Non-Isocyanate Polyurethanes from Kraft Lignin

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Abstract

Adhesives from isocyanate polyurethanes have strong bonding properties yet pose serious health risks in both production and daily life. **Kraft Lignin**, a common organic waste, contains the functional groups that can make a **renewable alternative** and replace isocyanate's role in adhesives. Our production plant will be placed in Rome, Georgia attached to an existing paper mill with competitive pricing of 26.47$/kg. Our three-step process proposes **a sustainable approach** to producing **polyurethane** adhesives without incorporating isocyanates.

Novelty

- **Eliminates isocyanates**
- Utilizing **protic ionic liquid** (PIL) to precipitate lignin on large scale
- Integration with existing papermill for conservation of costs

Impact

Safety: Isocyanates are removed, less harmful chemicals remain, and concerns are mitigated.[1]

Societal: Will be globally accepted based on waste valorization, create local jobs, and seen as an expansion of existing plant instead of a new plant.

Environment: Most chemicals are non-toxic and seen as "green chemicals" despite some gases including H_2S, CO_2, and O_2.

Objectives & Goals

1. Precipitate **lignin** out of **Black Liquor** waste.
2. Break down **lignin** into its main **monomers**.
3. Add a carbonate and amine group onto monomers for isocyanate free adhesive.

Reactions

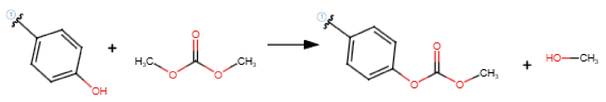
Lignin Precipitation via SLRP[2]

$$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$$

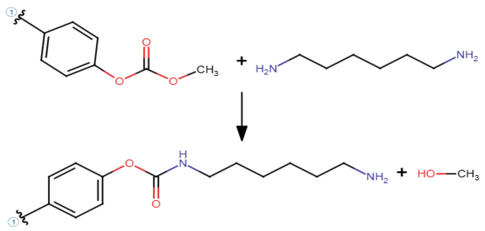
Depolymerization via Fenton Process[3]

