Global Journal of Engineering and Technology Advances
eISSN: 2582-5003
Cross Ref DOI: 10.30574/gjeta
Journal homepage: https://gjeta.com/

(RESEARCH ARTICLE)

Check for updates

Comparative FTIR Analysis of Liquid By-products from PET Hydrolysis Using Methanol and Ethylene Glycol

Yousif. A A *, Abdallah. I, Mohammed N, Amnah. A, Batool. M and Mohammed. H

Department of Polymer Engineering, Sudan University of Science and Technology, Khartoum, Sudan.

Global Journal of Engineering and Technology Advances, 2025, 25(01), 021-023

Publication history: Received on 20 August 2025; revised on 28 September 2025; accepted on 01 October 2025

Article DOI: https://doi.org/10.30574/gjeta.2025.25.1.0292

Abstract

Polyethylene terephthalate (PET) hydrolysis is a promising pathway for recycling plastic waste into valuable chemical feedstocks. In this work, the focus is shifted from the solid terephthalic acid product to the liquid by-products generated using two different solvents: ethylene glycol and methanol. Hydrolysis was conducted under controlled conditions using sodium hydroxide as the catalyst, followed by neutralization with sulfuric acid. Fourier Transform Infrared (FTIR) spectroscopy was employed to characterize the liquid fractions. Results indicated that the spectra of ethylene glycol-based hydrolysis products closely resembled that of pure ethylene glycol, with minor deviations due to impurities, while methanol-derived samples exhibited significant spectral differences compared to pure methanol. The broad absorption peaks between 3200–3500 cm^{-1} confirmed the presence of hydroxyl groups in all liquid samples. This study highlights the critical role of solvent selection in determining the quality and reusability of the liquid by-products during PET hydrolysis.

Keywords: Polyethylene terephthalate (PET); Hydrolysis; Ethylene glycol; Methanol; FTIR spectroscopy; Recycling

1. Introduction

The increasing accumulation of polyethylene terephthalate (PET) waste has raised global concerns regarding environmental sustainability and resource recovery [1].Conventional mechanical recycling often degrades polymer quality, whereas chemical recycling via hydrolysis offers the potential to recover high-value monomers and by-products [2].Most studies on PET hydrolysis emphasize terephthalic acid recovery as the main solid product. However, the fate and characteristics of the liquid fractions generated during hydrolysis remain less investigated [3].Fourier Transform Infrared (FTIR) spectroscopy provides a powerful analytical tool to assess functional groups within these liquids, thereby enabling the identification of changes induced by PET hydrolysis [4].This paper aims to comparatively analyze the FTIR spectra of liquid by-products obtained from PET hydrolysis using methanol and ethylene glycol, providing insights into solvent stability and purity during the recycling process [5]. Al-Sabagh et al. (2016) highlighted greener recycling approaches, demonstrating glycolysis as a practical route for PET valorization [6]. López-Fonseca et al. (2010) examined the influence of metal catalysts in PET glycolysis, showing improved reaction rates and selectivity [7]. Chen et al. (2019) optimized alkaline hydrolysis of PET, reporting enhanced terephthalic acid yields under controlled conditions [8]. Jehanno et al. (2020) proposed chemical recycling as a cornerstone of circular economy, focusing on solvent selection for depolymerization [9]. Peng and Chen (2021) studied comparative solvent effects in PET depolymerization, concluding ethylene glycol outperforms methanol in terms of by-product stability [10] Kosmidis et al. (2021) investigated PET hydrolysis kinetics, demonstrating how reaction temperature influences product distribution [11]. Rahimi and García (2017) reviewed chemical upcycling of plastics, emphasizing solvent-assisted depolymerization [12]. Krall et al. (2022) applied FTIR to monitor PET hydrolysis in real-time, highlighting spectral markers for functional groups [13].nPatel et al. (2022) investigated environmental aspects of PET chemical recycling, reporting reduced emissions with glycolysis compared to incineration [14]. Nguyen et al. (2023) developed hybrid

* Corresponding author: Yousif. A A

catalytic systems to accelerate PET methanolysis, reporting limitations in solvent recovery [15]. Zhang et al. (2024) analyzed solvent–solute interactions during PET depolymerization, confirming that ethylene glycol enables more efficient product purification [16]. Pohlmann et al. (2019) reviewed solvent-based recycling and highlighted the challenges in solvent recovery and purity [17].

2. Materials and methods

PET flakes were prepared by cutting post-consumer PET bottles into rectangular pieces (6–8 mm in length, 3–5 mm in width). The flakes were hydrolyzed using sodium hydroxide dissolved in either ethylene glycol or methanol, followed by heating until PET flakes melted completely. After neutralization with sulfuric acid, solid terephthalic acid was filtered out, leaving the liquid fractions for analysis. FTIR spectroscopy (wavenumber range: 4000–500 cm^{-1}) was employed to identify functional groups in the recovered liquid products. The obtained spectra were compared to reference spectra of pure ethylene glycol and pure methanol.

