PENGARUH PENAMBAHAN Fe_3O_4 TERHADAP KINERJA MEMBRAN NANOFILTRASI POLIVINILIDIN FLUORIDA UNTUK PEMISAHAN ION GARAM

TESIS

Diajukan untuk memenuhi salah satu syarat memperoleh gelar Magister Sains pada Program Studi Kimia

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PROGRAM STUDI KIMIA

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Sebuah Tesis yang diajukan untuk memenuhi salah satu syarat memperoleh gelar Magister Sains (M.Si) pada Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

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ABSTRAK

Teknologi membran nanofiltrasi sebagai proses *pre-treatment* desalinasi menjadi salah satu solusi alternatif untuk mengatasi masalah ketersediaan air bersih melaui desalinasi air. Penelitian ini bertujuan untuk mengetahui karakteristik, uji kinerja, dan kondisi optimum sintesis membran nanokomposit PVDF/MWCNT/Fe_3O_4. Membran disintesis melalui metode inversi fasa dengan komposisi PVDF (18%), MWCNT (0.001%), Fe_3O_4 NPs (0.001-0.005%). Karakteristik membran nanokomposit PVDF/MWCNT/Fe3O4 dianalisis menggunakan teknik dan instrumentasi antara lain, FTIR, XRD, SEM-EDX, sifat mekanik, hidrofilisitas, porositas, dan *point zero of charge* (PZC). Selain itu, kinerja membran diuji dengan sistem filtrasi *dead-end* (DE) dan *cross-flow* (CF) melalui permeabilitas, permselektivitas, MWCO, dan *antifouling.* Keberhasilan sintesis membran ditunjukkan dengan adanya interaksi khas pada spektrum FTIR 532 cm^{-1} (Fe-O) dan difraktogram XRD pada puncak 2θ 20.16^o [110], 26.39^o [002], dan 43.02^o [400] serta peningkatan %kristalinitas dari 33.10% menjadi 51.71%. Fotograf SEM menunjukkan bahwa penambahan MWCNT dan Fe_3O_4 NPs menyebabkan perubahan struktur morfologi dan ukuran pori dari 130 nm menjadi 100 nm. Penambahan Fe_3O_4 NPs juga meningkatkan hidrofilisitas dari 74.58^o menjadi 59.60^o, porositas dari 49.31% menjadi 70.49%, dan range nilai PZC berkisar antara 6.62-7.51. uji kinerja membran dengan sistem DE dan CF menunjukkan bahwa pnambahan Fe3O4 NPs meningkatkan permeabilitas air menjadi 35,16 dan 28,80 L/m^2·h·bar, selektivitas ion garam NaCl (65,62% dan 79,86%), $CaCl_2$ (70,03% dan 73,69%), dan $FeCl_3$ (83,06% dan 88,68%) serta meningkatkan flux recovery ratio (FRR) dari 66.25% menjadi 87.46%. Hasil uji MWCO menggunakan zat warna (RB, MO, dan MB) menunjukkan bahwa membran nanokomposit PVDF/MWCNT/Fe_3O_4 memiliki nilai MWCO sekitar 320 Da yang mengindikasikan membran termasuk dalam kategori *tight* nanofiltrasi.

Kata kunci: membran nanofiltrasi, PVDF/MWCNT/Fe_3O_4, sintesis, karakteristik, uji kinerja

ABSTRACT

Nanofiltration membrane technology as a process *pre-treatment* desalination is an alternative solution to overcome the problem of clean water availability through water desalination. This research aims to determine the characteristics, performance tests, and optimum conditions for the synthesis of PVDF/MWCNT/Fe_3O_4 nanocomposite membranes. The membrane was synthesized via the phase inversion method with the composition PVDF (18%), MWCNT (0.001%), Fe_3O_4 NPs (0.001-0.004%). The characteristics of PVDF/MWCNT/Fe_3O_4 nanocomposite membranes were analyzed using techniques and instrumentation including, FTIR, XRD, SEM-EDX, mechanical properties, hydrophilicity, porosity, and *point zero of charge* (PZC). Additionally, the membrane performance was tested with the filtration system *dead-end* (DE) then *cross-flow* (CF) through permeability, permselectivity, MWCO, and *antifouling.* The success of membrane synthesis is demonstrated by the presence of typical interactions FTIR spectrum in the 532 cm^{-1} (Fe-O) and XRD diffractogram at 2θ peak 20.16° [110], 26.39° [002], and 43.02° [400] as well as an increase in %crystallinity from 33.10% to 51.71%. SEM photography shows that the addition of MWCNT and Fe_3O_4 NPs caused changes in morphological structure and pore size from 130 nm to 100 nm. The addition of Fe_3O_4 NPs also increased the hydrophilicity of 74.58° to 59.60°, porosity from 49.31% to 70.49%, and the PZC value range is between 6.62-7.51. Membrane performance tests with DE and CF systems showed that the addition of Fe3O4 NPs increased water permeability to 35.16 and 28.80 $L/m^2 \cdot h \cdot bar$, NaCl salt ion selectivity (65.62% and 79.86%), $CaCl_2$ (70.03% and 73.69%), and $FeCl_3$ (83.06% and 88.68%) and increasing the flux recovery ratio (FRR) from 66.25% to 87.46%. MWCO test results using dyes (RB, MO, and MB) show that the PVDF/MWCNT/Fe_3O_4 nanocomposite membrane has an MWCO value of around 320 Da which indicates the membrane is included in the category *tight* nanofiltration.

Keyword: nanofiltration membrane, PVDF/MWCNT/Fe_3O_4, synthesis, characteristics, performances

DAFRAR ISI

DAFTAR TABEL

DAFTAR GAMBAR

DAFTAR PUSTAKA

Abd El-Aziz, A. M., & Afifi, M. (2024). Influence the β-PVDF phase on structural and elastic properties of PVDF/PLZT composites. *Materials Science and Engineering: B*, *301*. https://doi.org/10.1016/j.mseb.2023.117152

Agrawal, A., Sharma, A., Awasthi, K. K., & Awasthi, A. (2021). Metal oxides nanocomposite membrane for biofouling mitigation in wastewater treatment. *Materials Today Chemistry*, *21*. https://doi.org/10.1016/j.mtchem.2021.100532

Ai, X., Yu, P., Li, X., Lai, X., Yang, M., Liu, F., Luan, F., & Meng, X. (2023). Polysaccharides from Spirulina platensis: Extraction methods, structural features and bioactivities diversity. In *International Journal of Biological Macromolecules* (Vol. 231). Elsevier B.V. https://doi.org/10.1016/j.ijbiomac.2023.123211

Ajibade, T. F., Xu, J., Tian, H., Guan, L., & Zhang, K. (2021). O-mwcnt/pan/pvdf ultrafiltration membranes with boosted properties for oil and water separation. *Desalination and Water Treatment*, *224*, 122–135. https://doi.org/10.5004/dwt.2021.27200

