4-17-2024

# Closing the Loop: Glycolysis Via Bio-Based Solvent and Regeneration of Bio-based Polyurethane Foams

Anuridh Thorbole
*Pittsburg State University*

# Closing the Loop: Glycolysis Via Bio-Based Solvent and Regeneration of Bio-based Polyurethane Foams

Anirudh Thorbole, Pranabesh Sahu, and Ram K. Gupta

Department of Chemistry, National Institute for Materials Advancement, Pittsburg State University

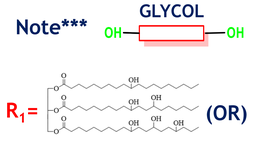
National Institute for Materials Advancement

## Abstract

The quest for sustainable and renewable materials is driving a paradigm shift towards a bio-based economy, propelled particularly by the imperatives of the Sustainable Development Goals (SDGs). The increased use of bio-based polyurethane foams (bio-PUFs) in industrial applications presents a challenge for researchers to develop innovative recycling methodologies conforming to evolving sustainability standards. This research represents an innovative approach to the recycling of bio-PUFs through depolymerization via Glycolysis, employing commercially available bio-based solvent. The degradation and recovery of polyol were validated through FTIR and NMR analysis, confirming the presence of amine groups, urethane linkages, and other byproducts. High yields (over 93%) of recovered polyol were achieved within comparable timeframes using both bio-based and traditional petroleum-based glycolysis agents. Comparative analyses revealed superior physical and chemical properties of bio-based recovered polyol over its petroleum-based counterpart. The resulting recovered polyol (RP) was utilized to fabricate new PUFs replacing up to 20% w/w of the virgin polyol, exhibiting physical characteristics akin to virgin PUFs with negligible deviations. Finally, this study underscores the enhanced circularity within the value chain by closing the loop of bio-PUFs through sustainable glycolysis processes, thus contributing to the advancement of circular economy principles.

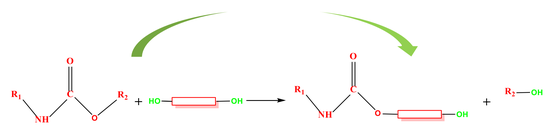
## Background

Note*** GLYCOL

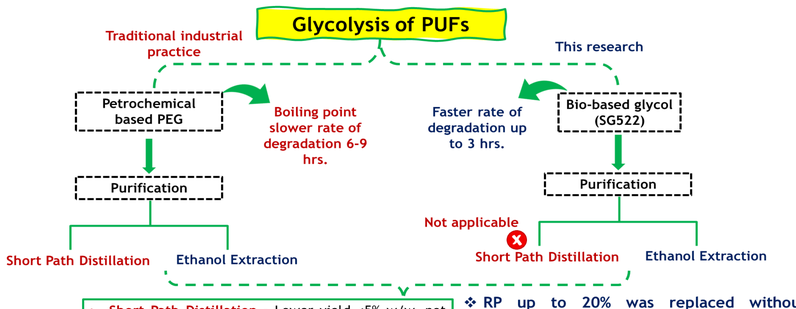









SUCROSE-GLOCOSE POLYOL (SG522)

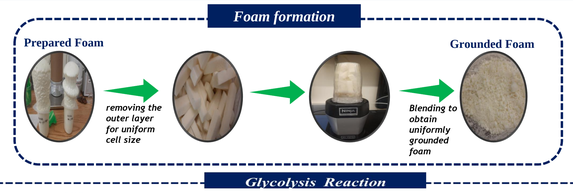



- **Short Path Distillation** - Lower yield <5% w/w, not feasible financially, higher resources and apparatus required
- **Ethanol Extraction** - Higher yield >93%, Faster process with comparatively less resources required

