Book of Abstracts

Workshop of Students' Presentations 2026

„Membranes and Membrane Processes“

5st November, 2026

Stráž pod Ralskem, Czech Republic

Organized by:

Czech Membrane Platform

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ISBN 978-80-909640-6-8

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The peer review process for the contributions included in this book of abstracts was managed and coordinated by **Professor Petr Mikulášek** from the University of Pardubice, Faculty of Chemical Technology, who served as the chief reviewer for the submitted papers. The evaluation focused on the quality, originality, and relevance of the contributions in relation to the scope of the workshop. Each paper was assessed with the aim of maintaining a high academic standard.

The editors would like to express their sincere thanks to Professor Petr Mikulášek for his time, expertise, and valuable contribution to the preparation of this book of abstracts.

Miroslav Strnad
Czech Membrane Platform

FOREWORD

Dear Ladies and Gentlemen,

On behalf of the Czech Membrane Platform and MemBrain, it is our great pleasure to welcome you to the 14th Workshop of Students' Presentations 2026 in Stráž pod Ralskem.

We are delighted to continue this long-standing tradition, which brings together talented students, experienced researchers, and industry professionals to share knowledge, exchange ideas, and explore the latest advancements in membrane technologies and water recycling.

Over the years, this workshop has become a valuable platform for young researchers to present their work, receive constructive feedback from experts, and gain vital experience in communicating and defending their results. We would like to express our sincere appreciation to all our partners and supporters, whose continued commitment makes this event possible.

A distinguished panel of experts will evaluate the student presentations, recognizing outstanding achievements with monetary awards and gifts. Beyond the competition itself, we believe that the opportunity to engage in professional discussions, establish new contacts, and bridge academic research with industrial practice remains one of the workshop's greatest benefits.

By supporting young scientists and fostering their innovative ideas, we contribute to the ongoing development of membrane science and help shape the next generation of professionals in this rapidly evolving field. We are proud that the workshop provides a welcoming environment for this exchange, particularly within the unique setting of the Membrane Innovation Centre.

We wish all participants an inspiring and successful workshop, fruitful discussions, valuable new connections, and every success in their future research and professional endeavours.

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ABSTRACTS

SUSTAINABLE CO_2 SEQUESTRATION AND REAGENT RECOVERY VIA BIPOLAR MEMBRANE ELECTRODIALYSIS INTEGRATION

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Abstract: Climate change is a global challenge that requires accelerated, sustainable efforts through integrated process designs to simultaneously address carbon dioxide (CO_2) emissions, resource recovery, and waste valorisation. This research explores enhanced acid and alkali regeneration from the indirect mineral carbonation waste stream of an industrial alkaline waste material, using an advanced niche separation technology to promote circularity. Alkaline industrial wastes, such as steel slag, exhibit promising potential for permanent CO_2 sequestration; however, the scalability and efficiency of the process remain limited, primarily due to reliance on non-renewable solvents for leaching, which, when used, must be recovered to mitigate cost and possible environmental pollution. The solvent regeneration can be achieved by integrating the process with the bipolar membrane electrodialysis technology to significantly reduce chemical utilisation and production, and secondary waste generation. This study explored a sustainable way of transforming climate risk into opportunities for resource recovery and waste valorisation through a novel approach to enhancing CO_2 fixation with improved acid/alkali recovery from waste-derived solutions, establishing BPED's role in sustainable waste valorisation, and setting a benchmark for large-scale carbon capture integration[1–3]. Varying concentrations of the simulated acid salt were tested under different applied voltages at ambient conditions and a defined flow rate. The preliminary results revealed that BPED significantly enhances acid and alkali recovery, and that applied voltage influenced regeneration yield, current efficiency and power demand. Understanding this will advance the large–scale implementation of indirect carbonation and greatly contribute to carbon dioxide capture, climate change mitigation, resource recovery, membrane technology, and closed loop design

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OPTIMIZATION OF THE EDBM PROCESS FOR DIFFERENT MEMBRANE AND SALT TYPES

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Abstract: Electrodialysis with bipolar membranes (EDBM) enables the conversion of salts into their corresponding acids and bases, making it a promising technology for applications such as industrial wastewater treatment. High process efficiency requires high current efficiency and low specific energy consumption, which can be hindered by proton transport through anion-exchange membranes (AEMs). This transport varies with membrane type and salt composition, affecting EDBM performance and operating conditions[1].