Ali, A., Zhang, N., & Santos, R. M. (2023). Mineral Characterization Using Scanning Electron Microscopy (SEM): A Review of the Fundamentals, Advancements, and Research Directions. In *Applied Sciences (Switzerland)* (Vol. 13, Issue 23). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/app132312600

Ali, E., Orfi, J., AlAnsary, H., Baakeem, S., Alsaadi, A. S., & Ghaffour, N. (2024). Advanced structures of reversal multi-stage flash desalination. *Desalination*, *571*. https://doi.org/10.1016/j.desal.2023.117095

Alkhouzaam, A., & Qiblawey, H. (2021). Functional GO-based membranes for water treatment and desalination: Fabrication methods, performance and advantages. A review. In *Chemosphere* (Vol. 274). Elsevier Ltd. https://doi.org/10.1016/j.chemosphere.2021.129853

Al-Obaidi, M., Alsarayreh, A. A., Rashid, F. L., Sowgath, M. T., Alsadaie, S., Ruiz-García, A., Khayet, M., Ghaffour, N., & Mujtaba, I. M. (2024). Hybrid membrane and thermal seawater desalination processes powered by fossil fuels: A comprehensive review, future challenges and prospects. In *Desalination* (Vol. 583). Elsevier B.V. https://doi.org/10.1016/j.desal.2024.117694

Altmann, T., Rousseva, A., Vrouwenvelder, J., Shaw, M., & Das, R. (2023). Effectiveness of ceramic ultrafiltration as pretreatment for seawater reverse osmosis. *Desalination*, *564*. https://doi.org/10.1016/j.desal.2023.116781

Aristizábal, S. L., Lively, R. P., & Nunes, S. P. (2023). Solvent and thermally stable polymeric membranes for liquid molecular separations: Recent advances, challenges, and perspectives. In *Journal of Membrane Science* (Vol. 685). Elsevier B.V. https://doi.org/10.1016/j.memsci.2023.121972

Asad, A., Sameoto, D., & Sadrzadeh, M. (2020). Chapter 1 - Overview of membrane technology. In M. Sadrzadeh & T. Mohammadi (Eds.), *Nanocomposite Membranes for Water and Gas Separation* (pp. 1–28). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-816710-6.00001-8

Azzian, M. I. M., Mohamad, S. F., Hakimi, N. M. F., Wan Salleh, W. N., Ismail, N. H., & Ismail, A. F. (2024). Radiation-induced graft polymerization acrylamide on PVDF membrane for cation dye removal. *Materials Today: Proceedings*, *96*, 55–61. https://doi.org/10.1016/j.matpr.2023.09.213

Bagheripour, E., Moghadassi, A. R., Parvizian, F., Hosseini, S. M., & Van der Bruggen, B. (2019). Tailoring the separation performance and fouling reduction of PES based nanofiltration membrane by using a PVA/Fe3O4 coating layer. *Chemical Engineering Research and Design*, *144*, 418–428. https://doi.org/10.1016/j.cherd.2019.02.028

Bamasag, A., Almatrafi, E., Alqahtani, T., Phelan, P., Ullah, M., Mustakeem, M., Obaid, M., & Ghaffour, N. (2023). Recent advances and future prospects in direct solar desalination systems using membrane distillation technology. In *Journal of Cleaner Production* (Vol. 385). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2022.135737

Behdarvand, F., Valamohammadi, E., Tofighy, M. A., & Mohammadi, T. (2021). Polyvinyl alcohol/polyethersulfone thin-film nanocomposite membranes with carbon nanomaterials incorporated in substrate for water treatment. *Journal of Environmental Chemical Engineering*, *9*(1). https://doi.org/10.1016/j.jece.2020.104650

Belgada, A., Achiou, B., Alami Younssi, S., Charik, F. Z., Ouammou, M., Cody, J. A., Benhida, R., & Khaless, K. (2021). Low-cost ceramic microfiltration membrane made from natural phosphate for pretreatment of raw seawater for desalination. *Journal of the European Ceramic Society*, *41*(2), 1613–1621. https://doi.org/10.1016/j.jeurceramsoc.2020.09.064

Bin Bandar, K., Alsubei, M. D., Aljlil, S. A., Bin Darwish, N., & Hilal, N. (2021). Membrane distillation process application using a novel ceramic membrane for Brackish water desalination. *Desalination*, *500*. https://doi.org/10.1016/j.desal.2020.114906

Bobrowski, A. (2021). Semigroup-theoretic approach to diffusion in thin layers separated by semi-permeable membranes. *Journal of Evolution Equations*, *21*(1), 1019–1057. https://doi.org/10.1007/s00028-020-00617-7

Brover, S., Lester, Y., Brenner, A., & Sahar-Hadar, E. (2022). Optimization of ultrafiltration as pre-treatment for seawater RO desalination. *Desalination*, *524*. https://doi.org/10.1016/j.desal.2021.115478

Bubela, H., Konovalova, V., Kujawa, J., Kolesnyk, I., Burban, A., & Kujawski, W. (2023). Enhancing of transport parameters and antifouling properties of PVDF membranes modified with Fe3O4 nanoparticles in the process of proteins fractionation. *Separation and Purification Technology*, *325*. https://doi.org/10.1016/j.seppur.2023.124573

Cairone, S., Hegab, H. M., Khalil, H., Nassar, L., Wadi, V. S., Naddeo, V., & Hasan, S. W. (2024). Novel eco-friendly polylactic acid nanocomposite integrated membrane system for sustainable wastewater treatment: Performance evaluation and antifouling analysis. *Science of the Total Environment*, *912*. https://doi.org/10.1016/j.scitotenv.2023.168715

Cao, P., Shi, J., Zhang, J., Wang, X., Jung, J. T., Wang, Z., Cui, Z., & Lee, Y. M. (2020). Piezoelectric PVDF membranes for use in anaerobic membrane bioreactor (AnMBR) and their antifouling performance. *Journal of Membrane Science*, *603*. https://doi.org/10.1016/j.memsci.2020.118037

Chang, S., Kandel, D. R., Lee, U., Tran, H. M., & Lee, J. (2024). Improving separation efficiency of various micropollutants from water by polymer-enhanced ultrafiltration using oxidized alginate featuring less viscous and low filtration resistance. *Journal of Environmental Chemical Engineering*, *12*(6). https://doi.org/10.1016/j.jece.2024.114753

Chubar, N., Gerda, V., Szlachta, M., & Yablokova, G. (2021). Effect of Fe oxidation state (+2 versus +3) in precursor on the structure of Fe oxides/carbonates-based composites examined by XPS, FTIR and EXAFS. *Solid State Sciences*, *121*. https://doi.org/10.1016/j.solidstatesciences.2021.106752

