Developing thin-film nanocomposite (TFN) membranes for removal of H2S scavenging products

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Developing thin-film nanocomposite (TFN) membranes for removal of H_2S scavenging products

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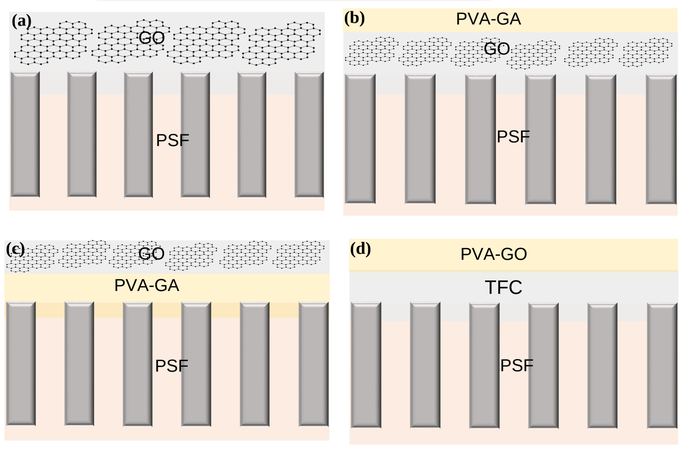
MOTIVATION

- Hydrogen sulfide (H_2S) is a highly toxic and corrosive gas that poses significant safety, health, and environmental risks to oil and gas production [1].
- MEA-triazine is the most common H_2S scavenger used on offshore platforms, but its excessive use and subsequent discharge into the sea, along with the resulting reaction products, led to a high environmental impact [2].
- The Challenge is to address the high environmental impact of the water discharge associated with H_2S scavenging in North Sea offshore platforms, which can contribute up to 20% of the overall environmental impact factor [3].

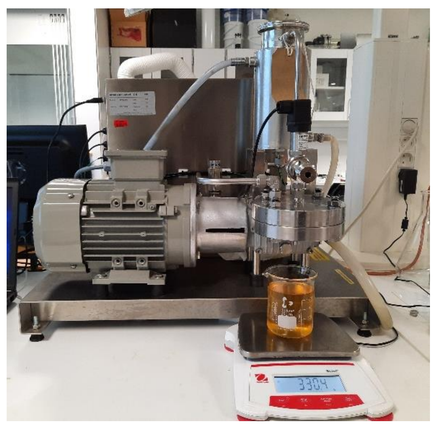
OBJECTIVE

- Develop a novel thin film nanocomposite (TFN) membrane for the removal of spent and unspent scavenger (SUS) wastewater produced in the offshore oil and gas industry.
- Improve the performance of the membrane by evaluating the effect of graphene oxide loading into the polyamide layer on its permeability, hydrophilicity, antifouling, and rejection.
- Reduce the environmental impact of the water discharge of spent and unspent H_2S scavengers.

METHODS



Schematic illustration of ultrathin coating layer integrated composite membranes, (a) TFN, (b) PVA@TFN, (c) TFN@PVA, and (d) GO-PVA@TFC membrane.



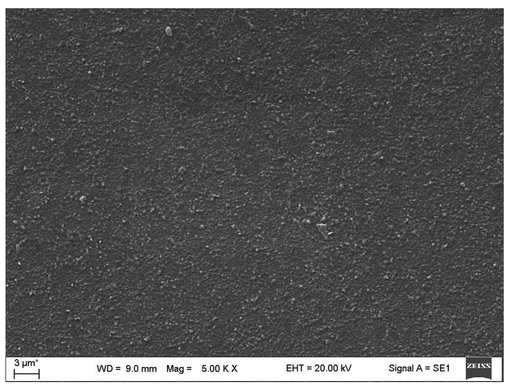
Operating conditions:

