Experimental investigation of products from single-use and multilayered waste plastics

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Thermal treatment options for single-use, multilayered and composite waste plastics in Africa

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ARTICLE INFO

Handling Editor: Petar Sabev Vバンド

Keywords:
Energy recovery
Waste plastics
Pyrolysis
Gasification
Waste-to-Energy
Thermal treatment

ABSTRACT

This review highlights the current level of waste plastics valorization through thermal treatment and its potential for African countries. Improved thermal treatment options are needed to convert the over 40% of mismanaged waste plastics in Africa to generate electrical and chemical energy. The values of measured and calculated energy yields from high-quality data are compared for treatment options such as pyrolysis, gasification, incineration, catalytic and plasma gasification. The investigation revealed that, for chemical energy production, catalytic gasification offers the best valuable product yield for single-use plastics with a promising liquid output of up to 50% with a low heating value (LHV) of 44 MJ/kg, gas output 6–7% with heating value of 48 MJ/m\textsuperscript{3}, and solid output of 10–20%. The liquid and gas products obtained at this quality could be used as fuel in a conventional gas/diesel engine for electricity generation. For the treatment of multi-layered and composite waste plastics, plasma gasification offers the best energy recovery approach with a potential of producing syngas with LHV of 10.8 MJ/m\textsuperscript{3} and consisting of H\textsubscript{2} and CO weight fraction of 62.5% and 34%, respectively. The feasible waste plastics treatment options are presented based on waste plastics profiles in selected regions of Africa.
Energy potential of mixed waste plastics for selected African countries

- **Plasma Gasification**
  - Nigeria: Minimum 5,000 GWh, Maximum 6,000 GWh
  - Kenya: Minimum 600 GWh, Maximum 900 GWh
  - Ghana: Minimum 1,200 GWh, Maximum 1,500 GWh
  - South Africa: Minimum 2,000 GWh, Maximum 3,000 GWh
  - Egypt: Minimum 1,000 GWh, Maximum 1,500 GWh

- **Catalytic Gasification**
  - Nigeria: Minimum 2,500 GWh, Maximum 3,500 GWh
  - Kenya: Minimum 800 GWh, Maximum 1,000 GWh
  - Ghana: Minimum 1,400 GWh, Maximum 1,800 GWh
  - South Africa: Minimum 2,200 GWh, Maximum 3,200 GWh
  - Egypt: Minimum 1,200 GWh, Maximum 1,600 GWh

- **Thermal conversion method**
  - Nigeria: Minimum 2,000 GWh, Maximum 2,500 GWh
  - Kenya: Minimum 500 GWh, Maximum 700 GWh
  - Ghana: Minimum 1,000 GWh, Maximum 1,200 GWh
  - South Africa: Minimum 1,800 GWh, Maximum 2,200 GWh
  - Egypt: Minimum 1,500 GWh, Maximum 2,000 GWh

- **Pyrolysis**
  - Nigeria: Minimum 1,500 GWh, Maximum 2,000 GWh
  - Kenya: Minimum 300 GWh, Maximum 400 GWh
  - Ghana: Minimum 600 GWh, Maximum 800 GWh
  - South Africa: Minimum 1,000 GWh, Maximum 1,500 GWh
  - Egypt: Minimum 800 GWh, Maximum 1,000 GWh

**Total Energy Potential:** 5,540 GWh
Pyrolysis of waste plastics

SUPs

N₂

300 - 800°C

Gases (5 – 20 wt.%)
• Non-condensable
• Condensable
Liquids (60 – 93 wt.%)
Solids (5 – 20 wt.%)

Polymers
- PP
- PE
- PVC
- PS
- PET

Fuels
36 - 48 MJ/kg

Chemicals

36 - 48 MJ/kg
Feedstock sampling

A

B
Feedstock characterisation

- REJECTED WASTE PLASTICS (%)
  - LLDPE(4) 65%
  - PP(5) 11%
  - PS(6) 1%
  - LDPE(4) 6%
  - PVC(3) 1%
  - HDPE(2) 1%
  - Composite+Other plastics(7) 4%
  - PET(1) 11%

SRH Berlin University of Applied Sciences and Universität Rostock – Uduak Bassey
Characterization of Municipal Solid Waste and Assessment of Its Potential for Refuse-Derived Fuel (RDF) Valorization