Comez, L., Gentili, P. L., Paolantoni, M., Paciaroni, A., & Sassi, P. (2021). Heat-induced self-assembling of BSA at the isoelectric point. *International Journal of Biological Macromolecules*, *177*, 40–47. https://doi.org/10.1016/j.ijbiomac.2021.02.112

De Guzman, M. R., Andra, C. K. A., Ang, M. B. M. Y., Dizon, G. V. C., Caparanga, A. R., Huang, S. H., & Lee, K. R. (2021). Increased performance and antifouling of mixed-matrix membranes of cellulose acetate with hydrophilic nanoparticles of polydopamine-sulfobetaine methacrylate for oil-water separation. *Journal of Membrane Science*, *620*. https://doi.org/10.1016/j.memsci.2020.118881

DuChanois, R. M., Porter, C. J., Violet, C., Verduzco, R., & Elimelech, M. (2021). Membrane Materials for Selective Ion Separations at the Water–Energy Nexus. *Advanced Materials*, *33*(38), 2101312. https://doi.org/https://doi.org/10.1002/adma.202101312

Duraikkannu, S. L., Castro-Muñoz, R., & Figoli, A. (2021). A review on phase-inversion technique-based polymer microsphere fabrication. In *Colloids and Interface Science Communications* (Vol. 40). Elsevier B.V. https://doi.org/10.1016/j.colcom.2020.100329

Eloffy, M. G., El-Sherif, D. M., Abouzid, M., Elkodous, M. A., El-Nakhas, H. S., Sadek, R. F., Ghorab, M. A., Al-Anazi, A., & El-Sayyad, G. S. (2022). Proposed approaches for coronaviruses elimination from wastewater: Membrane techniques and nanotechnology solutions. In *Nanotechnology Reviews* (Vol. 11, Issue 1, pp. 1–25). De Gruyter Open Ltd. https://doi.org/10.1515/ntrev-2022-0001

El-Sayed, M. Y., Alsohaimi, I. H., Alrashidi, A. N., Aldawsari, A. M., Alshahrani, A. A., & Hassan, H. M. A. (2023). Mixed matrix membrane comprising functionalized sulfonated activated carbon from tea waste biomass for enhanced hydrophilicity and antifouling properties. *Diamond and Related Materials*, *136*. https://doi.org/10.1016/j.diamond.2023.109945

Enemuo, N., Richards, H., & Daramola, M. O. (2024). Evaluation of the performance of Fe3O4-NPs/PVDF nanocomposite membrane for removal of BTEX from contaminated water. *Journal of Water Process Engineering*, *60*. https://doi.org/10.1016/j.jwpe.2024.105185

Eun, J. H., Sung, S. M., Kim, M. S., Choi, B. K., & Lee, J. S. (2021). Effect of MWCNT content on the mechanical and piezoelectric properties of PVDF nanofibers. *Materials and Design*, *206*. https://doi.org/10.1016/j.matdes.2021.109785

Ezeuko, A. S., Ojemaye, M. O., Okoh, O. O., & Okoh, A. I. (2022). The effectiveness of silver nanoparticles as a clean-up material for water polluted with bacteria DNA conveying antibiotics resistance genes: Effect of different molar concentrations and competing ions. In *OpenNano* (Vol. 7). Elsevier Inc. https://doi.org/10.1016/j.onano.2022.100060

Fergani, Z., Triki, Z., Menasri, R., Tahraoui, H., Zamouche, M., Kebir, M., Zhang, J., & Amrane, A. (2024). Optimizing Sustainability: Exergoenvironmental Analysis of a Multi-Effect Distillation with Thermal Vapor Compression System for Seawater Desalination. *Frontiers in Heat and Mass Transfer*, *22*(2), 455–473. https://doi.org/https://doi.org/10.32604/fhmt.2024.050332

Figueira, M., Rodríguez-Jiménez, D., López, J., Reig, M., Luis Cortina, J., & Valderrama, C. (2023). Evaluation of the nanofiltration of brines from seawater desalination plants as pre-treatment in a multimineral brine extraction process. *Separation and Purification Technology*, *322*. https://doi.org/10.1016/j.seppur.2023.124232

Fu, M., Liu, Y., Lyu, Q., Zhang, S., Liu, Y., Li, B., Wang, S. Q., & Dong, Y. (2025). Sustainable vapor-phase deposition and applications of MOF films and membranes: A critical review. *Separation and Purification Technology*, *356*. https://doi.org/10.1016/j.seppur.2024.129883

Fu, Y., Cheng, Y., Chen, C., Li, D., & Zhang, W. (2022). Study on preparation process and enhanced piezoelectric performance of pine-needle-like ZnO@PVDF composite nanofibers. *Polymer Testing*, *108*. https://doi.org/10.1016/j.polymertesting.2022.107513

Gayatri, R., Fizal, A. N. S., Yuliwati, E., Hossain, M. S., Jaafar, J., Zulkifli, M., Taweepreda, W., & Ahmad Yahaya, A. N. (2023). Preparation and Characterization of PVDF–TiO2 Mixed-Matrix Membrane with PVP and PEG as Pore-Forming Agents for BSA Rejection. *Nanomaterials*, *13*(6). https://doi.org/10.3390/nano13061023

Geleta, T. A., Maggay, I. V., Chang, Y., & Venault, A. (2023). Recent Advances on the Fabrication of Antifouling Phase-Inversion Membranes by Physical Blending Modification Method. In *Membranes* (Vol. 13, Issue 1). MDPI. https://doi.org/10.3390/membranes13010058

Gong, Y., Chen, X., & Wu, W. (2024). Application of fourier transform infrared (FTIR) spectroscopy in sample preparation: Material characterization and mechanism investigation. *Advances in Sample Preparation*, *11*. https://doi.org/10.1016/j.sampre.2024.100122

Harby, K., Ali, E. S., & Almohammadi, K. M. (2021). A novel combined reverse osmosis and hybrid absorption desalination-cooling system to increase overall water recovery and energy efficiency. *Journal of Cleaner Production*, *287*. https://doi.org/10.1016/j.jclepro.2020.125014

Harrington, G. F., & Santiso, J. (2021). Back-to-Basics tutorial: X-ray diffraction of thin films. *Journal of Electroceramics*, *47*(4), 141–163. https://doi.org/10.1007/s10832-021-00263-6

He, X., Xu, X., Bo, G., & Yan, Y. (2020). Studies on the effects of different multiwalled carbon nanotube functionalization techniques on the properties of bio-based hybrid non-isocyanate polyurethane. *RSC Advances*, *10*(4), 2180–2190. https://doi.org/10.1039/c9ra08695a

Huang, H., Xu, Y., Lu, Z., Zhang, A., Zhang, D., Xue, H., Dong, P., Zhang, J., & Goto, T. (2022). Highly permeable and dye-rejective nanofiltration membranes of TiO2and Bi2S3double-embedded Ti3C2Txwith a visible-light-induced self-cleaning ability. *Journal of*