Table 1 Properties of PET and solvents used in hydrolysis

Property	PET	Ethylene Glycol (EG)	Methanol (MeOH)
Molecular weight (g/mol)	~192	62	32
Boiling point (°C)	–	197	64.7
Density (g/cm^3)	1.38	1.11	0.79
Functional group	Ester linkages	OH, CH_2	OH, CH_3
Solubility in water	Insoluble	Miscible	Miscible

3. Results and discussion

3.1. FTIR spectra of ethylene glycol-derived liquids

FTIR analysis revealed that liquid samples obtained using ethylene glycol exhibited spectra very close to that of pure ethylene glycol. Minor variations were attributed to the presence of residual by-products and impurities. The characteristic O–H stretching band was observed in the broad region between 3200–3500 cm^{-1}, confirming hydroxyl functionalities.

3.2. FTIR spectra of methanol-derived liquids

In contrast, FTIR spectra of liquid samples produced with methanol showed noticeable deviations from pure methanol. While hydroxyl-related bands were still present, additional peaks suggested the presence of impurities or possible side reactions. Unlike ethylene glycol, methanol appeared less stable under hydrolysis conditions, resulting in altered spectral fingerprints.

3.3. Comparative analysis

The comparative analysis demonstrated that ethylene glycol samples shared multiple matching peaks with pure ethylene glycol, whereas methanol samples deviated significantly from pure methanol.

Table 2 Comparative FTIR peaks of reference solvents and hydrolysis liquids

Wavenumber (cm^{-1})	Functional Group	Pure EG	EG-derived liquid	Pure MeOH	MeOH-derived liquid
3200–3500	O–H stretching	Broad peak	Broad peak (similar)	Broad peak	Broad peak + impurities
2900–2950	C–H stretching	Sharp	Sharp	Sharp	Reduced intensity
1720–1735	C=O stretching	–	Weak trace	–	Weak impurity band
1080–1115	C–O stretching	Present	Present	Present	Shifted peak

850–900	C–H bending	–	Minor band	Weak	Broader than reference

4. Conclusion

This study demonstrated that the choice of solvent plays a decisive role in determining the composition and purity of liquid by-products from PET hydrolysis. Ethylene glycol provided liquid products that closely resembled the original solvent, suggesting high stability and reusability. Methanol-derived liquids, however, exhibited substantial spectral differences, highlighting potential limitations in its application for PET hydrolysis.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed

References

[1] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, 3(7), e1700782.

[2] Awaja, F., & Pavel, D. (2005). Recycling of PET. *European Polymer Journal*, 41(7), 1453–1477.

[3] Sinha, V., Patel, M. R., & Patel, J. V. (2010). PET waste management by chemical recycling: A review. *Journal of Polymers and the Environment*, 18, 8–25.

[4] Fujita, H., et al. (2020). Advanced depolymerization methods for PET recycling. *Journal of Material Cycles and Waste Management*, 22, 1331–1342.

[5] Hahladakis, J. N., et al. (2020). A review on chemical recycling of plastics. *Waste Management*, 108, 164–187.

[6] Al-Sabagh, A. M., et al. (2016). Greener routes for recycling of polyethylene terephthalate. *Egyptian Journal of Petroleum*, 25(1), 53–64.

[7] López-Fonseca, R., et al. (2010). Chemical recycling of post-consumer PET wastes by glycolysis in the presence of metal salts. *Polymer Degradation and Stability*, 95(6), 1022–1028.

[8] Chen, Y., et al. (2019). Optimized alkaline hydrolysis of PET. *Journal of Applied Polymer Science*, 136(12), 47235.

[9] Jehanno, C., et al. (2020). Chemical recycling of plastics in circular economy. *Nature Reviews Materials*, 5(9), 706–724.

[10] Peng, X., & Chen, Y. (2021). Chemical recycling of plastics by hydrolysis. *Green Chemistry*, 23(5), 1919–1937.

[11] Kosmidis, P. A., et al. (2021). Kinetics of PET hydrolysis. *Polymer Engineering and Science*, 61(7), 1452–1461.

[12] Rahimi, A., & García, J. M. (2017). Chemical recycling by depolymerization. *Nature Reviews Chemistry*, 1(6), 0046.

[13] Krall, E. M., et al. (2022). FTIR monitoring of PET depolymerization. *Polymer Testing*, 106, 107466.

[14] Patel, S., et al. (2022). Environmental evaluation of PET recycling. *Journal of Cleaner Production*, 330, 129853.

[15] Nguyen, H. T., et al. (2023). Hybrid catalytic systems for PET methanolysis. *ACS Sustainable Chemistry & Engineering*, 11(3), 1243–1254.

[16] Zhang, L., et al. (2024). Solvent–solute interactions in PET hydrolysis. *Macromolecular Chemistry and Physics*, 225(4), 230042.

[17] Pohlmann, J., et al. (2019). Solvent-based recycling of plastics: A review. *ChemSusChem*, 12(1), 414–430.

[18] Shukla, S. R., & Harad, A. M. (2006). Glycolysis of PET waste. *Journal of Applied Polymer Science*, 100(6), 4870–4876.

[19] Lopez, G., et al. (2017). Recent advances in the chemical recycling of PET. *Journal of Cleaner Production*, 150, 142–155.

[20] Rahman, M., et al. (2021). Emerging technologies in PET recycling. *Renewable and Sustainable Energy Reviews*, 135, 110236.