❖ RP up to 20% was replaced without experiencing major changes in properties

**Regeneration of PUFs**

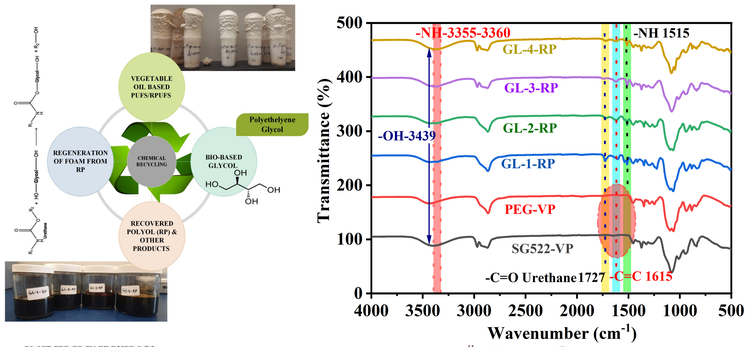
## Recovery of Polyol (RP)

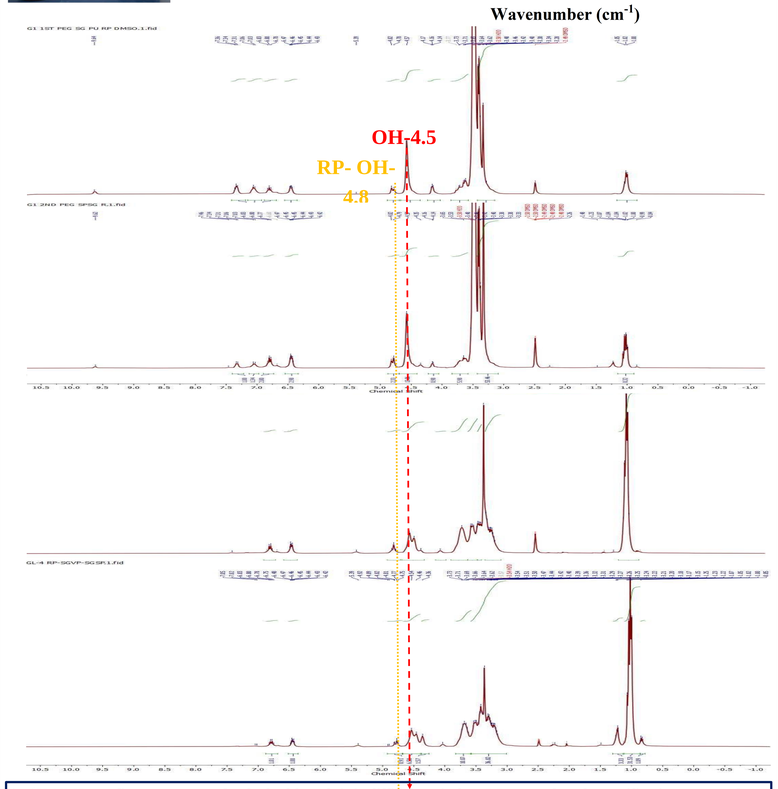



- 50 g of sample was further investigated to extract the VP PEG from the obtained RP utilizing a Short Path Distillation (SPD) process under a high vacuum of 60 hp and at temp. 230 - 280℃ to Obtain RPEG
- Transparent PEG was recovered by SPD in the purest form possible

➢ Polyol recovery was carried out via glycolysis reaction in the presence of bio-reagent, Sucrose Glucose-based polyol. Obtained reaction mixture is then further processed for purification using ethanol as a solvent and polyol is recovered