Materials Research and Technology, *18*, 4156–4168. https://doi.org/10.1016/j.jmrt.2022.04.104

Imbrogno, A., Calvo, J. I., Breida, M., Schwaiger, R., & Schäfer, A. I. (2025). Molecular weight cut off (MWCO) determination in ultra- and nanofiltration: Review of methods and implications on organic matter removal. In *Separation and Purification Technology* (Vol. 354). Elsevier B.V. https://doi.org/10.1016/j.seppur.2024.128612

Jafari, M., Vanoppen, M., van Agtmaal, J. M. C., Cornelissen, E. R., Vrouwenvelder, J. S., Verliefde, A., van Loosdrecht, M. C. M., & Picioreanu, C. (2021). Cost of fouling in full-scale reverse osmosis and nanofiltration installations in the Netherlands. *Desalination*, *500*. https://doi.org/10.1016/j.desal.2020.114865

Ji, Y. L., Yin, M. J., An, Q. F., & Gao, C. J. (2022). Recent developments in polymeric nano-based separation membranes. In *Fundamental Research* (Vol. 2, Issue 2, pp. 254–267). KeAi Communications Co. https://doi.org/10.1016/j.fmre.2021.11.029

Jose, H., Arumugham, T., Gnanasundaram, N., Krishnamoorthy, R., Hasan, S. W., & Banat, F. (2024). 2D/2D nanohybrid of MoS2/g-C3N4 engineered polysulfone (PSF) membrane with enhanced filtration and anti-fouling performance. *Process Safety and Environmental Protection*, *186*, 933–943. https://doi.org/10.1016/j.psep.2024.04.047

Kanehashi, S., & Nagai, K. (2017). Gas and Vapor Transport in Membranes. In *Membrane Characterization* (pp. 309–336). Elsevier Inc. https://doi.org/10.1016/B978-0-444-63776-5.00014-0

Khan, A. A., Maitlo, H. A., Khan, I. A., Lim, D., Zhang, M., Kim, K. H., Lee, J., & Kim, J. O. (2021). Metal oxide and carbon nanomaterial based membranes for reverse osmosis and membrane distillation: A comparative review. In *Environmental Research* (Vol. 202). Academic Press Inc. https://doi.org/10.1016/j.envres.2021.111716

Khoerunnisa, F., Amanda, P. C., Nurhayati, M., Hendrawan, H., Lestari, W. W., Sanjaya, E. H., Handayani, M., Oh, W. Da, & Lim, J. K. (2023). Promotional effect of ammonium chloride functionalization on the performance of polyethersulfone/chitosan composite-based ultrafiltration membrane. *Chemical Engineering Research and Design*, *190*, 366–378. https://doi.org/10.1016/j.cherd.2022.12.040

Khoerunnisa, F., Sihombing, M., Nurhayati, M., Dara, F., Triadi, H. A., Nasir, M., Hendrawan, H., Pratiwi, A., Ng, E.-P., & Opaprakasit, P. (2022). Poly(ether sulfone)-based ultrafiltration membranes using chitosan/ammonium chloride to enhance permeability and antifouling properties. *Polymer Journal*, *54*(4), 525–537. https://doi.org/10.1038/s41428-021-00607-7

Khoo, Y. S., Lau, W. J., Liang, Y. Y., Yusof, N., & Fauzi Ismail, A. (2021). Surface modification of PA layer of TFC membranes: Does it effective for performance Improvement? *Journal of Industrial and Engineering Chemistry*, *102*, 271–292. https://doi.org/10.1016/j.jiec.2021.07.006

Koyuncu, I., Yavuzturk Gul, B., Esmaeili, M. S., Pekgenc, E., Orhun Teber, O., Tuncay, G., Karimi, H., Parvaz, S., Maleki, A., & Vatanpour, V. (2022). Modification of PVDF membranes by incorporation Fe3O4@Xanthan gum to improve anti-fouling, anti-bacterial, and separation performance. *Journal of Environmental Chemical Engineering*, *10*(3). https://doi.org/10.1016/j.jece.2022.107784

Kruszelnicki, M., Polowczyk, I., & Kowalczuk, P. B. (2024). Insight into the influence of surface wettability on flotation properties of solid particles – Critical contact angle in flotation. *Powder Technology*, *431*. https://doi.org/10.1016/j.powtec.2023.119056

Kurt, T., & Topuz, B. (2021). Sol-gel control on mixed network silica membranes for gas separation. *Separation and Purification Technology*, *255*. https://doi.org/10.1016/j.seppur.2020.117654

Kusworo, T. D., Kumoro, A. C., Utomo, D. P., Kusumah, F. M., & Pratiwi, M. D. (2021). Performance of the Crosslinked PVA Coated PES-TiO2Nano Hybrid Membrane for the Treatment of Pretreated Natural Rubber Wastewater Involving Sequential Adsorption - Ozonation Processes. *Journal of Environmental Chemical Engineering*, *9*(2). https://doi.org/10.1016/j.jece.2020.104855

Latif, S., Imran, M., Siddique, M. H., & Hussain, N. (2023). Chapter 1 - Biofouling: current status and challenges. In R. K. Gupta, A. K. Nadda, T. A. Nguyen, S. Sharma, & M. Bilal (Eds.), *Advances in Nanotechnology for Marine Antifouling* (pp. 1–13). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-323-91762-9.00009-5

Lau, H. S., & Yong, W. F. (2021). Recent progress and prospects of polymeric hollow fiber membranes for gas application, water vapor separation and particulate matter removal. *J. Mater. Chem. A*, *9*(47), 26454–26497. https://doi.org/10.1039/D1TA07093B

Li, M., Pan, Y., Ntshole, S., Li, Z., Shen, S., & Zhang, G. (2025). Fabrication of COF-LZU1/PVDF composite loose nanofiltration membranes through oligomer-triggered interfacial polymerization (OT-IP) for highly efficient dye/salt separation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *705*. https://doi.org/10.1016/j.colsurfa.2024.135713

Li, S., Wang, X., Guo, Y., Hu, J., Lin, S., Tu, Y., Chen, L., Ni, Y., & Huang, L. (2022). Recent advances on cellulose-based nanofiltration membranes and their applications in drinking water purification: A review. In *Journal of Cleaner Production* (Vol. 333). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2021.130171

Li, Y., Otsubo, M., & Kuwano, R. (2022). Interpretation of static and dynamic Young’s moduli and Poisson’s ratio of granular assemblies under shearing. *Computers and Geotechnics*, *142*. https://doi.org/10.1016/j.compgeo.2021.104560

Liu, Q., Lan, F., Chen, J., Zeng, C., & Wang, J. (2022). A review of proton exchange membrane fuel cell water management: Membrane electrode assembly. In *Journal of Power Sources* (Vol. 517). Elsevier B.V. https://doi.org/10.1016/j.jpowsour.2021.230723

