# Analysis of Fuel Alternative Products Obtained by the Pyrolysis of Diverse Types of Plastic Materials Isolated from a Dumpsite Origin in Pakistan

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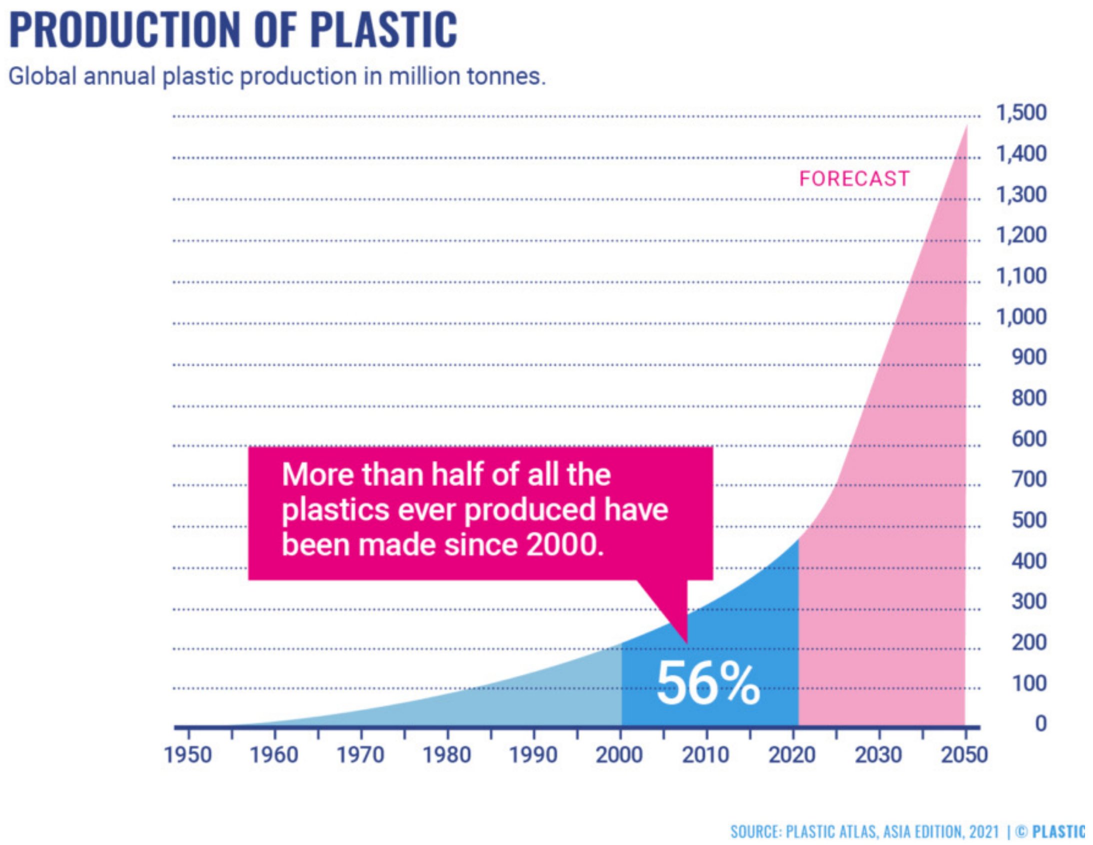
A kutatás a Technológiai és Ipari Minisztérium „A körforgásos gazdaságra történő átállás előkészítési feladatai a mezőgazdasági és zöldhulladékok esetében" című, KEHOP-3.2.1-15-2021-00037 azonosítószámú Környezet és Energiahatékonysági Operatív Program támogatásával valósult meg.

# Introduction

- Every year, approximately 300 million tons of plastic waste is generated globally.
- In developing countries, the dual challenge of managing plastic waste and addressing energy needs is even more pronounced.
- Pakistan alone generated more than two million metric tons of plastic waste in 2016 (Law et al., 2020).
- Due to poor waste management, majority of this waste is disposed off into the dumpsites unattended.
- This study was therefore conducted to find a solution for plastic waste management problems, as well as to find an alternative to mitigate the current energy crisis.