To investigate these effects, experiments were conducted using fumasep® (FKL+FAB+FBM) and Lanran (CLE+ANH+BPM2) membrane stacks with Na_2SO_4 and NaCl feed solutions. Each stack contained ten membrane triplets, and experiments were performed primarily at constant current, with a maximum current density of approximately 300 A/m².

First, batch desalination experiments were conducted over a feed conductivity range of 20-2 mS/cm. Higher current efficiencies were observed for NaCl than for Na_2SO_4, suggesting lower proton transport due to the higher mobility of chloride ions compared with sulfate ions. Although both membrane types exhibited similar current efficiencies with NaCl, Lanran membranes showed lower energy consumption, attributed to their lower electrical resistance.

Second, concentration experiments were performed. The final NaOH concentrations were approximately 49 g/L for fumasep® membranes and 62 g/L for Lanran membranes. The higher concentration achieved with Lanran membranes indicates better performance at high concentrations, consistent with their approximately tenfold lower proton transport through the AEM.

Finally, batch and feed-and-bleed operation were compared for NaCl using 0.8 and 1 mol/L HCl. Batch operation showed higher current efficiency and lower energy consumption due to better membrane performance at lower concentrations. Lanran membranes had higher current efficiency in both modes due to lower proton transport through the AEM, but higher energy consumption in feed-and-bleed operation because the feed became alkaline, exceeding the AEM operating pH range and increasing electrical resistance. Selecting a cation-exchange membrane with better hydroxide blocking could therefore reduce energy consumption.

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DESALINATION PERFORMANCE OF DIFFERENT MEMBRANE TYPES FOR THE 2ND STAGE OF ELECTRODIALYSIS IN THE ZLD PROCESS

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Abstract: Electrodialysis is a membrane separation process used to remove and concentrate salts from aqueous solutions. During electrodialysis, ions are transported through ion-exchange membranes under an applied electric potential. This creates a diluate stream with lower salt concentration and a concentrate stream with higher salt concentration. The aim of this project was to determine the maximum salt concentration in the concentrate during repeated electrodialysis tests. Four different membrane types were tested and compared: Lanran, Fuji 10, Fuji 12 and Membrane Foil. A NaCl solution was used as a feed. The membrane modules were tested by hydraulic flowthrough tests, salt tests and repeated desalination tests. The membrane performance was compared based on maximum concentrate concentration, salt mass flux and specific energy consumption. The highest concentrate concentration, 217 g/l, was reached with Fuji 12. Lanran and Fuji 10 reached similar concentrations of 179 and 180 g/l, while Membrane Foil reached 133 g/l. Fuji 10 had the lowest specific energy consumption and still showed a relatively high salt mass flux.

Key words:
electrodialysis, ion-exchange membranes, desalination, NaCl, salt concentration

EXTENDED CHARACTERIZATION OF ANION SELECTIVE MEMBRANES

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Abstract: Anion exchange membranes play a crucial role in various industrial electrochemical processes, including electrodialysis and electrolysis. Improving membrane properties is essential for enhancing overall process efficiency. In this study, four different anion exchange membranes were characterized: one commercial heterogeneous membrane (RALEX®, MEGA a.s. / MemBrain s.r.o.) and three homogeneous membranes: the commercial Fumasep® (Fumatech BWT GmbH) and two membranes synthesized at the Institute of Macromolecular Chemistry of the Czech Academy of Sciences (named DK8-THD and DK10-MPy).

I evaluated the main electrochemical properties such as resistance, permselectivity and ion exchange capacity. Water transport and proton transport / leakage were also tested. I also examined physical properties such as water uptake. Among the tested samples, the DK10-MPy membrane exhibited the most promising electrochemical performance. However, its poor mechanical stability limits its industrial application. The remaining membranes also demonstrated suitable characteristics for electrochemical applications.

EXPERIMENTAL VERIFICATION OF THE MAXIMUM NAOH CONCENTRATION ACHIEVABLE BY ELECTRODIALYSIS

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Abstract: Electrodialysis (ED) is an electromembrane separation process that utilizes an electric field to selectively transport ions across ion-exchange membranes, separating feed solutions into diluate and concentrate streams. Consequently, it has become an essential technology across water desalination, food processing, and zero-liquid-discharge resource recovery [1].