Liu, X., Shan, Y., Zhang, S., Kong, Q., & Pang, H. (2023). Application of metal organic framework in wastewater treatment. In *Green Energy and Environment* (Vol. 8, Issue 3, pp. 698–721). KeAi Publishing Communications Ltd. https://doi.org/10.1016/j.gee.2022.03.005

Liu, Y., Wang, J., Zhou, R., Ding, Z., Gu, Y., Bai, B., & Sun, C. (2024). Innovations and challenges in large-area graphene oxide membranes for seawater desalination: Preparation techniques, bottlenecks, and module developments. In *Desalination* (Vol. 592). Elsevier B.V. https://doi.org/10.1016/j.desal.2024.118177

Liu, Y., Wang, X. ping, Zong, Z. ao, Lin, R., Zhang, X. yin, Chen, F. shan, Ding, W. de, Zhang, L. li, Meng, X. min, & Hou, J. (2022). Thin film nanocomposite membrane incorporated with 2D-MOF nanosheets for highly efficient reverse osmosis desalination. *Journal of Membrane Science*, *653*. https://doi.org/10.1016/j.memsci.2022.120520

Lusiana, R. A., Sangkota, V. D. A., Sasongko, N. A., Gunawan, G., Wijaya, A. R., Santosa, S. J., Siswanta, D., Mudasir, M., Abidin, M. N. Z., Mansur, S., & Othman, M. H. D. (2020). Permeability improvement of polyethersulfone-polietylene glycol (PEG-PES) flat sheet type membranes by tripolyphosphate-crosslinked chitosan (TPP-CS) coating. *International Journal of Biological Macromolecules*, *152*, 633–644. https://doi.org/10.1016/j.ijbiomac.2020.02.290

Ma, M., Qi, Y., Gu, C., & Zhang, Z. (2024). The adsorption behavior of BSA protein on amphiphilic PEG-PS membrane. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *703*. https://doi.org/10.1016/j.colsurfa.2024.135282

Ma, W., Pan, J., Ren, W., Chen, L., Huang, L., Xu, S., & Jiang, Z. (2022). Fabrication of antibacterial and self-cleaning CuxP@g-C3N4/PVDF-CTFE mixed matrix membranes with enhanced properties for efficient ultrafiltration. *Journal of Membrane Science*, *659*. https://doi.org/10.1016/j.memsci.2022.120792

Mahdavi Far, R., der Bruggen, B., Verliefde, A., & Cornelissen, E. (2022). A review of zeolite materials used in membranes for water purification: history, applications, challenges and future trends. *Journal of Chemical Technology & Biotechnology*, *97*(3), 575–596. https://doi.org/https://doi.org/10.1002/jctb.6963

Mahlangu, O. T., Nthunya, L. N., Motsa, M. M., Morifi, E., Richards, H., & Mamba, B. B. (2023). Fouling of high pressure-driven NF and RO membranes in desalination processes: Mechanisms and implications on salt rejection. In *Chemical Engineering Research and Design* (Vol. 199, pp. 268–295). Institution of Chemical Engineers. https://doi.org/10.1016/j.cherd.2023.09.037

Mamah, S. C., Goh, P. S., & Ismail, A. F. (2022). Membrane-based filtration technology. In *Particle Separation Techniques: Fundamentals, Instrumentation, and Selected Applications* (pp. 117–154). Elsevier. https://doi.org/10.1016/B978-0-323-85486-3.00015-9

Marsono, B. D., Yuniarto, A., Purnomo, A., & Soedjono, E. S. (2022). Comparison Performances of Microfiltration and Rapid Sand Filter Operated in Water Treatment Plant. *IOP Conference Series: Earth and Environmental Science*, *1111*(1). https://doi.org/10.1088/1755-1315/1111/1/012048

Mishra, S., & Sundaram, B. (2023). Efficacy and challenges of carbon nanotube in wastewater and water treatment. In *Environmental Nanotechnology, Monitoring and Management* (Vol. 19). Elsevier B.V. https://doi.org/10.1016/j.enmm.2022.100764

Mohamat, R., Suriani, A. B., Mohamed, A., Muqoyyanah, M., Othman, M. H., Kamal, S., Mamat, M., Ahmad, M., & Ramakrishna, S. (2023). Incorporation of Different Polymeric Additives for Polyvinylidene Fluoride Membrane Fabrication and Its Performance on Methylene Blue Rejection and Antifouling Improvement. *Journal of Polymers and the Environment*, *31*, 1–14. https://doi.org/10.1007/s10924-023-02774-5

Muqoyyanah, M., Khoerunnisa, F., Handayani, M., Rahmayanti, Y. D., Triadi, H. A., Annifah, R. U., Iasya, Y. K. A. A., Gunawan, T., Lestari, W. W., Sanjaya, E. H., & Astuti, W. D. (2023). Effect of silver nanoparticles on the morphological, antibacterial activity and performance of graphene oxide-embedded polyvinylidene fluoride membrane. *Journal of Environmental Chemical Engineering*, *11*(6). https://doi.org/10.1016/j.jece.2023.111394

Nasir, A. M., Goh, P. S., & Ismail, A. F. (2020). Chapter 3 - Synthesis route for the fabrication of nanocomposite membranes. In M. Sadrzadeh & T. Mohammadi (Eds.), *Nanocomposite Membranes for Water and Gas Separation* (pp. 69–89). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-816710-6.00003-1

Nassrullah, H., Anis, S. F., Hashaikeh, R., & Hilal, N. (2020). Energy for desalination: A state-of-the-art review. In *Desalination* (Vol. 491). Elsevier B.V. https://doi.org/10.1016/j.desal.2020.114569

Navarro Oliva, F. S., Sahihi, M., Lenglet, L., Ospina, A., Guenin, E., Jaramillo-Botero, A., Goddard, W. A., & Bedoui, F. (2023). Nanoparticle size and surface chemistry effects on mechanical and physical properties of nano-reinforced polymers: The case of PVDF-Fe3O4 nano-composites. *Polymer Testing*, *117*. https://doi.org/10.1016/j.polymertesting.2022.107851

Nayak, K., Kumar, A., & Tripathi, B. P. (2022). Molecular grafting and zwitterionization based antifouling and underwater superoleophobic

PVDF membranes for oil/water separation. *Journal of Membrane Science*, *643*. https://doi.org/10.1016/j.memsci.2021.120038

Nazri, A. I., Ahmad, A. L., & Hussin, M. H. (2019). Fabrication of microcrystalline cellulose incorporated polyethersulfone hybrid mixed matrix membrane for humic acid removal. *Journal of Physical Science*, *30*, 41–53. https://doi.org/10.21315/JPS2019.30.S2.4