# Aims & Objectives

- To provide an efficient solution to mitigate the issues of energy crisis and plastic waste management by pyrolysis of the most abundantly found plastics in MSW
- Analyze and compare the yield and quality of fuel derived from different types of plastics, particularly those frequently found in waste locations in Pakistan.
- Explore the feasibility and efficiency of the pyrolysis process with and without the use of a catalyst.
- Address the pressing challenges of plastic waste management in developing countries, using Pakistan as a case study.
- Contribute to sustainable solutions for developing countries by converting plastic waste to fuel.
- Without advocating plastic production, find a cost-efficient solution which leads to eliminating plastic waste and reducing municipal solid waste.

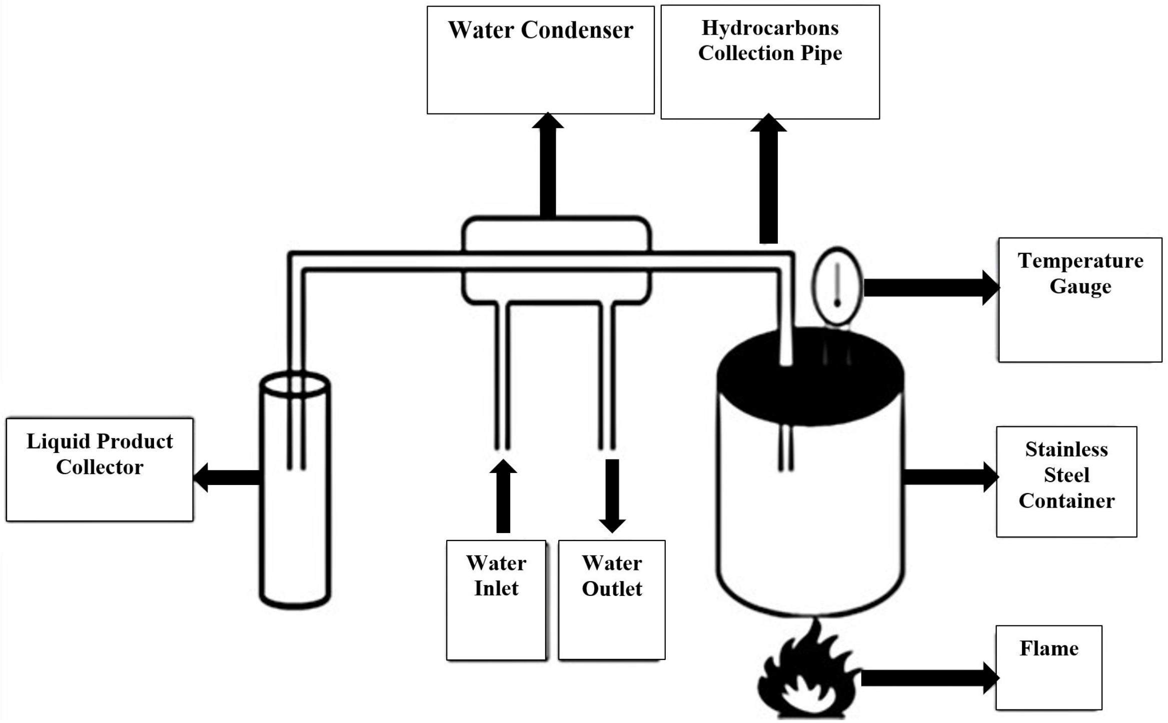
# Materials and Methods

- Five types of plastic materials were used:
- Polyethylene terephthalate (PET)
- High-density polyethylene (HDPE)
- Low-density polyethylene (LDPE)
- Polypropylene (PP)
- Polystyrene (PS)
- All of these plastics were collected from dumpsites.
- Chosen because they constitute the majority of plastic waste volume.
- Subjected to thermal decomposition in a pyrolysis reactor ( Approx. Total Cost: < 700 € )

# Materials and Methods

- Post initial pilot study in lab, main study was conducted using a steel reactor (figure).
- Pyrolysis at 450 °C for PS and HDPE; 500–550 °C for LDPE, PP, and PET.
- With and without catalyst (Ca(OH)2)
- Average conversion time: 90 mins
- Physical Analysis (yield, color, density, viscosity)
- Calorific Value
- By-Products and Conversion Rate.
- Chemical Analysis;
- Techniques: FT-IR and GC-MS.