This project had two main objectives. First was to determine maximum NaOH concetration in the concentrate using several cycles of electrodialysis. Tests were conducted by using two different membranes; first heterogeneous Ralex membrain, second homogeneous Lanran membranes. Second aim of this project was to determine how quickly the concentration curve changes when the volume ration of the diluate solution to the concentrate remains constant and we vary the initial concentration of the concentrate. Tests were conducted only by using Ralex membranes.

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ELECTRODIALYSIS WITH ULTRAFILTRATION MEMBRANES FOR BIOACTIVE PEPTIDE CHARGE-BASED FRACTIONATION FROM WATER LENTIL PROTEIN HYDROLYSATES

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Abstract: Water lentils, also known as duckweeds, are small, fast-growing aquatic plants rich in proteins. As with other sources, enzymatic hydrolysis can break these proteins down to release bioactive peptides, short chains of amino acids capable of influencing biological functions. However, recovering these peptides from complex hydrolysates remains a challenge because they are mixed with numerous other peptides with diverse physicochemical properties. Electrodialysis with ultrafiltration membranes (EDUF) offers a way to exploit these differences for selective peptide separation and recovery. In this technology, an electric field drives charged peptides through ultrafiltration membranes, which control their passage according to pore size[1]. Therefore, this study investigated, for the first time, the application of EDUF to water lentil protein hydrolysates to obtain peptide fractions with distinct biological activities. Water lentil proteins were first hydrolysed with trypsin, and after centrifugation, 600 mL of the resulting supernatant was processed by EDUF for three hours at room temperature under controlled pH and conductivity. An electric field strength of 2 V/cm was applied to recover positively and negatively charged peptide fractions, alongside the residual supernatant containing peptides that did not migrate. EDUF performance was evaluated through peptide migration and relative energy consumption. The initial supernatant and resulting fractions were characterized by mass spectrometry for their peptide populations and tested for enzyme-inhibitory activities. EDUF achieved a peptide migration rate of 7.96 ± 0.26 g m^{-2} h^{-1} and a relative energy consumption of 38.70 ± 0.67 Wh g^{-1} of peptides. Mass spectrometry identified

65 peptides across the samples. The positively charged fraction exhibited 2.5-fold greater inhibition of angiotensin-converting enzyme (ACE), an enzyme involved in blood pressure regulation, than the initial supernatant. Inhibition of dipeptidyl peptidase IV (DPP-IV), an enzyme involved in blood glucose regulation, remained higher in the initial supernatant and final feed fraction. Subsequently, partial least squares discriminant analysis (PLS-DA), a statistical classification method, guided peptide selection for synthesis and testing, revealing 11 novel ACE-inhibitory peptides with IC_{50} between 22.9 and 394.6 µM. These results highlight the potential of EDUF to selectively recover bioactive peptide fractions from food protein hydrolysates such as water lentils and develop health-promoting food ingredients.

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PROTIC IONIC LIQUID-MODIFIED PVDF: FROM DENSE SEALS TO EFFICIENT AMMONIA GAS SEPARATION

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Abstract: Converting hydrogen (H_2) to higher-boiling-point compounds such as methanol, ethanol, and particularly ammonia (NH_3) is an attractive strategy to store energy in safer and more cost-effective approches[1]. However, NH_3 streams must be purified for reuse, either for direct combustion or as a feed for fuel cells. Developing efficient NH_3/H_2 purification technologies is therefore essential, and membrane separation offers a lower-energy alternative to conventional purification[2].

In this work, we investigate PVDF-based polymer membranes modified with ionic liquid for NH_3/H_2 separation. The membranes were fabricated by solvent casting and modified with ionic liquid [EIM][NTf_2] at different weight loadings (0-25 wt.% relative to PVDF), in 5 wt.% steps. Membranes were characterized by TGA, DSC, SEM, and FTIR. Gas permeation experiments were then performed for NH_3 and H_2 gases at 5 bar and 40 °C. Time-lag analysis was used to estimate NH_3 solubility and diffusivity. Furthermore, mixed-gas permeability was measured using NH_3/H_2 mixtures (equimolar 50:50 and a 15:85 NH_3/H_2 mixture) at different feed flow rates (10-80 mL/min) and 10 bar feed pressure.

