IOCS 2025 Conference

The 1st International Online Conference on Separations

15–17 October 2025 | Online

Development of PLA-Based Membrane Materials from Lignocellulosic Biomass for Efficient Separation Processes

SENILA LACRIMIOARA

National Institute for Research and Development of Optoelectronics INOE 2000, Research Institute for Analytical Instrumentation, Donath 67, 400293 Cluj-Napoca, Romania, lacri.senila@icia.ro

INTRODUCTION & AIM

In recent years, membranes have been extensively used, particularly in wastewater treatment and food packaging. As a result, significant research efforts are focused on identifying eco-friendly alternatives to the materials traditionally employed in membrane fabrication. One promising material is polylactic acid (PLA), a renewable and biodegradable polymer derived from lignocellulosic agricultural waste. In this study, PLA was synthesized from lignocellulosic biomass via a comprehensive multi-step process comprising autohydrolysis, delignification, and simultaneous saccharification and fermentation (SSF) of cellulose derived from lignocellulosic waste, lactic acid recovery, and subsequent polycondensation of lactic acid. The production of bioplastics from lignocellulosic feedstocks involves the extraction of key polysaccharide components, namely cellulose and hemicellulose. These are then subjected to pretreatment and hydrolysis processes. The polymerization of L-lactic acid obtained above was conducted in two stages: dehydration, followed by microwave-assisted polycondensation in the presence of $SnCl_2$ as a catalyst. This sustainable approach utilizes renewable biomass as a raw material for the production of biodegradable polymers, presenting a viable alternative to conventional petroleum-based plastics. The synthesized PLA was subsequently used to fabricate polymeric membranes aiming to separate heavy metals from wastewater. These membranes can be used to separate the metals Cd, Cu, Zn, Mn, Ni, and Pb from wastewater, with separation efficiencies ranging from 5% to 17%. The highest separation efficiencies are achieved for Co and Ni (83% and 84%, respectively) when using a filter such as cellulose nanowhiskers. Membranes derived from PLA have shown promising potential in environmental remediation applications. PLA-based membranes can effectively remove contaminants such as heavy metals, dyes, and organic pollutants from wastewater. Due to their biodegradability and eco-friendly nature, these membranes contribute to sustainable water treatment processes by reducing secondary pollution and minimizing environmental impact. Overall, this work demonstrates a sustainable and environmentally friendly strategy for converting biomass into high-value materials for water purification applications.

METHOD

The procedure for PLA production was conducted as illustrated in Figure 1.

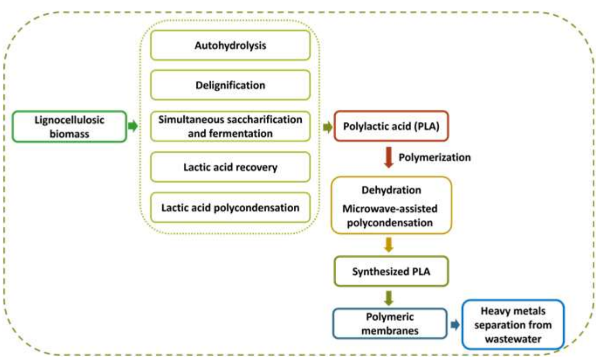

Figure 1. Schematic representation of the process flow for the production of polymeric membranes derived from PLA synthesized from lignocellulosic biomass.

A novel polymer inclusion membrane (PIM) was fabricated using PLA as the base polymer, dioctyl phthalate (DOP) as the plasticizer, and Chelex-100 as the carrier. The membrane's extraction performance was evaluated using an aqueous donor phase containing Cd, Cu, Zn, Mn, Ni, and Pb ions, each at a concentration of 10 mg L^{-1}.