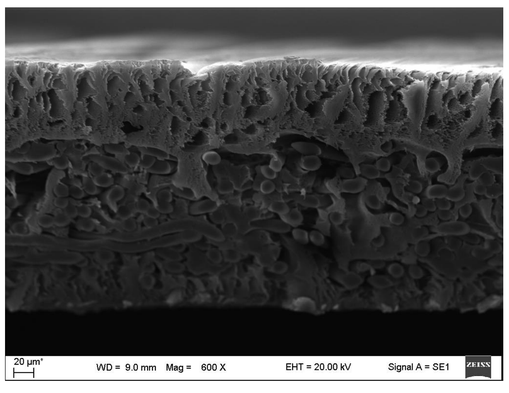
SUS wastewater: 500 mL.
Circulated at zero gauge pressure for 30 min.
Temperature: 40 °C, Feed flow rate: 21 L/h.
Cross-flow velocity: 0.5 m/s, Recovery: 50%.
GO: 0, 0.05, 0.1, 0.2, 0.3 wt.%.

Key Message

- Incorporating graphene oxide (GO) into the polyamide layer of thin film nanocomposite (TFN) membranes can improve their permeability, hydrophilicity, and antifouling properties while maintaining a high rejection of SUS.
- The TFN0.3@PVA membrane showed the highest improvement in permeability by 27 times.
- The TFN0.2@PVA and PVA@TFN0.3 membranes showed better SUS rejection with ~80% HET rejection, with negligible nanofiller leaching out.

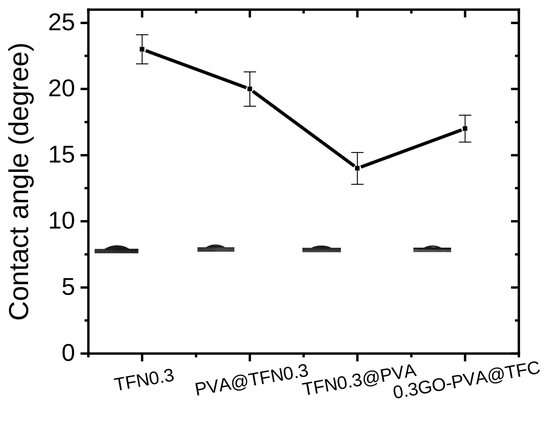
MEMBRANE CHARACTERIZATION

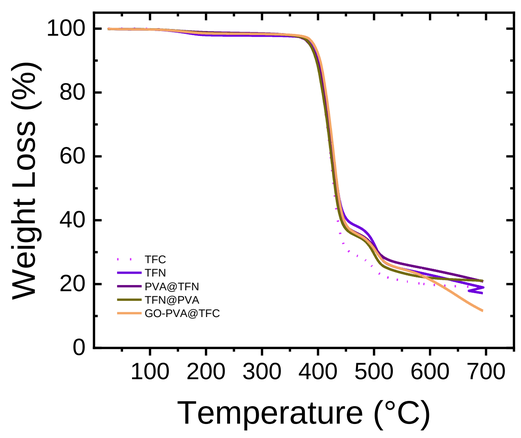




The PA active layers exhibited a typical ridge-like-valley morphology.

The cross-sectional SEM images of the synthesized TFN membranes show a finger-like pore structure that initiates just below the top surface of the porous PSF support, which is uniformly coated with a thin layer of polyamide (100–250 nm).

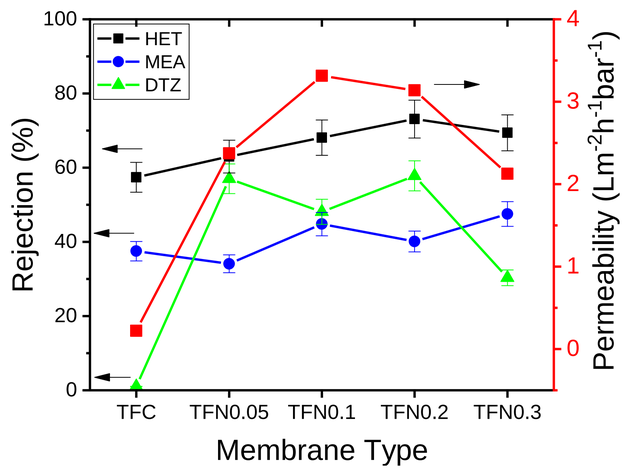




The hydrophilicity and the thermal stability of the synthesized TFN membrane was improved for all the synthesized membranes .