$$Lignin \rightarrow Sinapyl + Coumaryl + Coniferyl$$

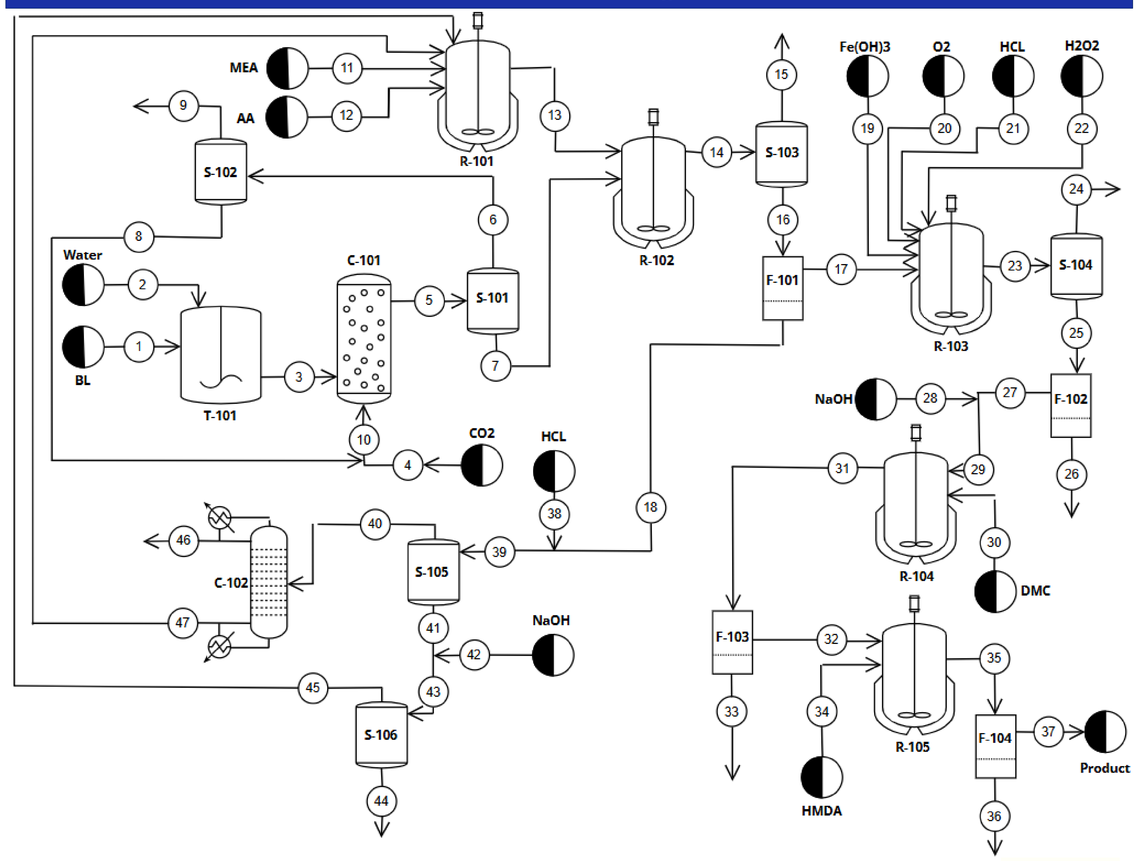
Carbonation with DMC



Polyaddition with HMDA



Process Flow Diagram

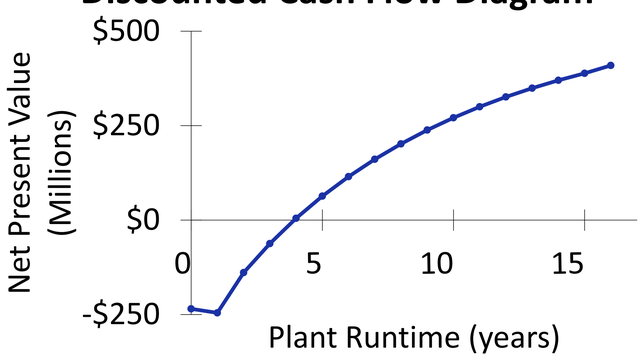


PFD Table Index

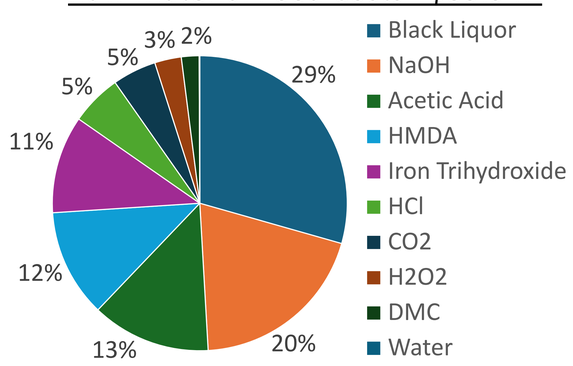
Unit	Description
T-101	Pretreatment Tank
C-101	CO_2 Bubble Column
C-102	Acetic Acid and Water Distillation
S-101	Gas Removal
S-102	H_2S Removal
S-103	Gas Removal
S-104	Oxygen Removal
S-105	Acetic Acid Separation
S-106	MEA Separation
R-101	PIL Reactor
R-102	Lignin Precipitation Reactor
R-103	Fenton Reactor
R-104	DMC Reactor
R-105	HMDA Reactor
F-101	Lignin Filtration
F-102	Monomer Filtration
F-103	Intermediate Filtration
F-104	Adhesive Collection

Economics and Profitability

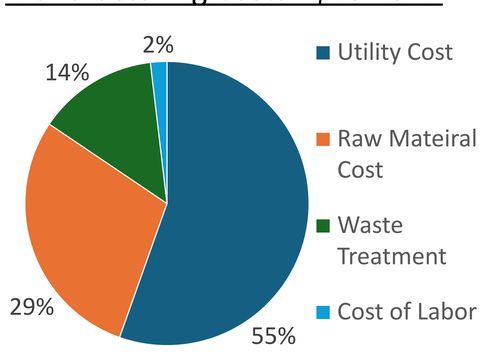
Discounted Cash Flow Diagram



Raw Material Feed Costs - $39.9 M



Manufacturing Costs - $137.3 M



Key Takeaways & Next Steps

Lignin-based NIPU adhesives offer a safer and more sustainable alternative to traditional polyurethane adhesives. The process shows strong potential for greener production and creating a pilot plant will be our next step.

References

1. Iswanto, et al., *Polymers* (2023).
2. Lake & Blackburn, *Cellul. Chem. Technol* (2014).
3. Méndez, et al., *J. Envr Chem E* (2025).