Setup of the Reactor



# Results

- Similar yields with/without catalyst; non-catalyzed took longer.
- Catalyst abandoned due to cost, odor, and coke formation.
- Effective pyrolysis temperature: 400–600°C.
- HDPE: highest yield at 82%.
- Yields align with other scientific studies.
- Fuels' viscosities ranged between 0.9 to 2.2 cSt.
- Fuels had distinct colors due to colorants in plastics


Fuels post pyrolysis

# Results

- **Calorific Value**
- LDPE- and PET-derived fuels: highest and lowest values (46.2 MJ/kg and 42.8 MJ/kg).
- Average calorific value: 44.7 ± 1.9 MJ/kg.
- Comparable to gasoline or diesel.

- **High Conversion Rates**
- Most plastics converted effectively into fuel.
- PET: 96.5%, HDPE: 93.5%
- Highest rate: 99% for PP , PET: 96.5%, HDPE: 93.5% .
- High conversion rates demonstrate plastics' potential for cost-effective conversion into alternative fuels.

| Plastic Type [1] | Fuel | | | | Energy |
|---|---|---|---|---|---|
| | Yield (%) | Density (g/mL) | Viscosity [2] (cSt) | Calorific Value (MJ/kg Fuel) | Conversion (MJ/kg Plastic) |
| PET | 10.7 | 1.00 | 2.20 | 42.4 | 4.5 |
| HDPE | 82.2 | 0.78 | 1.60 | 45.9 | 37.7 |
| LDPE | 58.0 | 0.70 | 1.41 | 46.2 | 26.8 |
| PP | 61.8 | 0.75 | 1.58 | 46.2 | 28.6 |
| PS | 50.0 | 0.91 | 0.99 | 42.8 | 21.4 |
| Gasoline | – | 0.74 | 1.70 [3] | 45.8 | – |
| Diesel | – | 0.83 | 2.61 [3] | 45.5 | – |

[1] Abbreviations: PET—polyethylene terephthalate; HDPE—high density polyethylene; LDPE—low density polyethylene; PP—polypropylene; PS—polystyrene. [2] Viscosity determined at 60 °C. [3] Viscosity determined at 40 °C.

# Results – Chemical Analysis

**FTIR Results**

1. **PET-Derived Fuel:** Presence of functional groups like alkene, alkane, carbonyl, and ether.
2. **HDPE-Derived Fuel:** Indicated three significant functional groups: aldehydes, alkenes, and alkanes. Peaks like 873 cm-1 and 1411 cm-1 represented respective functional groups.
3. **Observations:** FT-IR results across different plastic-derived fuels showed similar functional group compositions, with alkenes and alkanes being the most common. Peaks ranging from 675 to 1000 cm-1 indicated the existence of alkenes.

**GC-MS Results**

1. **PET-Derived Fuel:** Hydrocarbon chains ranged from C9–C24, with notable compounds like biphenyl and quaterphenyl identified.
2. **HDPE & LDPE-Derived Fuel:** Aliphatic hydrocarbons detected in HDPE fuel ranged from C10 to C21, while LDPE fuel showed chains between C10 and C28.
3. **Observations:** Pyrolysis fuels contained compounds are also found in commercial fuels, such as diesel, suggesting their potential for diverse applications.

# Key Takeaways

- **Pyrolysis Success**:
  - Fuels from 5 plastics were obtained.
  - Especially relevant for developing countries like Pakistan.
- **Comparison to Traditional Fuels**:
  - Comparable properties to diesel and gasoline.
  - High calorific values suitable for heating, cooking, and boilers.
- **Refinement and Application**:
  - Potential for use in combustion engines post-refinement.
  - Some pyrolysis fuels emitted more gases due to unsaturated hydrocarbons.
  - Direct use as furnace oil in industries or homes after refining.
- **Economic Benefits**:
  - Emphasis on the cost-effectiveness of this technology.
  - Solution to energy crises and plastic waste problems.

# Conclusions

1. **Dual Solutions**: Addressed energy crisis and plastic waste in developing countries through pyrolysis of plastics obtained from MSW.
2. **Fuel Quality**: Pyrolysis fuels, especially from HDPE, yielded high calorific values comparable to diesel and gasoline.
3. **Reactor Design**: Potential improvements in reactor design can enhance yield and efficiency.
4. **Future Potential**: Promising technique for waste management, energy needs, and promoting circular economy in regions like Pakistan.

6. **Future Directions & Collaborations**:

- Collaboration with refineries, especially Attock Refinery Limited (ongoing)
- Encourage replication at smaller scales due and use in other cases (ongoing)
- Entrepreneurship opportunities for local community.

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