The results show that neat PVDF exhibits low permeability toward both gases (13.4 ± 0.5 Barrer for NH_3 and 0.83 ± 0.03 Barrer for H_2). Incorporating ionic liquid significantly increases gas transport. The maximum permeability was observed at 25 wt.% IL, reaching 2702 ± 207 Barrer, while the highest NH_3/H_2 selectivity was obtained at 15 wt.% IL with a value of 491 ± 41. For the equimolar 50:50 mixture, ammonia purity increased to the range of 97-99% as the feed flow rate increased to 80 mL/min. However, ammonia recovery showed a trade-off behavior: the highest NH_3 recovery (55%) was achieved at a lower feed flow rate (20 mL/min) using 20 wt.% IL. For the NH_3/H_2 mixture with the composition of 15:85, the membranes still provided reasonable performance, with ammonia recovery of 22% at 20 mL/min and 25 wt.% IL, and purity of 85% at 80 mL/min using 15-20 wt.% IL.

Overall, this work demonstrates promising NH_3/H_2 separation performance using IL-modified PVDF membranes. The measured permeability and selectivity are competitive with-and in key cases exceed-reported values from the literature. We propose that forming interconnected IL-rich pathways within the PVDF

matrix can enhance gas transport while preserving selectivity, and this will be the focus of future work.

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ENANTIOSELECTIVE DNB-LEUCINE TRANSPORT THROUGH PVDF BASED MIXED MATRIX MEMBRANES AND THE INFLUENCE OF EXPERIMENTAL CONDITIONS

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Abstract: Chiral compounds are important in the pharmaceutical, agrochemical, and fine chemical industries because individual enantiomers may differ in their biological, pharmacological, or toxicological effects. Chromatography is widely used for enantioseparation, while membrane processes offer an alternative compatible with continuous operation, low energy demand, and scale-up.

Enantioselective mixed matrix membranes based on poly(vinylidene fluoride) (PVDF) were investigated for the separation of N-(3,5-dinitrobenzoyl)-leucine enantiomers. The membranes contained silica particles functionalized with a quinidine-derived chiral selector, combining the mechanical stability of PVDF with selective chiral recognition sites.[1]

Transport was studied under concentration-driven conditions using methanol-water mixtures containing 50-100 % methanol and chromatographic mobile phase modifiers: formic acid and triethylamine. Increasing the water content enhanced retention and enantioselective performance relative to pure methanol. Formic acid increased the enantiomeric excess, whereas the addition of triethylamine reduced it.[2]

Single-stage enantiomeric excess values up to 90 % were obtained under optimized conditions with a higher water content and 25 or 50 mM formic acid. The PVDF-based membranes remained mechanically stable and could be regenerated in methanolic ammonium acetate solution for repeated use. These results show how solvent composition and solution modifiers can affect transport and retention across chiral membrane.

Ackowledgement:
The authors acknowledge financial support from the Czech Science Foundation, project No. 25-15195S, and the Internal Grant Agency of the University of Pardubice, project No. SGS_2026_006.

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FROM CONVENTIONAL TO GREEN SOLVENTS: IMPACT ON CELLULOSE ACETATE FILM MICROSTRUCTURE

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Abstract: The development of more sustainable membrane requires careful selection of processing solvents, as solvent properties can influence both film formation and the structure of the resulting material. Cellulose acetate (CA) is a promising polymer for membrane applications because of its film-forming ability and potential for more sustainable use. [1–3] Therefore, in this work, CA films are prepared using a range of conventional and alternative solvents to explore how each solvent characteristics relate to the formation of the final structure. The films are produced by non-solvent-induced phase separation and characterized using complementary techniques, including SEM, FTIR, XRD, DSC, and contact-angle measurements. These methods are used to investigate film morphology, structural organization, and surface wettability. The study considers the combined roles of solvent–polymer compatibility, solvent evaporation, and solvent–non-solvent exchange during coagulation. The comparison provides insight into how solvent selection can be used to influence CA film formation and supports the evaluation of more sustainable solvent systems for the preparation of membrane materials.

