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Valorisation of Waste Tires by Pyrolysis in the Republic of Congo

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Abstract

The pyrolysis of waste tires represents an effective strategy for simultaneous energy recovery and waste reduction, yet further empirical characterization of the resulting pyrolytic oil is needed to assess its suitability as an alternative fuel. This study aims to obtain pyrolytic oil from end-of-life tires and analyze its main physical characteristics to evaluate its potential for energy applications. The oil produced by pyrolysis exhibits a density of 769.4 kg/m³, a specific gravity of 0.7694, a low kinematic viscosity of 1.5 cSt, and a slightly acidic pH of 4, values that are consistent with those reported in the literature. These characteristics indicate a high proportion of light hydrocarbons, suggesting that the oil is suitable for use as a fuel or as a fuel additive. Observed variations compared with other studies highlight the influence of tire composition and pyrolysis conditions on the quality and properties of the obtained oil, underlining the importance of process optimization. Overall, the findings confirm that tire pyrolysis is a promising method for energy recovery from waste tires, providing a sustainable pathway for hydrocarbon production while contributing to improved solid waste management and resource valorization.

Keywords: Waste Tire Pyrolysis; Pyrolytic Oil; Physical Properties; Energy Recovery; Waste Valorization.

INTRODUCTION

The management of end-of-life tires represents a major environmental challenge due to their high durability and increasing volume, which can lead to soil and water pollution as well as storage problems (Han, W. et al). Pyrolysis, a thermal process carried out in the absence of oxygen, appears as an attractive technology to convert these wastes into valuable resources: liquid oil, combustible gas, and solid residue (char) (Han, W. et al). This thermochemical valorization not only reduces the environmental impact of waste tires but also allows the recovery of hydrocarbons usable as fuel or additives. Furthermore, the production of recovered carbon black from pyrolysis provides another pathway for high-value valorization. In this study, we aim to produce pyrolytic oil from waste tires and to characterize its physical properties (density, viscosity, pH, etc.) in order to evaluate its potential as an alternative energy source and to identify the pyrolysis parameters influencing its quality.

MATERIALS AND METHODS

Materials

1. Balance

A balance is an instrument that allows the precise measurement of the mass of samples, which is crucial for quantitative analyses.

Fig. 1: A precision balance

2. pH Paper

pH paper is a simple and effective tool used to determine the acidity or alkalinity of a solution. It indicates the level of acidity or alkalinity on a scale from 0 to 14.

Fig. 2: pH paper

3. Graduated Cylinder

A graduated cylinder is a measuring instrument primarily used in the laboratory to measure the volume of liquids. The markings on the cylinder indicate the volume in milliliters (mL) or liters (L).

4. Stopwatch

A stopwatch allows precise measurement of the time taken for the ball to reach the bottom of the cylinder, which is crucial for obtaining reliable results.

Fig. 3: Stopwatch [2]

5. Aluminum sphere

The sphere is used to investigate the falling time in oil from a given height.

6. Heating tank

This equipment allowed us to heat the inner tubes in the absence of oxygen; it is even the essential apparatus in our work. It served as the reactor.

Fig. 4: Heating tank

7. A heating furnace

To heat the tank (reactor), we used a wood-fired furnace. This furnace served as an energy source.

Fig. 5: Heating furnace

Methodology

1. Raw materials

The process used in this work is endothermic. The raw materials used are the following:

- Used tires collected from various streets in Mfilou;
- A mixture of silicone and sand to ensure the airtightness of our reactor;
- Firewood.

Fig. 4: Raw materials

2. Steps in the production of pyrolytic oil

The steps of this production are as follows:

a. Preparation of the raw material

The pyrolytic oil was produced from used plastic bottles, which were used as feedstock in a reactor heated to a high temperature and deprived of oxygen to ensure their chemical decomposition. This process yields different outputs depending on the proportions of material introduced. For the preparation, the bottles were sorted, cut, and then weighed to ensure an accurate quantity of raw material. A total mass of 2 kg of plastic was introduced into the reactor to initiate the pyrolysis process and enable the production of pyrolytic oil for the study.