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Abstract: Reuse and recycling are preferred strategies in waste management to ensure the high position of waste resources in the waste management hierarchy. However, challenges are still pronounced in many developing countries, where disposal as a final solution is prevalent, particularly for municipal solid waste. On the other hand, refuse-derived fuel as a means of energy recovery provides a sustainable option for managing mixed, contaminated and residual municipal solid waste (MSW). This study provides one of the earliest assessments of refuse-derived fuel (RDF) from MSW in Ghana through a case study in the cities of Accra and Kumasi. The residual/reject fractions (RFs) of MSW material recovery were characterized for thermochemical energy purposes. The studied materials had the potential to be used as RDF. The combustible portions from the residual fractions formed good alternative fuel, RDF, under the class I, II-III classification of the EN 15359:2011 standards. The RDF from only combustible mixed materials such as plastics, paper and wood recorded a significant increase in the lower heating value (28.66–30.24 MJ/kg) to the mass RF, with the presence of organics (19.73 to 23.75 MJ/kg). The chlorine and heavy metal content met the limits set by various standards. An annual RDF production of 12 to 57 kilotons is possible from the two cities. This can offset 10–30% of the present industrial coal consumption, to about 180 kiloton/yr CO2 eq emissions and a net cost saving of USD 8.7 million per year. The market for RDF as an industrial alternative fuel is developing in Ghana and similar jurisdictions in this context. Therefore, this study provides insights into the potential for RDF in integrated waste management system implementation for socioeconomic and environmental benefits. This supports efforts towards achieving the Sustainable Development Goals (SDGs) and a circular economy.

Keywords: refuse-derived fuel (RDF); energy recovery; municipal solid waste; co-combustion; alternative fuel; thermochemical valorization
# Proximate and elemental analysis of feedstock

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<td>Proximate analysis, (wt.%)</td>
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<tr>
<td>Volatile matter</td>
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<tr>
<td>Carbon</td>
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<td>Oxygen</td>
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<td>0</td>
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<td>Density (kg/m$^3$) (own study)</td>
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<tr>
<td>Loose bulk density (@15mm particle size)</td>
<td>72.57</td>
<td>88.13</td>
<td>66.75</td>
<td>245.76</td>
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</table>

S1: Mixed single use plastics
S2: PE+PP (50/50)
S3: LDPE
S4: PP
S5: PET
Experimental setup
DTG of waste plastic feedstocks

LDPE

\[
\frac{dw}{dT}
\]

T [°C]

250 300 350 400 450 500 550 600

PET

\[
\frac{dw}{dT}
\]

T [°C]

250 300 350 400 450 500 550 600

10°C/min ————

20°C/min _______
DTG of waste plastic feedstocks

PE+PP

10°C/min

20°C/min

PP
DTG of waste plastic feedstocks

- 10°C/min
- 20°C/min
**Experimental plan**

**Aim**
- To investigate all the products obtainable from thermally treating single-use and multi-layered waste plastics
- To identify and define the valuable products that are free of toxins
- To analyze the input energy and exergy of the conversion processes

**Method**
- Pyrolysis
Effect of residence time on Vr

Heat transfer to the sample

25:30:00, 457,7

46:00:00, 472,4
Effect of Nitrogen flow rate in slow pyrolysis using a tube furnace
Effect of temperature on product yield

Calorific value of PP

Calorific value of LDPE

Calorific value of SUPs

Calorific value of LDPE+PP

Calorific value of PET

23.06.2023
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DTG of oil/wax of SUP

SUP 7 oil

WtPercent = 100.13 [%]
Temp = 46.16 [°C]

WtPercent = 96.954 [%]
Temp = 100.85 [°C]

\[ \frac{d(\text{WtPercent})}{d(\text{Temp})} = -0.02456 \]
Temp = 56.52 [°C]

WtPercent = 5.6473 [%]
Temp = 496.81 [°C]
Effect of HHT on the quality of gaseous products

Nitrogen

Hydrogen

CO

CH₄

CO₂

550°C
450°C
550°C
Findings

- Slow pyrolysis is not optimal for SUPs
- Varying residence time may not be critical when SUPs are pyrolyzed in a tube furnace
- Bulk density of the feedstock is an important property to be considered when varying gas flow rate (in tube reactor)
Further analysis of the gaseous products to identify the valuable compounds

Critical analysis of the liquid fraction

Analysis and assessment of the char fraction

Fast pyrolysis investigation using a continuous reactor

Parameter optimization
Thank you for your attention!

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This research was supported by the German Federal Ministry of Education and Research within the project “Waste to Energy: Hybrid Energy from Waste as Sustainable Solution for Ghana” (03SF0591E).
Prospects