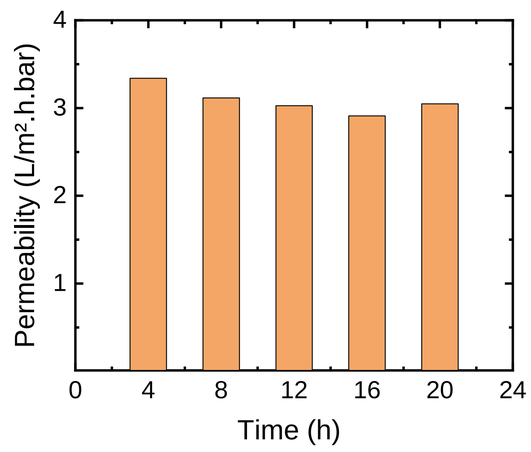
FILTRATION EXPERIMENT

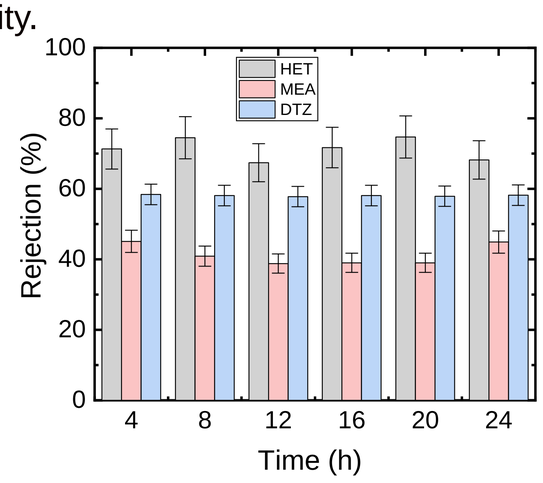
The rejection rate of HET increased from 57% to 74% with the addition of GO and then decreased slightly when the GO concentration was 0.3 wt%, but the rejection rate was still higher than that of the TFC membranes.



The results show that HET had the highest rejection rate, followed by DTZ and MEA, indicating that the membrane mechanism is attributed to the synergetic effects of size exclusion and Donnan exclusion.

The water permeability increased from 0.22 to 3.4 L m^{-2} h^{-1} bar^{-1} when the GO concentration increased from 0 to 0.1 wt%, before slightly decreasing to 2.2 L m^{-2} h^{-1} bar^{-1}. This behavior is attributed to the agglomeration of GO at higher concentrations, despite increased hydrophilicity.





The results revealed a consistent and stable high performance of the TFN membrane, with a slight variations in permeability and rejection.

The TFN membrane showed a higher rejection for HET, MEA, and DTZ about 75%, 44%, and 59%, respectively.

CONCLUSIONS

- The PVA@TFN0.3 membrane has the lowest water contact angle (16°), while the TFC membrane has the highest water contact angle (51°) due to the hydrophilic carboxylic groups on the GO surface.
- The hydrophilicity of the TFN membrane increases with an increase in the concentration of GO, leading to an increase in permeability from 0.22 to 3.4 L/m^2 h bar and an increase in the rejection of HET, MEA, and DTZ by 63-73%, 37-48%, and 30-57%, respectively.
- These findings highlight the potential of GO for the development of high-performance TFN membranes to reduce the overall environmental impact of produced water from offshore oil and gas production.

ACKNOWLEDGEMENTS

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REFERENCES

[1] F. Pouliquen, et al., Perrot, Wiley-VCH Verlag GmbH Co. KGaA, Weinheim, 2000.
[2] N. Montesantos , et al., Water Research, 230 (2023).
[2] A. Khalil, et al., Journal of Environmental Chemical Engineering 10 (6), 2022, 108735.
[3] M.A. Kelland, Hydrogen Sulde Scavengers, Production Chemicals for the Oil and Gas Industry CRC Press, 2014.

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