\text{ cm}^{-1}$  shows peaks connected with  $\text{CH}_3$  and  $\text{CH}_2$  twisting vibrations, affirming the LDPE structure[26]. Another critical component is the shortfall of peaks in the carbonyl ( $\text{C}=\text{O}$ ) area, which recommends LDPE's low extremity and protection from oxidation contrasted with different plastics like HDPE[21]. FTIR can identify minor pollutants or added substances in LDPE wastes, for example, stabilizers which might show up as extra peaks in the range. The FTIR range of LDPE plastic waste is described by particular standards related with its polyethylene structure and can be utilized to survey its arrangement and potential for reusing.



**Figure 5: FT-IR spectra of LDPE wastes and fuel oil**

- **GC-MS Analysis**

The HDPE wastes of fuel oil had 30 components. The greatest peak areas of the compounds when area percentage was taken into consideration were 1-octadecane (5.00%), 1-Heptadecane (4.94%), 1-Heptadecane (4.94%), 1-Tetradecene (4.73%), 1-Pentadecene (4.86%), and 1-Nonadecene (4.71%)[28,29].



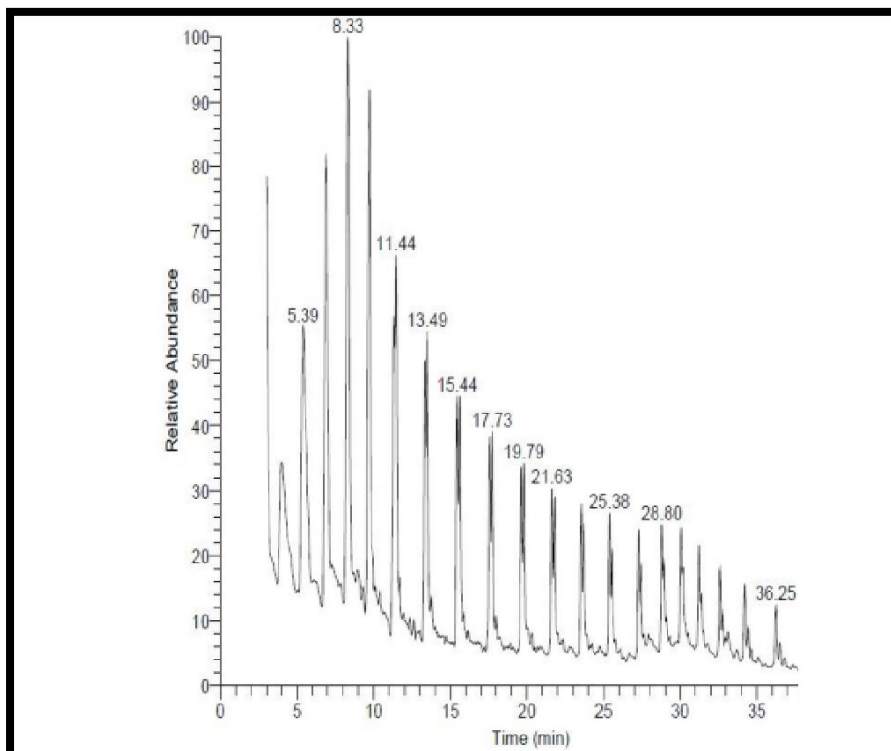
**Figure 6: GC-MS chromatograph of fuel oil from HDPE wastes**

The name of the above figure is GCMS compositions of fuel oil which was produced through HDPE wastes. The above figure has 30 components[30].

Retention time (min)	Compound	Area, %
3.98	1-Nonene	1.55
5.38	Nonane	0.93
6.88	1-Decene	2.63
8.33	Decane	1.23
9.00	1-Undecene	3.02
9.74	Undecane	1.74
10.43	1-Dodecene	3.34
10.96	Dodecane	2.27
11.48	1-Tridecene	3.90
13.01	Tridecane	2.51
13.53	1-Tetradecene	4.73
15.68	Tetradecane	2.87
17.61	1-Pentadecene	4.86
18.94	Pentadecane	3.22
19.82	1-Octadecene	5.00
20.73	Hexadecane	3.70
21.66	1-Heptadecene	4.94
22.80	Hexadecane	3.65
23.56	1-Nonadecene	4.71
25.38	Hexadecane	3.74
27.29	1-Nonadecene	4.38
28.79	Hexadecane	3.65
30.06	1-Nonadecene	3.79
31.22	Eicosane	3.21
32.58	1-Nonadecene	3.15
34.21	Heneicosane	2.92
36.24	1-Nonadecene	2.51
36.52	Docosane	2.48
38.79	1-Nonadecene	1.95
39.16	Tricosane	1.28