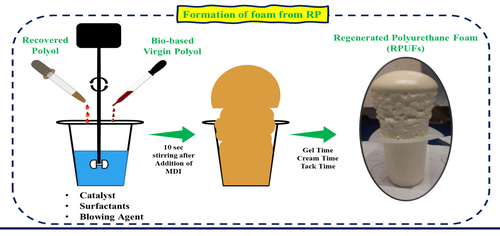
## Characterizations to confirm RP



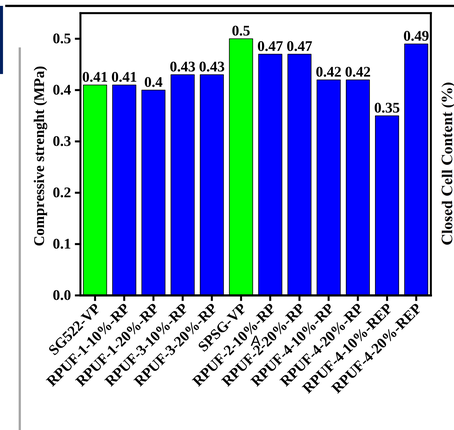



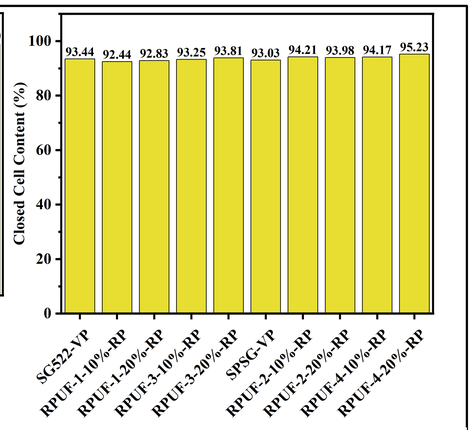

➢ $^{1}H$ NMR confirms recovery of polyol, although it is difficult to isolate RP even after the purification process from the reaction mixture after glycolysis. FTIR confirms the presence of amine ($NH_3$), Urea, and Urethane group.

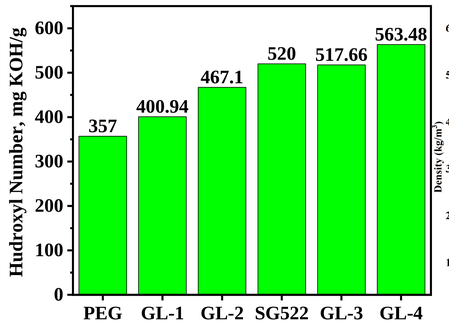
## Regeneration of PUFs from RP

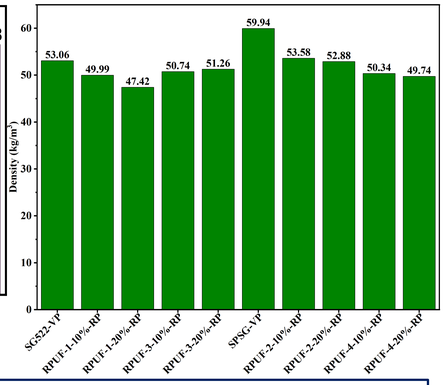



➢ Regeneration of foam was carried out as an application to replace virgin polyol which is a starting material with 10% and 20% w/w to obtain similar or negligible deterioration outlined in physical and chemical characterization of recovered polyol when compared to the virgin once. Results when compared highlighted low values for density on the contrary for closed cell content the values were higher than the foam formulated from the virgin polyol




➢ Based on the literature study and obtained information properties such as Compressive strength, closed-cell content, Oh value, and Density were negligibly short to that of virgin PUFs, and replacement of RP of up to 20% w/w represents similar properties that of freshly prepared PUFs

## Conclusions and Future Work

- ➢ Traditionally recycling of foam was carried out under the presence of glycol which is obtained from petroleum-based compounds, but this research explores the alternative path for recovery.
- ➢ The reaction takes place at a higher temperature of 220℃ and comparatively lower time as reported in the various literature.
- ➢ The degradation reaction was completed within 3 hours enhancing the process efficiency with less time and higher recovery
- ➢ Successful recovery of polyol from bio-based PUFs was carried out using greener alternatives for recycling polymers in the presence of novel bio-based glycol
- ➢ More than 93% recovery of PUFs was obtained after glycolysis which is directly reusable without further processing for various applications of coating, films, adhesive, and foam formation
- ➢ One such application was focused on in this research to understand the change in physical properties of foam formulated from recovered polyol
- ➢ Future work can be focused on the isolation of Polyol from the precursors and exploring the mechanical behavior of the recovered polyol in end applications such as foam
- ➢ Numerous applications from recovered polyol can also be explored

## Acknowledgements

➢ National Institute for Materials Advancement

➢ Pittsburg State University