Nedylakova, M., Medinger, J., Mirabello, G., & Lattuada, M. (2024). Iron oxide magnetic aggregates: Aspects of synthesis, computational approaches and applications. In *Advances in Colloid and Interface Science* (Vol. 323). Elsevier B.V. https://doi.org/10.1016/j.cis.2023.103056

Park, H. M., Oh, H., Jee, K. Y., & Lee, Y. T. (2020). Synthesis of PVDF/MWCNT nanocomplex microfiltration membrane via atom transfer radical addition (ATRA) with enhanced fouling performance. *Separation and Purification Technology*, *246*. https://doi.org/10.1016/j.seppur.2020.116860

Ponomar, M., Krasnyuk, E., Butylskii, D., Nikonenko, V., Wang, Y., Jiang, C., Xu, T., & Pismenskaya, N. (2022). Sessile Drop Method: Critical Analysis and Optimization for Measuring the Contact Angle of an Ion-Exchange Membrane Surface. *Membranes*, *12*(8). https://doi.org/10.3390/membranes12080765

Pu, L., Zhang, J., Wang, C., Pan, Y., Zhao, Y., Bu, Y., Zhang, Q., Pan, B., & Gao, G. (2021). Membrane cleaning strategy via in situ oscillation driven by piezoelectricity. *Journal of Membrane Science*, *638*. https://doi.org/10.1016/j.memsci.2021.119722

Qasem, N. A. A., Mohammed, R. H., & Lawal, D. U. (2021). Removal of heavy metal ions from wastewater: a comprehensive and critical review. In *npj Clean Water* (Vol. 4, Issue 1). Nature Research. https://doi.org/10.1038/s41545-021-00127-0

Rahimpour, A., Kebria, M. S., Dadashi Firouzjaei, M., Mozafari, M., Elliott, M., & Sadrzadeh, M. (2024). Chapter 1 - Nonsolvent-induced phase separation. In N. Tavajohi & M. Khayet (Eds.), *Polymeric Membrane Formation by Phase Inversion* (pp. 1–36). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-323-95628-4.00009-4

Rahman, A., Kumar, P., & Dominguez, F. (2022). Increasing freshwater supply to sustainably address global water security at scale. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-24314-2

Rashed, A. O., Merenda, A., Kondo, T., Lima, M., Razal, J., Kong, L., Huynh, C., & Dumée, L. F. (2021). Carbon nanotube membranes – Strategies and challenges towards scalable manufacturing and practical separation applications. In *Separation and Purification Technology* (Vol. 257). Elsevier B.V. https://doi.org/10.1016/j.seppur.2020.117929

Ren, J., Li, Z., Zhou, Y., Huang, L., Ma, B., Pan, J., & Tao, L. (2023). Effect of different pore membrane on ultrafiltration treatment of wastewater contained heavy metals complexed by palygorskite. *Desalination and Water Treatment*, *281*, 112–121. https://doi.org/10.5004/dwt.2023.29026

Saleem, H., & Zaidi, S. J. (2020). Nanoparticles in reverse osmosis membranes for desalination: A state of the art review. In *Desalination* (Vol. 475). Elsevier B.V. https://doi.org/10.1016/j.desal.2019.114171

Sanaeepur, H., Ebadi Amooghin, A., Shirazi, M. M. A., Pishnamazi, M., & Shirazian, S. (2022). Water desalination and ion removal using mixed matrix electrospun nanofibrous membranes: A critical review. In *Desalination* (Vol. 521). Elsevier B.V. https://doi.org/10.1016/j.desal.2021.115350

Sawant, S. R., Kalla, S., & Murthy, Z. V. P. (2023). Enhanced properties of the PVDF membrane with carboxylated MWCNT and sodium alginate for membrane distillation. *Journal of Environmental Chemical Engineering*, *11*(2). https://doi.org/10.1016/j.jece.2022.109259

Saxena, P., & Shukla, P. (2021). A comprehensive review on fundamental properties and applications of poly(vinylidene fluoride) (PVDF). In *Advanced Composites and Hybrid Materials* (Vol. 4, Issue 1, pp. 8–26). Springer Science and Business Media B.V. https://doi.org/10.1007/s42114-021-00217-0

Schiffer, S., Matyssek, A., Hartinger, M., Bolduan, P., Mund, P., & Kulozik, U. (2021). Effects of selective layer properties of ceramic multi-channel microfiltration membranes on the milk protein fractionation. *Separation and Purification Technology*, *259*. https://doi.org/10.1016/j.seppur.2020.118050

Sh Awad, E., Sabirova, T. M., Tretyakova, N. A., Alsalhy, Q. F., Figoli, A., & Salih, I. K. (2021). *chemengineering A Mini-Review of Enhancing Ultrafiltration Membranes (UF) for Wastewater Treatment: Performance and Stability*. https://doi.org/10.3390/chemengineering

Shamet, O., & Antar, M. (2023). Mechanical vapor compression desalination technology – A review. In *Renewable and Sustainable Energy Reviews* (Vol. 187). Elsevier Ltd. https://doi.org/10.1016/j.rser.2023.113757

Sherugar, P., Naik, N. S., Padaki, M., Nayak, V., Gangadharan, A., Nadig, A. R., & Déon, S. (2021). Fabrication of zinc doped aluminium oxide/polysulfone mixed matrix membranes for enhanced antifouling property and heavy metal removal. *Chemosphere*, *275*. https://doi.org/10.1016/j.chemosphere.2021.130024

Shi, W., Yang, C., Qiu, M., Chen, X., & Fan, Y. (2022). A new method for preparing α-alumina ultrafiltration membrane at low sintering temperature. *Journal of Membrane Science*, *642*. https://doi.org/10.1016/j.memsci.2021.119992

Shoukat, A., Zubair, M., Uddin, J., Khan, A., & Al-Harrasi, A. (2023). Innovative synthesis of non-porous polyurethane membranes with enhanced mechanical, thermal and adsorption properties. *Polymer Bulletin*, *80*(7), 7429–7450. https://doi.org/10.1007/s00289-022-04383-z

Shrestha, R., Ban, S., Devkota, S., Sharma, S., Joshi, R., Tiwari, A. P., Kim, H. Y., & Joshi, M. K. (2021). Technological trends in heavy metals removal from industrial wastewater: A review. In *Journal of Environmental Chemical Engineering* (Vol. 9, Issue 4). Elsevier Ltd. https://doi.org/10.1016/j.jece.2021.105688

Siddique, T., Dutta, N. K., & Choudhury, N. R. (2021). *membranes Mixed-Matrix Membrane Fabrication for Water Treatment*. https://doi.org/10.3390/membranes

Singh, R., Prasad, B., & Ahn, Y. H. (2024). Recent developments in gas separation membranes enhancing the performance of oxygen and nitrogen separation: A comprehensive review. In *Gas Science and Engineering* (Vol. 123). Elsevier B.V. https://doi.org/10.1016/j.jgsce.2024.205256