Fig. 5: Preparation of the raw material**.**

b. Heating

According to the scientific literature, the pyrolysis of plastic waste generally occurs at temperatures between 400 and 800 °C (J Aguado, J. et al) a range considered optimal to ensure the complete thermal decomposition of polymers and to reduce the formation of solid residues such as microplastics. Several studies confirm this temperature range. Aguado et al emphasize that most polyolefins show significant degradation above 400 °C, while Singh and Kumar (2020) indicate that increasing the temperature to around 800 °C promotes the production of lighter liquid fractions and reduces carbonaceous components. Similarly, Miandad et al. (2019) report that high temperatures improve conversion efficiency while limiting the formation of unwanted solid particles. In our study, we implemented a simple and artisanal process inspired by these principles. The used tires were introduced into a cylindrical tank serving as a reactor. This reactor was sealed with silicone to ensure optimal airtightness and to prevent any gas leakage during the reaction. The entire setup was then heated for approximately 2 hours and 30 minutes, a duration allowing for sufficient degradation of the plastic based on preliminary observations.

Fig. 6: Heating of the used tires

c. Collection of the pyrolytic oil

During the heating phase of the reactor, the plastic material subjected to high temperatures gradually decomposes, generating a mixture of vapors rich in volatile organic compounds. These vapors are then directed out of the reactor through a heat- and pressure-resistant metal pipe. Upon exiting, they pass through a water-cooled condenser operating at ambient temperature, which lowers the temperature of the gas stream sufficiently to allow the condensation of the condensable fraction. As a result of cooling, part of the vapors condenses into a hydrocarbon liquid, commonly referred to as pyrolytic oil. This oil is collected in a sealed storage container to prevent any loss or contamination. It constitutes the valuable liquid fraction of the process, often used as fuel or as a raw material for energy and chemical applications. Meanwhile, another portion of the vapors does not condense under these cooling conditions. This fraction consists of non-condensable gases, such as light hydrocarbons or permanent gases, which remain in the gaseous state despite passing through the condenser. These gases can then be released, burned, or reused as an energy source to power the reactor's heating system, thereby improving the overall efficiency of the process.

Fig. 7: Pyrolysis setup.

All these steps can be summarized in the following diagram:

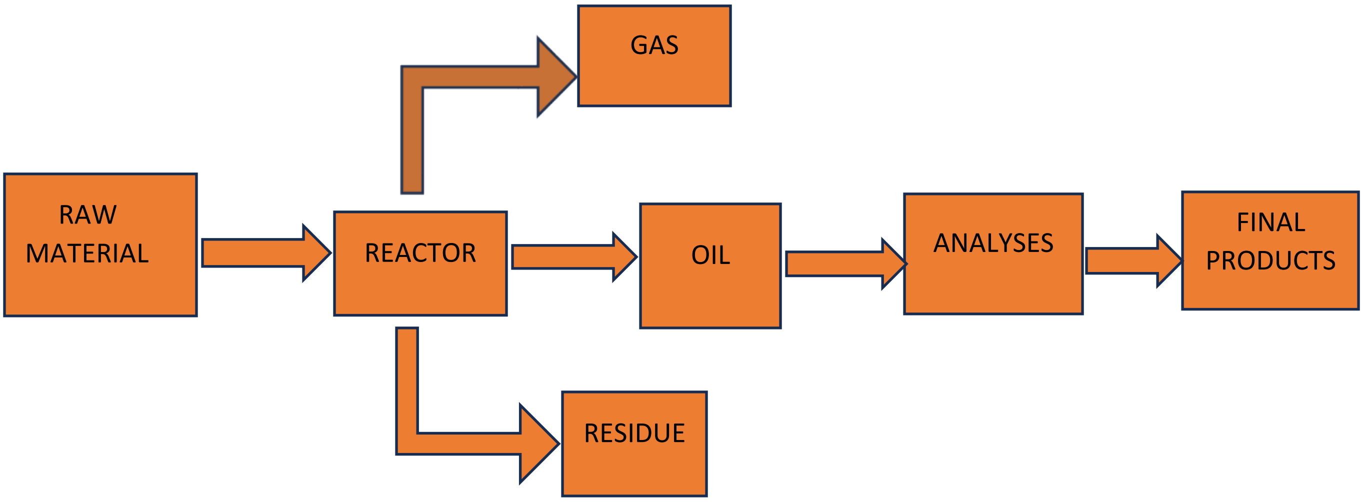

Fig. 8: Schematic diagram of pyrolytic oil production (Stanislas U.B.M et al, 2025).

