The influence of flame retardant additives on the properties of bio-based polyurethane-polyisocyanurate foams

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INTRODUCTION

Polyurethane-polyisocyanurate foams, due to their porous structure and low density, are widely used across various industrial sectors, making them materials of high practical value. However, a significant drawback of these foams is their flammability, which can be mitigated by the use of flame retardants. These substances enhance fire resistance, for example, by neutralizing free radicals or forming a protective char layer. One innovative and environmentally friendly approach involves replacing petrochemical-based polyols with biopolyols derived from vegetable oils. This solution helps reduce environmental impact and is characterized by a low carbon footprint. The study focused on analyzing the mechanical properties and flammability of bio-foams modified in this manner

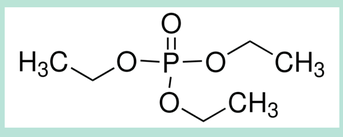
RESULTS AND DISCUSSION

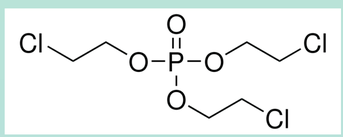
FLAME RETARDANTS USED IN FOAMS

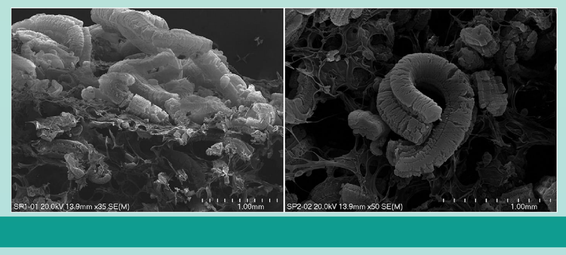
TEP (triethyl phosphate) is an organophosphorus liquid flame retardant that acts mainly in the gas phase. It inhibits combustion reactions by neutralizing free radicals and partially forms a char layer, while being non-toxic and environmentally friendly.

TCPP (tris(2-chloropropyl) phosphate) is a liquid compound containing both phosphorus and chlorine, offering high flame-retardant efficiency through action in both the gas and condensed phases. Despite its effectiveness, it releases toxic gases during combustion and is considered less environmentally sustainable.

Expandable graphite, especially in its expanded form, acts as a physical flame retardant—under high temperatures, it swells and creates a protective layer that shields the material from fire and limits oxygen access. It is a non-toxic, durable, and highly eco-friendly solution.





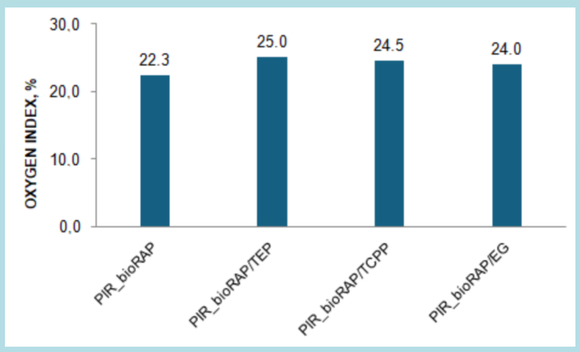


APPARENT DENSITY

Foam symbol	Apparent density, kg/m^3
PIR_bioRAP	39.37
PIR_bioRAP/TEP	38.87
PIR_bioRAP/TCPP	39.78
PIR_bioRAP/EG	45.01

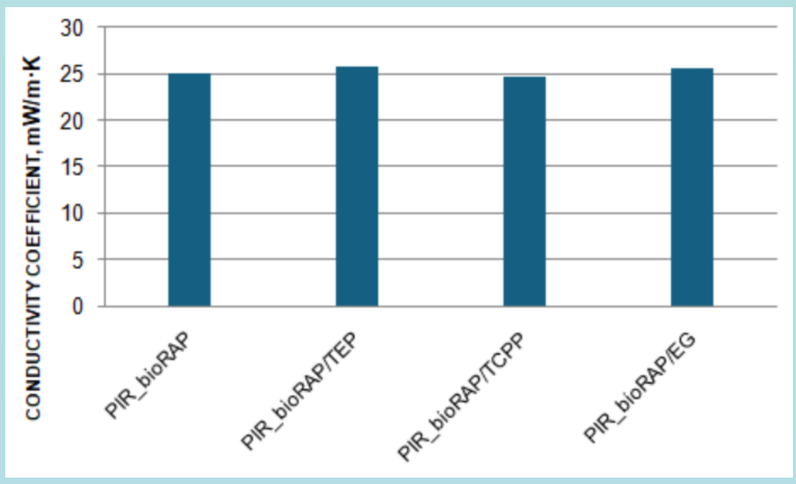
OXYGEN INDEX

One of the fundamental indicators used to assess the flammability of polymer materials. The higher the limiting oxygen index, the more difficult it is for the material to burn, as it requires a higher concentration of oxygen to sustain combustion. The addition of flame retardants increases the LOI value, allowing the effectiveness of various fire-retardant modifiers to be evaluated.



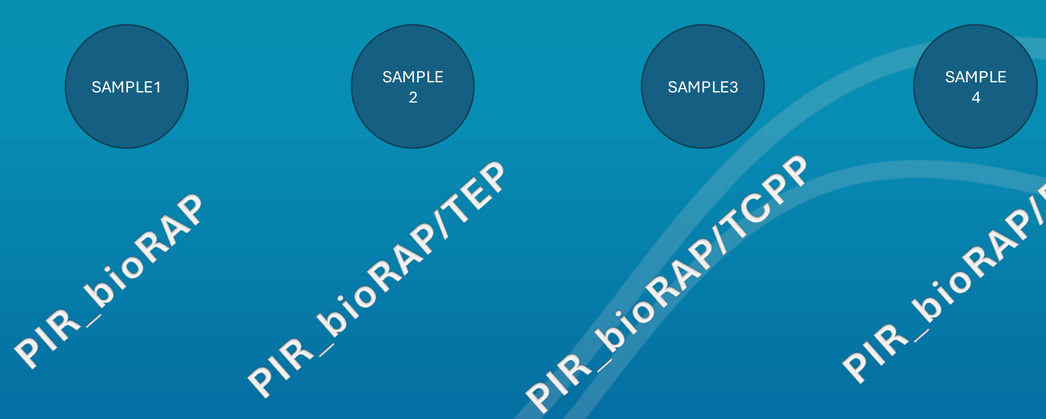
CONDUCTIVITY COEFFICIENT

The thermal conductivity coefficient is a measure of a material's ability to conduct heat. Its low value is a key advantage of PUR foams, determining their widespread use in thermal insulation applications.



COMPRESSIVE STRENGHT

Foam symbol	Compression Strenght, kPa	
	Perpendicular	Parallel
PIR_bioRAP	147 ± 4.1	303.5 ± 9.9
PIR_bioRAP/TEP	130.4 ± 6.6	251.0 ± 26.8
PIR_bioRAP/TCPP	175.0 ±19.2	360.2 ± 14.4
PIR_bioRAP/EG	182.5 ±10.9	301.7 ± 9.4



SUMMARY

As part of the conducted research, it was found that it is possible to obtain polyurethane–polyisocyanurate foams by replacing 100% of the petrochemical polyol with a biopolyol derived from modified rapeseed oil. The most effective flame retardant was TEP; however, foams modified with this compound exhibited the lowest mechanical strength. Further studies will focus on incorporating other halogen-free flame retardants into the PUR–PIR matrix containing biopolyol. The obtained results will be compared with those of the most commonly used flame retardants presented in this study.

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