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POSSIBILITIES OF SEPARATING SILICA FROM SATURATED SOLUTIONS USING ELECTRODIALYSIS

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Abstract: Silica scaling represents a critical limitation in industrial water-treatment and membrane desalination processes, particularly in reverse osmosis systems where concentrated streams easily exceed silica solubility limits. The resulting deposits reduce process efficiency and are notoriously difficult to clean. This work investigated the feasibility of using electrodialysis (ED) as a supportive treatment step for silica-containing concentrate streams. The primary aim was to evaluate the behaviour of silica and divalent ions (Ca^{2+},Mg^{2+}) in model solutions during laboratory-scale ED, monitor silica removal in relation to diluate conductivity reduction, and assess possible impacts on ED cell performance.

Laboratory experiments showed that common salts are removed first, while significant silica removal occurs only at low diluate conductivities below approximately 0.3 – 0.4 mS/cm. Apparent silica losses from the liquid phase were recorded across several runs, though their exact origin remains unconfirmed. The missing silica could have been retained inside the membrane stack or lost due to slow precipitation kinetics and subsequent post-experimental precipitation in sample containers, making it undetectable during delayed dissolved-phase analysis. Nevertheless, repeated standard salt tests and visual inspections showed no measurable deterioration in module performance or obvious scaling under the tested conditions. In addition, preliminary tests demonstrated that ED can concentrate Ca^{2+} and Mg^{2+}, promoting subsequent silica precipitation at elevated pH outside the cell. Overall, ED appears promising as a supportive or pre-concentration step, though further work is needed to clarify the precise mechanisms of silica loss.

INFLUENCE OF PROCESS PARAMETERS ON THE SELECTIVITY OF MONOSELECTIVE MEMBRANES

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Abstract: This work investigated the monovalent/multivalent selectivity of the VM-FKS-PK-75 cation-exchange membrane, paired with a FAS-PET-130 anion-exchange membrane in an EDR-H3/2×10-0.5 electrodialysis module, using a binary Na^+/Mg^{2+} system.

A total of 18 batch electrodialysis tests were performed, varying the applied current (1.5–2.5 A), solution composition (Na:Mg ratios of 1:4, 1:1, and 4:1), and diluate flow rate (50–100 l/h). During each test, samples were withdrawn from the diluate at regular intervals and analyzed for Na^+ and Mg^{2+} content by ICP-OES.

Selectivity was evaluated as the permselectivity, which ranged from 0.74 to 0.95 and remained below 1 in every test. This indicates that, contrary to its intended monoselective function, the membrane consistently favored the transport of the divalent Mg^{2+} ion over the monovalent Na^+ ion under every tested condition, with solution composition being the dominant influencing factor.

MIXED MATRIX MEMBRANES BASED ON POLYIMIDES AND THIACALIXARENES

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Mixed-matrix membranes (MMMs) frequently incorporate fillers like MOFs, COFs, or zeolites. Recently, macrocyclic molecular fillers with defined cavities—such as cucurbiturils and calixarenes—have emerged as promising alternatives, though systematic studies on their fundamental behavior remain scarce[1]. This work systematically investigates the influence of thiacalix[4]arene (H-TC) and *p-tert*-butylthiacalix[4]arene (tBu-TC) on the morphology, mechanical strength, and gas separation performance of solution-cast 6FDA-DAM and Matrimid polyimide membranes. Membranes loaded with 0–20 wt% filler were evaluated under 2–8 bar overpressures using CO_2/CH_4 and H_2/CH_4 mixtures at 1:3, 1:1, and 3:1 feed ratios. While low filler loadings yielded homogeneous, defect-free structures, exceeding a matrix-specific threshold triggered filler crystallization. Notably, tBu-TC in Matrimid demonstrated the highest crystallization resistance, remaining stable up to 20 wt%. Mechanical testing revealed divergent matrix dependencies: thiacalixarene addition enhanced the tensile strength of 6FDA-DAM by up to 103%, but slightly compromised Matrimid's mechanical integrity. Crucially, certain Matrimid-based MMMs achieved a simultaneous increase in permeability and in selectivity for H_2/CH_4 separation, up to 161% and 134%, respectively[2].

The research was supported by Czech Science Foundation Grant No. 26-23755S.