3. Pyrolysis products

At the conclusion of the pyrolysis process, three primary products are generated. The first product is pyrolytic oil, a hydrocarbon-rich liquid obtained from the condensation of vapors released during the thermal decomposition of tires. This oil is considered valuable due to its potential use as a fuel or as a feedstock for chemical industries. The second product is carbon black, a solid residue with a high carbon content, which forms as a result of the carbonization of the organic fraction of the tires. Carbon black is widely utilized in various industrial applications, including reinforcing agents in rubber and as pigments in inks and coatings. The third product comprises non-condensable gases, primarily light hydrocarbons, which are frequently recovered and used to supply energy for the pyrolysis process itself, thereby improving the overall energy efficiency of the system. The distribution and characteristics of these three fractions depend on several factors, such as temperature, heating rate, and reactor design. The generation of pyrolytic oil, carbon black, and non-condensable gases from tire pyrolysis is extensively documented in scientific literature, highlighting their consistent occurrence across different pyrolysis setups (Miandad, R, 2019). These products represent both environmental management solutions and opportunities for resource recovery from end-of-life tires.

(a) Oil (b) Gas (c) Char

Fig. 9: The three products obtained

4. Analysis of the pyrolytic oil

The characterization of the pyrolytic oil was performed on carefully measured samples using standardized analytical instruments. This approach enabled the precise evaluation of key physical and chemical properties, including density, specific gravity, viscosity, and pH, which are essential for assessing the quality and potential applications of the oil. Determining these parameters allows for a better understanding of the oil's behavior under different conditions and its suitability for use as fuel or as a chemical feedstock. The adopted methodology follows well-established procedures widely recognized in specialized literature, ensuring reliability and reproducibility of the results (López-Urionabarrenechea, A. et al, 2011 ;Al-Salem, S. M. et al, 2017). Accurate measurement of these properties is crucial not only for industrial applications but also for comparing pyrolytic oils obtained from different feedstocks or pyrolysis conditions. By adhering to these standardized techniques, the study provides consistent and credible data, contributing to the broader knowledge of tire-derived pyrolytic oil characteristics.

a. Mass Density

Density was determined by analyzing a measured amount of each sample. For each sample, the mass was precisely weighed, and the corresponding volume was accurately measured. Density is then calculated as the ratio of mass to volume, representing a fundamental physical property of the material. This property is essential for characterizing substances, enabling comparisons between different materials, and predicting their behavior under various environmental conditions. Understanding the density of a material is particularly important in applications involving fluid dynamics, material processing, and energy storage, where interactions with surrounding media depend on density differences. Additionally, density can provide insight into the composition and structural integrity of a sample. It is important to note that density is not a fixed property; it changes with variations in temperature and pressure, which must be considered when interpreting results (Cengel, Y. A. et al, 2015). Accurate determination of density therefore supports both practical applications and theoretical analyses in material science and engineering.

$$\rho = \frac{m}{V} \quad (1)$$

Where m: the mass of the sample (kg), **v**: the volume of the sample (m^3), ϱ: the density of the sample (kg/m^3).

b. Density

It was determined by taking the ratio between the density of the sample and the density of water at 4 °C (1000 kg/m^3).

$$d = \frac{\rho}{\rho e} \quad (2)$$

With d: density of the sample, ϱ: density (mass per unit volume) of the sample (kg/m^3), ϱ_e: density of water at 4 °C (1000 kg/m^3).

c. Viscosity

It was determined using the Hoppler method (falling-ball viscometer) based on Stokes' law.

$$u_h = \frac{2}{9} \cdot \frac{(\rho_b - \rho_h).g.r^2}{v} \quad (3)$$

With u_h: dynamic viscosity of the sample (Pa·s), ϱ_b and ϱ_h: the densities of the ball and the sample, respectively (kg/m³), g: gravitational acceleration (m/s²), r: radius of the ball (m), and **v**: falling velocity of the particle (m/s).

d. pH

The pH of the samples was determined using pH paper, a simple yet effective method for evaluating the acidity or alkalinity of a substance. To perform the measurement, the pH paper was carefully inserted into a test tube containing the sample, ensuring full contact with the liquid. After a brief interaction, the paper changed color according to the sample's hydrogen ion concentration. The resulting color was then compared with the standardized color scale provided on the pH paper packaging to determine the corresponding pH value. This technique allows for a rapid and straightforward assessment of the sample's chemical environment, which is critical for understanding its stability, reactivity, and potential applications. Although less precise than instrumental methods, pH paper provides a reliable estimate suitable for preliminary analysis and routine measurements. This methodology aligns with standard procedures described in the literature (Cengel, Y. A. et al, 2015).