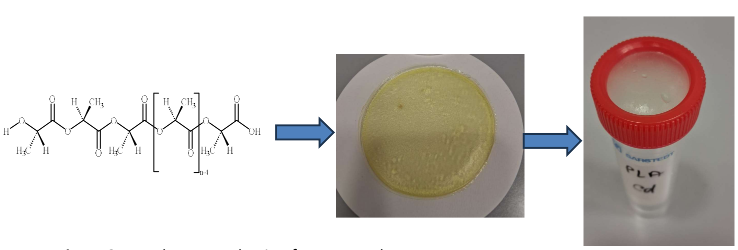

Figure 2. Membrane production from PLA polymer

RESULTS & DISCUSSION

PLA production from lignocellulosic biomass

Lignocellulosic biomass is predominantly composed of cellulose (25–55%), hemicellulose (11–50%), and lignin (10–40%). The fermentable sugars obtained from these components serve as essential substrates in microbial fermentation processes for the synthesis of biopolymers, such as PLA. Specifically, the carbohydrate fractions of cellulosic biomass—cellulose and hemicellulose—can be effectively converted into PLA through biochemical transformation pathways.

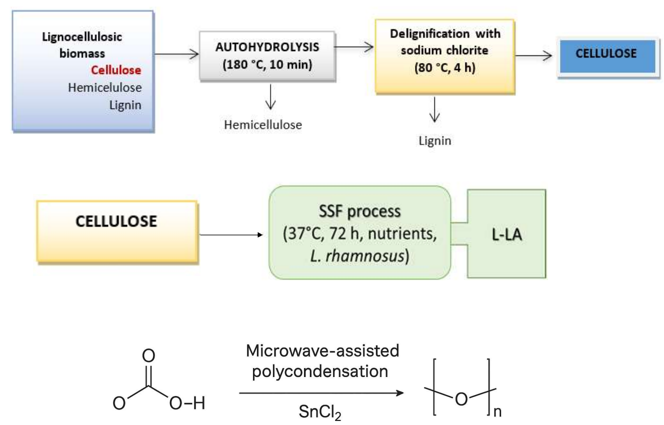

Figure 1. PLA production from lignocellulosic biomass

This study demonstrates the feasibility of utilizing PLA as a sustainable base polymer for the fabrication of polymer inclusion membranes (PIMs) aimed at heavy metal removal from wastewater. The incorporation of suitable plasticizers and carriers enables the development of PLA-based PIMs with promising mechanical stability and effective metal ion transport performance. The results indicate that PLA, being biodegradable and derived from renewable resources, represents an environmentally friendly alternative to conventional polymers such as PVC in PIM fabrication. Overall, PLA-based PIMs hold significant potential for the selective extraction, separation, and preconcentration of heavy metals, contributing to greener and more sustainable wastewater treatment technologies. Further optimization of membrane composition and long-term performance evaluation under real wastewater conditions are recommended to advance their practical applications.

In this study, polymer inclusion membranes (PIMs) composed of PLA as the base polymer, DOP as the plasticizer, and Chelex-100 as the carrier were fabricated using the casting method and evaluated for the separation of heavy metals under conditions suitable for passive sampling. The membranes demonstrated high transport efficiency, achieving approximately 83% extraction of Co(II) and 84% of Ni(II) from wastewater. These findings underline the potential of PLA-based PIMs as efficient, biodegradable alternatives for the extraction, separation, and preconcentration of heavy metals from complex aqueous matrices.

CONCLUSION

This study demonstrated the successful fabrication of PLA-based polymer inclusion membranes (PIMs) incorporating dioctyl phthalate (DOP) as a plasticizer and Chelex-100 as a carrier for heavy metal removal from wastewater. The membranes exhibited efficient transport and extraction performance, particularly for Co(II) and Ni(II) ions, confirming the potential of PLA as a sustainable and biodegradable alternative to conventional polymers in wastewater treatment applications.

FUTURE WORK / REFERENCES

Further research should focus on optimizing the composition and structural properties of polymer inclusion membranes to enhance their selectivity and transport efficiency for heavy metal ions. Investigations into alternative biodegradable base polymers, such as PLA, and environmentally benign plasticizers could contribute to developing more sustainable membrane systems.

Acknowledgement

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CCCDI UEFISCDI, project number PN-IV-P8-8.3-PM-RO-TR-2024-0017, within PNCDI IV.