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PREPARATION AND CHARACTERIZATION OF CELLULOSE-BASED MEMBRANES FOR SUSTAINABLE WATER ELECTROLYSIS AND HYDROGEN PRODUCTION

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Abstract: Proton-exchange membrane water electrolysis (PEMWE) enables green hydrogen production, but commercial fluorinated membranes such as Nafion raise environmental and cost concerns.[2,3] This study explores cellulose as a renewable, fluorine-free membrane material.[1] Cellulose was dissolved in N,N-dimethylacetamide/lithium chloride (DMAc/LiCl) or aqueous NaOH using a freeze–thaw process, and the resulting solutions were cast into films. DMAc/LiCl yielded transparent, homogeneous membranes after gradual drying at room temperature; drying at 80 °C caused cracking. For NaOH-derived films, substrate selection affected film formation: crystallization occurred on glass, while paper support was explored as an alternative casting route. Fourier-transform infrared spectroscopy (FTIR) identified characteristic cellulose bands in the DMAc/LiCl-derived film. Scanning electron microscopy (SEM) revealed a transition from fibrous cellulose towards a more continuous structure, while energy-dispersive X-ray spectroscopy (EDS) indicated residual chlorine-containing species, emphasizing the need for improved purification. Overall, the results highlight the feasibility of processing cellulose into transparent films as well as challenges related to drying, substrate selection and residual chemicals. Future work will investigate sulfonation to introduce proton-conducting groups, followed by measurements of proton conductivity, water uptake, hydrogen permeability and suitability for PEMWE operation.

Acknowledgement
Supported by the Ministry of Education, Youth and Sports (OP JTF REFRESH, CZ.10.03.01/00/22_0030/0000048) and SGS VŠB-TUO (SP2026/080).

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TOWARDS SCALABLE, MULTIFUNCTIONAL MEMBRANES FOR SUSTAINABILITY

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Abstract: Membrane technology has emerged as a cornerstone in addressing global environmental challenges due to its compact design, energy efficiency, and versatility [1]. Synthetic membranes, whether hydrophobic or hydrophilic, enable applications in desalination, wastewater treatment, oil–water separation, gas purification, and volatile organic compound removal [1, 2]. Their performance is critically influenced by fabrication routes, such as phase inversion, electrospinning, interfacial polymerization, stretching, and track-etching, as well as by polymer selection and surface chemistry [2]. The wettability, antifouling properties, and long-term stability of the tailored material are further enhanced by modification strategies such as grafting, plasma treatment, nanoparticle incorporation, and polymer blending [2]. Recent studies have concentrated on developing scalable, multifunctional designs that integrate high permeability, selectivity, fouling resistance, and chemical durability [1, 2]. The major challenge is to produce materials appropriate for cost-effective applications at a large scale, while maintaining their stability under harsh operating conditions, and translating recent lab scientific advances into practical solutions for industry [1].

This bibliographic study reviews current progress in membrane fabrication and characterization, particularly focusing on Non-Solvent Induced Phase Separation (NIPS) and electrospinning techniques [3, 4]. Special attention is given to the use of recycled polymers such as polyethylene terephthalate (PET) in the development of multifunctional and scalable membranes [4]. By synthesizing these findings, the study highlights opportunities and limitations in translating laboratory advances into cost-effective, durable, and environmentally sustainable solutions for real-world separation challenges [2-4].

Keywords: Electrospinning, Non-Solvent Induced Phase Separation (NIPS), Recycled PET, Membrane Characterization, Environmental Applications.

Acknowledgments

The authors gratefully acknowledge the Generalitat Valenciana, Spain, for funding the DEMEMPOR project *"Desarrollo de membranas microporosas de bajo ensuciamiento por inversión de fase, a partir de poliestireno reciclado. Aplicación a la regeneración de aguas residuales"* (Ref. AICO/2021/190). The project is led by Prof. Mª Isabel Iborra Clar, Universitat Politècnica de València (ISIRYM).

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Workshop of Students' Presentations 2026

Edited by:	**Czech Membrane Platform**
Published by:	**Czech Membrane Platform** Manesova 1580/17, 470 01 Ceska Lipa, Czech Republic
Printed by:	**AMCA s.r.o.**, Vysehradska 320/49 128 00 Praha 2 - Nove Mesto, Czech Republic
Date of publishing:	October 2026
ISBN:	978-80-909640-6-8

ISBN 978-80-909640-6-8

9 788090 964068