RESULTS AND DISCUSSION

Quantities	Symbols	Values	Units
Mass	m	0.03847	kg
Volume	V	0.000050	m³
Density (mass density)	ϱ	769.4	kg/m³
Falling time	t	0.42	s
Falling height	h	0.094	m
Falling velocity	V	0.22	m/s
Color	—	Dark red	—
pH	—	4	—
Dynamic viscosity	μ	0.12	Pa·s
Kinematic viscosity	ϑ	0.00015	m²/s
Density of the ball	ϱ_b	2700	kg/m³

Quantities	Symbols	Values	Units
Radius of the ball	R	0.0025	m
Liquid density	d	0.7694	—
Density of water	ϱ_e	1000	kg/m³

- **Density and mass density**

The pyrolytic oil obtained from waste tires exhibited a measured density of 769.4 kg/m³, corresponding to a relative density of 0.7694. This value falls well within the typical range reported in the literature for tire-derived pyrolytic oils, indicating that the sample's properties are consistent with previously observed results. The measured density suggests a relatively high content of light hydrocarbons, which is characteristic of oils produced under certain pyrolysis conditions. The presence of these light fractions affects both the fuel properties and potential chemical applications of the oil. Variations in density are commonly influenced by several factors, including the composition of the tires, the temperature at which pyrolysis is conducted, and the residence time within the reactor. These parameters can significantly alter the distribution of hydrocarbons in the final oil product. Similar trends regarding the relationship between pyrolysis conditions and oil density have been reported by Han and Chen., Furthermore, distillation studies conducted by Campuzano and colleagues (Campuzano, F at al, 2020 ; Campuzano, F.) confirm that pyrolytic oils contain a wide range of hydrocarbon fractions, with density values reflecting the relative proportions of light and heavy components.

- **Viscosity**

The obtained pyrolytic oil exhibits a kinematic viscosity of 1.5 cSt, indicating a relatively low resistance to flow. In comparison, Miandad et al. (2019) reported a viscosity of 1.9 cSt for catalytic tire pyrolysis oil, slightly higher than that measured in our sample. Čepić et al. (2021) investigated the influence of the final pyrolysis temperature and observed viscosities of 4.7 cSt at 500 °C and approximately 5.0 cSt at 750 °C, demonstrating that higher pyrolysis temperatures generally produce oils with increased viscosity due to the formation of heavier hydrocarbon fractions. Additionally, a broader review by Nkosi, Muzenda, Gorimbo, and Belaid (Nkosi, N. et al, 2021) reported that the viscosity of tire-derived oil (TDO) typically averages around 3.2 cSt at 40 °C, with values ranging from 2 to 21 cSt depending on the feedstock and process conditions. These comparisons indicate that our pyrolytic oil (1.5 cSt) is more fluid than the oil obtained by Miandad et al. and significantly less viscous than oils produced at higher temperatures, such as those reported by Čepić et al. The relatively low viscosity suggests a higher proportion of light hydrocarbons and fewer heavy molecular chains, reflecting a pyrolysis process that favors the formation of low-molecular-weight compounds. Such characteristics are advantageous for fuel-related applications, as low-viscosity oils generally improve combustion efficiency, facilitate handling and pumping, and offer better blending potential with conventional fuels. Overall, these results highlight the efficiency of our process in producing a light, low-viscosity pyrolytic oil suitable for practical use.

- **pH**

The measured pH is 4. A pH of 4 indicates that the pyrolytic oil is mildly acidic. This is consistent with the literature on tyre-derived pyrolytic oils, which often contain light acids (carboxylic acids, phenols, oxygenated compounds) produced during thermal decomposition of rubber and additives. Nkosi et al. (2021) report that pH values for tyre pyrolysis oils generally range between 3.5 and 5, depending on the process and temperature, confirming that our value is typical. Miandad et al. (Miandad, R, 2019) found a pH of 4.2 for pyrolytic oil produced at 500 °C, very close to our measurement. Campuzano et al report pH values between 3.8 and 4.5 for various tyre pyrolysis oil fractions, depending on distillation and the recovered fraction.