Song, W., Li, N., Ding, S., Wang, X., Li, H., Zhang, Y., Feng, X., Lu, J., & Ding, J. (2021). Nanofiltration desalination of reverse osmosis concentrate pretreated by advanced oxidation with ultrafiltration: Response surface optimization and exploration of membrane fouling. *Journal of Environmental Chemical Engineering*, *9*(6). https://doi.org/10.1016/j.jece.2021.106340

Stanley, R., Balu, S. K., Alphas Jebasingh, J., & Manisha Vidyavathy, S. (2023). Super-efficient photocatalytic degradation of methylene blue, methyl orange and rhodamine B dyes using low-cost ZnO–MgO nanocomposite under natural sunlight and its bactericidal activity. *Research on Chemical Intermediates*, *49*(6), 2583–2602. https://doi.org/10.1007/s11164-023-04985-w

Suhaimi, N. A. A., Kong, C. P. Y., Shahri, N. N. M., Nur, M., Hobley, J., & Usman, A. (2022). Dynamics of Diffusion- and Immobilization-Limited Photocatalytic Degradation of Dyes by Metal Oxide Nanoparticles in Binary or Ternary Solutions. In *Catalysts* (Vol. 12, Issue 10). MDPI. https://doi.org/10.3390/catal12101254

Suhalim, N. S., Kasim, N., Mahmoudi, E., Shamsudin, I. J., Mohammad, A. W., Zuki, F. M., & Jamari, N. L. A. (2022). Rejection Mechanism of Ionic Solute Removal by Nanofiltration Membranes: An Overview. In *Nanomaterials* (Vol. 12, Issue 3). MDPI. https://doi.org/10.3390/nano12030437

Sun, M., Wang, D., Ma, H., & Wang, G. (2024). Small Channels Assembled by Multilayer ZIF-8 in Nanocomposite Membranes for Filtration of Ofloxacin in Water. *Langmuir*, *40*(9), 4904–4913. https://doi.org/10.1021/acs.langmuir.3c03867

Sun, Q., Kong, S., Wang, L., Luo, H., Zhou, X., Zhang, W., & Wu, L. (2024). Facile preparation of superhydrophobic PVDF/MWCNTs distillation membranes: Synthesis, characteristics and separation performance. *Separation and Purification Technology*, *347*. https://doi.org/10.1016/j.seppur.2024.127567

Tang, Y., Lin, Y., Ford, D. M., Qian, X., Cervellere, M. R., Millett, P. C., & Wang, X. (2021). A review on models and simulations of membrane formation via phase inversion processes. In *Journal of Membrane Science* (Vol. 640). Elsevier B.V. https://doi.org/10.1016/j.memsci.2021.119810

Tawalbeh, M., Qalyoubi, L., Al-Othman, A., Qasim, M., & Shirazi, M. (2023). Insights on the development of enhanced antifouling reverse osmosis membranes: Industrial applications and challenges. *Desalination, 553*. https://doi.org/10.1016/j.desal.2023.116460

Tehranipoor Mark and Nalla Anandakumar, N. and F. F. (2023). Scanning Electron Microscope Training. In *Hardware Security Training, Hands-*

on! (pp. 293–318). Springer International Publishing. https://doi.org/10.1007/978-3-031-31034-8_16

Thomas, S. M., Anjana, R., Joseph, B., Kalarikkal, N., & Thomas, S. (2023). Chapter 4 - Evaluating the mechanical properties of sutures. In S. Thomas, P. Coates, B. Whiteside, B. Joseph, & K. Nair (Eds.), *Advanced Technologies and Polymer Materials for Surgical Sutures* (pp. 77–93). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-12-819750-9.00002-4

Tiruneh Adugna, A. (2023). Development in nanomembrane-based filtration of emerging contaminants. *Physical Sciences Reviews, 8*(8), 1659–1683. https://doi.org/10.1515/psr-2021-0057

Tofighy, M. A., Mohammadi, T., & Sadeghi, M. H. (2021). High-flux PVDF/PVP nanocomposite ultrafiltration membrane incorporated with graphene oxide nanoribbones with improved antifouling properties. *Journal of Applied Polymer Science, 138*(4), 49718. https://doi.org/https://doi.org/10.1002/app.49718

Tomoda, B. T., Yassue-Cordeiro, P. H., Ernesto, J. V., Lopes, P. S., Péres, L. O., da Silva, C. F., & de Moraes, M. A. (2020). Chapter 3 - Characterization of biopolymer membranes and films: Physicochemical, mechanical, barrier, and biological properties. In M. A. de Moraes, C. F. da Silva, & R. S. Vieira (Eds.), *Biopolymer Membranes and Films* (pp. 67–95). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-818134-8.00003-1

Undavalli, V. K., Ling, C., & Khandelwal, B. (2021). Chapter 6 - Impact of alternative fuels and properties on elastomer compatibility. In B. Khandelwal (Ed.), *Aviation Fuels* (pp. 113–132). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-818314-4.00001-7

Veisi, P., Seyed Dorraji, M. S., Vatanpour, V., & Rasoulifard, M. H. (2023). Dimensional effect of ZnO-g-C3N4 heterostructures on hydrophilic and anti-fouling properties of the PVDF/PAN composite membrane:

Dye rejection. *Journal of Environmental Chemical Engineering*, *11*(4). https://doi.org/10.1016/j.jece.2023.110249

Waghchaure, R. H., Adole, V. A., & Jagdale, B. S. (2022). Photocatalytic degradation of methylene blue, rhodamine B, methyl orange and Eriochrome black T dyes by modified ZnO nanocatalysts: A concise review. In *Inorganic Chemistry Communications* (Vol. 143). Elsevier B.V. https://doi.org/10.1016/j.inoche.2022.109764

Wang, C., Park, M. J., Yu, H., Matsuyama, H., Drioli, E., & Shon, H. K. (2022). Recent advances of nanocomposite membranes using layer-by-layer assembly. In *Journal of Membrane Science* (Vol. 661). Elsevier B.V. https://doi.org/10.1016/j.memsci.2022.120926

Wang, C., Xu, G., Gu, X., Gao, Y., & Zhao, P. (2021). High value-added applications of coal fly ash in the form of porous materials: A review. In *Ceramics International* (Vol. 47, Issue 16, pp. 22302–22315). Elsevier Ltd. https://doi.org/10.1016/j.ceramint.2021.05.070

Wang, Q., Tang, X., Liang, H., Cheng, W., Li, G., Zhang, Q., Chen, J., Chen, K., & Wang, J. (2022). Effects of Filtration Mode on the Performance of Gravity-Driven Membrane (GDM) Filtration: Cross-Flow Filtration and Dead-End Filtration. *Water (Switzerland)*, *14*(2). https://doi.org/10.3390/w14020190