**Table 9: GC-MS composition of fuel oil produced from HDPE wastes**

There are a total of 30 peaks identified in LDPE fuel oil waste. The highest area was in 1-Tridecene (10.78%), then 1-Undecene (10.06%), Cyclopentane (10.02%), Dodecene (8.29%), and 1-Pentene (7.87%)[31].



**Figure 7: GC-MS chromatograph of fuel oil from LDPE wastes**

The above figure is related to GC-MS composition of fuel oil produced from LDPE wastes. 1- Undecene is having then highest area[32].

Retention time (min)	Compound	Area, %
3.98	1-Pentadecene	3.22
5.39	1-pentyne	7.87
6.29	Butane	0.46
6.88	Cyclopentane	10.02
7.41	Nonane	0.29
8.33	1-Tridecene	10.78
8.96	Naphthalene	0.46
9.30	Benzene, ethyl-	0.24
9.71	1-Undecene	10.06
10.40	Benzene, heptyl-	0.24
10.91	1-Dodecene	0.31
11.44	Dodecene	8.79
13.49	Cyclopropane	6.90
15.44	Hexadecene	5.81
17.57	1- Hexadecene	4.82
18.93	Heptadecane, 9-octyl-	0.29
19.79	Octadecane	4.67
21.63	Eicosane	3.99
23.54	Heneicosane	3.46
25.38	Docosane	3.13
27.27	10- Heneicosane	2.57
27.92	3-Eicosene	0.26
28.30	9-Tricosene	2.49
30.06	Heptacosane	2.06
31.22	Tetracosane	1.78
32.59	Octacosane	1.53
33.12	Hexacosane	0.73
34.22	Tetraetracontane	1.30
36.25	Triacostane	1.14
38.81	Nonacosane	0.86

**Table 10: GC-MS composition of fuel oil produced from LDPE wastes**

- **Comparison of fuel oil properties with petrol and diesel fuels**

The moisture content, density and calorific values of the Produced fuel oil were comparable to the petrol and diesel [33–35].

Properties	HDPE wastes	LDPE wastes
Moisture content, %	1.23	1.32
Density, kg/m <sup>3</sup>	321	356
Calorific value, MJ /kg	32.32	32.65
Proximate composition(dry basis)		35.65
volatile matter, %	12.32	98.64
Ash content, %	56.32	64.32
Fixed content, %	32.45	24.23

**Table 11: Comparison of fuel oil properties with petrol and diesel fuels**

- **Elemental composition analysis**

Elemental composition analysis by CHNS analyzer using ASTM D-5291-96. The results are indicated in the table below [16,24,36].

Elemental Composition in Weight %	LDPE	HDPE
Carbon	84.44	83.84
Hydrogen	13.05	12.76
Nitrogen	0.00	0.00
Sulfur	0.53	1.04
Oxygen	0	0

**Table 12: Elemental composition analysis**

### 3. Conclusion

The overall part discusses the purpose of the study of waste management of non-biodegradable plastic products. The usage of Nano-cobalt carbonate catalysts introduces an original dimension to plastic waste management, making it ready for proficient waste-to-fuel conversion technologies. This research aims to give a sustainable solution by successfully overseeing plastic waste and producing useful fuels. The study is mainly about the investigation of Non-biodegradable waste such as HDPE and LDPE to fuel conversion through the “Nanometal carbonate catalysts”. The results indicated high liquid product yield in HDPE and LDPE plastic wastes through the pyrolytic process.

Further, it can reduce gaseous pollutants due to the absence of O<sub>2</sub> and can significantly reduce the volume of waste (<50– 90%) in municipal solid waste. Changing over plastic waste into significant fills adds to asset recovery and diminishes the reliance on limited non-renewable energy sources. In addition to providing a promising path for the responsible management of non-biodegradable waste, this dual strategy highlights the potential of nanomaterials to catalyse sustainable chemical processes, which is in line with the larger objectives of protecting the environment and optimizing resources.

### Conflict of Interest

The authors declare no Conflict of Interest.



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