CONCLUSION

The pyrolysis of waste tyres effectively produced light hydrocarbons, resulting in a pyrolytic oil with low viscosity (1.5 cSt), a density of 0.7694, and a slightly acidic pH (4) all values consistent with those reported in the literature. These results confirm the energy recovery potential of end-of-life tyres and highlight the relevance of pyrolysis as a sustainable solution for resource recovery and waste reduction.

REFERENCES

Aguado, J., Serrano, D. P., & Escola, J. M. (2008). *Feedstock recycling of plastic wastes*. RSC Publishing.

Al Salem, S. M., Antelava, A., Constantinou, A., Manos, G., & Dutta, A. (2017). A review on thermal and catalytic pyrolysis of plastic solid waste (PSW). *Journal of*

Environmental Management, 197, 177–198. https://doi.org/10.1016/j.jenvman.2017.03.084

Berry Moukila, S. U., Nkeletela, L. B., Samba, R., Mabiala Mikanou, O., Makosso Voula, R., & Kiesse, D. S. (2025). Contribution to the production and physicochemical characterization of pyrolytic oil from used inner tubes for the production of conventional fuels in Congo Republic (RC). *International Journal of Current Advanced Research, 14*(6), 289–292.

Campuzano, F., Abdul Jameel, A. G., Zhang, W., Emwas, A.-H., Agudelo, A. F., Martínez, J. D., & Sarathy, S. M. (n.d.-a). Fuel and chemical properties of waste tire pyrolysis oil derived from a continuous twin-auger reactor. *Energy & Fuels, 34*(10), 12688–12702. https://doi.org/10.1021/acs.energyfuels.0c02271

Campuzano, F., Abdul Jameel, A. G., Zhang, W., Emwas, A.-H., Agudelo, A. F., Martínez, J. D., & Sarathy, S. M. (n.d.-b). On the distillation of waste tire pyrolysis oil: A structural characterization of the derived fractions. *Fuel, 290*, 120041. https://doi.org/10.1016/j.fuel.2020.120041

Cengel, Y. A., & Boles, M. A. (2015). *Thermodynamics: An engineering approach* (8th ed.). McGraw Hill Education.

Čepić, Z., Mihajlović, V., Đurić, S., Milotić, M., Stošić, M., Stepanov, B., & Ilić Mićunović, M. (2021). Experimental analysis of temperature influence on waste tire pyrolysis: Novel combustion techniques for clean energy. https://doi.org/10.3390/en14175403

Google. (n.d.). [Image result]. Retrieved November 18, 2025, from https://www.google.com/imgres

Han, W., Han, D., & Chen, H.-. (n.d.). Pyrolysis of waste tires: A review. *Polymers, 15*(7), 1604. https://doi.org/10.3390/polym15071604

Kumar, S., & Singh, R. K. (2011). Pyrolysis of plastic waste: A review. *Renewable and Sustainable Energy Reviews, 16*(6), 2467–2477.

López Urionabarrenechea, A., de Marco, I., Caballero, B. M., Laresgoiti, M. F., & Adrados, A. (2011). Influence of time and temperature on pyrolysis of plastic wastes in a semi-batch reactor. *Chemical Engineering Journal, 173*(1), 62–71. https://doi.org/10.1016/j.cej.2011.07.037

Miandad, R., Rehan, M., Barakat, M. A., Aburiazaiza, A. S., Khan, H., Ismail, I. M. I., ... & Nizami, A.-S. (2019). Catalytic pyrolysis of plastic waste: Advancing toward pyrolysis based biorefineries. *Frontiers in Energy Research, 7*, Article 27. https://doi.org/10.3389/fenrg.2019.00027

Nkosi, N., Muzenda, E., Gorimbo, J., & Belaid, M. (2021). Developments in waste tyre thermochemical conversion processes: Gasification, pyrolysis and liquefaction. *RSC Advances, 11*, 11844–11871. https://doi.org/10.1039/D0RA08966D

Singh, R. K., & Kumar, S. (2011). Pyrolysis of plastic waste: A review. *Renewable and Sustainable Energy Reviews, 16*(6), 2467–2477.