Wang, W., Xu, X., Zhang, Z., Zhang, P., Shi, Y., & Ding, P. (2021). Study on the improvement of PVDF flat ultrafiltration membrane with MWCNTs-OH as the additive and the influence of different MWCNTs-OH scales. In *Colloids and Interface Science Communications* (Vol. 43). Elsevier B.V. https://doi.org/10.1016/j.colcom.2021.100433

Wei, X., Liu, Y., Zheng, J., Wang, X., Xia, S., & Van der Bruggen, B. (2022). A critical review on thin-film nanocomposite membranes enabled by nanomaterials incorporated in different positions and with diverse dimensions: Performance comparison and mechanisms. In

Journal of Membrane Science (Vol. 661). Elsevier B.V. https://doi.org/10.1016/j.memsci.2022.120952

Witt, K., & Radzymińska-Lenarcik, E. (2019). Characterization of PVC-based polymer inclusion membranes with phosphonium ionic liquids. *Journal of Thermal Analysis and Calorimetry*, *138*(6), 4437–4443. https://doi.org/10.1007/s10973-019-08912-3

Wu, S., Shi, W., Cui, L., & Xu, C. (2024). Enhancing contaminant rejection efficiency with ZIF-8 molecular sieving in sustainable mixed matrix membranes. *Chemical Engineering Journal*, *482*. https://doi.org/10.1016/j.cej.2024.148954

Xu, Y., Ren, L. F., Sun, H., Shao, J., & He, Y. (2023). Revealing the selective separation of organics from salty solution in novel aqueous-aqueous membrane extraction co-driven by concentration and pressure difference. *Separation and Purification Technology*, *323*. https://doi.org/10.1016/j.seppur.2023.124419

Xu, Z., Croft, Z. L., Guo, D., Cao, K., & Liu, G. (2021). Recent development of polyimides: Synthesis, processing, and application in gas separation. In *Journal of Polymer Science* (Vol. 59, Issue 11, pp. 943–962). John Wiley and Sons Inc. https://doi.org/10.1002/pol.20210001

Yıldız, A., Kara, A. A., & Acartürk, F. (2020). Peptide-protein based nanofibers in pharmaceutical and biomedical applications. In *International Journal of Biological Macromolecules* (Vol. 148, pp. 1084–1097). Elsevier B.V. https://doi.org/10.1016/j.ijbiomac.2019.12.275

Younos Tamim and Lee, J. (2020). Desalination: Concept and System Components. In A. A. and S. A. A. Saji Viswanathan S. and Meroufel (Ed.), *Corrosion and Fouling Control in Desalination Industry* (pp. 3–27). Springer International Publishing. https://doi.org/10.1007/978-3-030-34284-5_1

Yun, K. H., Sim, S., Hong, H. S., Jeong, K. J., & Bae, T. H. (2025). Optimizing PES microfiltration membranes for sterile filtration: A comparative study of polydopamine coating in acidic and basic conditions to minimize protein adsorption. *Journal of Membrane Science*, *713*. https://doi.org/10.1016/j.memsci.2024.123398

Zeng, H., Sun, F., Zhang, J., Wang, Y., Yang, S., & Xing, D. (2023). Gradient crosslinking optimization for the selective layer to prepare polyvinyl alcohol (PVA) nanofiltration (NF) membrane: The enhanced filtration performance and potential rejection for EDCs. *Journal of Membrane Science*, *675*. https://doi.org/10.1016/j.memsci.2023.121548

Zhang, B., Wang, W., Zhu, L., Li, N., Chen, X., Tian, J., & Zhang, X. (2022). Simultaneously enhanced permeability and anti-fouling performance of polyethersulfone ultrafiltration membranes by structural control and mixed carbon quantum dots. *Journal of Membrane Science*, *641*. https://doi.org/10.1016/j.memsci.2021.119931

Zhang, J., Wu, H., Shi, L., Wu, Z., Zhang, S., Wang, S., & Sun, H. (2024). Photocatalysis coupling with membrane technology for sustainable and continuous purification of wastewater. In *Separation and Purification Technology* (Vol. 329). Elsevier B.V. https://doi.org/10.1016/j.seppur.2023.125225

Zhang, M., Jiang, S., Guo, X., Tang, X., Bai, L., Wang, J., Zhang, H., Xu, D., Wu, R., Liu, L., & Liang, H. (2023). Fabrication of high permeability and antifouling composite membrane loaded with Fe3O4 nanoparticles via a magnetic field induced phase separation. *Journal of Water Process Engineering*, *56*. https://doi.org/10.1016/j.jwpe.2023.104422

Zhang, W., & Zhang, X. (2021). Effective inhibition of gypsum using an ion–ion selective nanofiltration membrane pretreatment process for seawater desalination. *Journal of Membrane Science*, *632*. https://doi.org/10.1016/j.memsci.2021.119358

Zhang, X. (2022). Selective separation membranes for fractionating organics and salts for industrial wastewater treatment: Design strategies and process assessment. In *Journal of Membrane Science* (Vol. 643). Elsevier B.V. https://doi.org/10.1016/j.memsci.2021.120052

Zhang, Z., Fu, H., Li, Z., Huang, J., Xu, Z., Lai, Y., Qian, X., & Zhang, S. (2022). Hydrogel materials for sustainable water resources harvesting & treatment: Synthesis, mechanism and applications. In *Chemical Engineering Journal* (Vol. 439). Elsevier B.V. https://doi.org/10.1016/j.cej.2022.135756

Zhao, S., Liao, Z., Fane, A., Li, J., Tang, C., Zheng, C., Lin, J., & Kong, L. (2021). Engineering antifouling reverse osmosis membranes: A review. In *Desalination* (Vol. 499). Elsevier B.V. https://doi.org/10.1016/j.desal.2020.114857

Zheng, Y., & Hatzell, K. B. (2020). Technoeconomic analysis of solar thermal desalination. *Desalination*, *474*. https://doi.org/10.1016/j.desal.2019.114168

Zhong, L., Wang, Y., Liu, D., Zhu, Z., & Wang, W. (2021). Recent advances in membrane distillation using electrospun membranes: advantages, challenges, and outlook. *Environ. Sci.: Water Res. Technol.*, *7*(6), 1002–1019. https://doi.org/10.1039/D1EW00128K

Zhu, H., Fu, Z., Wang, Y., & Zhang, N. (2023). Study on splitting tensile strength of interface between the full lightweight ceramsite concrete and ordinary concrete. *Case Studies in Construction Materials*, *18*. https://doi.org/10.1016/j.cscm.2023.e01829

Zhu, J., Zhou, S., Li, M., Xue, A., Zhao, Y., Peng, W., & Xing, W. (2020). PVDF mixed matrix ultrafiltration membrane incorporated with deformed rebar-like Fe3O4–palygorskite nanocomposites to enhance strength and antifouling properties. *Journal of Membrane Science*, *612*. https://doi.org/10.1016/j.memsci.2020.118467