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Impact of Membrane Housing Height on Oil Retention and Filtration Efficiency in Quartz-Based Separation Systems

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Abstract:

The increasing global demand for efficient and cost-effective oil-water separation technologies has necessitated the exploration of advanced filtration techniques. This study investigates the effect of membrane housing height on residual oil concentration and overall filtration efficiency in quartz-based membrane separation systems. The research focuses on the use of a first-coated quartz membrane with hydrophilic nanoparticles to enhance separation performance. The study systematically evaluates membrane heights of 1 mm, 2 mm, 3 mm, and 4 mm above the filtration stick, analyzing their impact on post-filtration oil concentration. The experimental results indicate a clear inverse relationship between membrane height and residual oil concentration. At a 1 mm height, the oil concentration was 3,761.5 mg/L, significantly decreasing to 440.6 mg/L at 2 mm, 78.5 mg/L at 3 mm, and reaching the lowest concentration of 1.2 mg/L at 4 mm. These findings suggest that increasing membrane height optimizes oil-water separation efficiency by reducing turbulence and enhancing membrane contact with contaminants. The study contributes to optimizing membrane housing design, ensuring improved performance in industrial oily wastewater treatment.

Methodology and Theoretical Orientation: A pressure-driven quartz membrane filtration system was employed to assess the impact of membrane housing height on oil separation efficiency. The experiment utilized a first-coated quartz membrane, modified with hydrophilic nanoparticles to enhance wettability. A synthetic oil-water mixture with an initial oil concentration of 39,567.4 mg/L was prepared to simulate industrial wastewater conditions. Four membrane housing heights—1 mm, 2 mm, 3 mm, and 4 mm—were tested, and the corresponding residual oil concentrations in the filtrate were measured. The filtration performance was assessed using gravimetric oil and grease analysis, while structural changes in the membrane were characterized using X-ray diffraction (XRD) and scanning electron microscopy (SEM).

Findings: The results demonstrate a significant decline in oil concentration with increasing membrane housing height. At 1 mm, the residual oil concentration was 3,761.5 mg/L, while increasing the height to 2 mm reduced it to 440.6 mg/L. A further increase to 3 mm led to a substantial drop to 78.5 mg/L, with the lowest concentration of 1.2 mg/L observed at 4 mm. These findings suggest that a taller membrane housing enhances oil separation by improving fluid dynamics and reducing flow disturbances. The enhanced separation performance at greater heights is attributed to improved interaction between the quartz membrane and oil droplets, allowing for more effective capture and retention. Additionally, XRD analysis confirmed that the membrane maintained its structural integrity across all tests, while SEM imaging revealed a more uniform oil distribution on higher-positioned membranes.

Conclusion & Significance: This study highlights the critical role of membrane housing height in optimizing oil-water separation efficiency in quartz-based filtration systems. The results demonstrate that a 4 mm housing height significantly reduces residual oil concentration, making it the optimal configuration for enhanced separation performance. These findings have direct



implications for the design of next-generation filtration systems for industrial wastewater treatment, promoting sustainability and cost-effectiveness in water reuse applications. Future research will explore the integration of advanced coating techniques to further enhance membrane hydrophilicity and longevity.

Biography

Ms. Nthabiseng J. Ramanamane is a distinguished lecturer and researcher at the University of South Africa (UNISA), specializing in material sciences and membrane technology for sustainable water recovery. She serves as the Study Leader and Chairperson of the Quartz Membranes Research Group and Deputy Chair of Teaching and Learning in CSET. Currently pursuing her PhD in Engineering at UNISA, her research focuses on quartz-based oil-water filtration membranes to address global water scarcity challenges. She holds an MEng (Cum Laude) from the Vaal University of Technology and a BTech (Cum Laude) from UNISA. With seven peer-reviewed publications, multiple research grants from NRF (BAAP), ISP, and pending TIA-UNISA funding, her work bridges scientific innovation and real-world applications.

About Research Topic

This study investigates the effect of membrane housing height on oil retention and filtration efficiency in quartz-based separation systems. The objective is to determine the optimal housing height for maximizing oil removal while ensuring efficient water recovery. Four different membrane heights (1 mm, 2 mm, 3 mm, and 4 mm) were tested using a hydrophilic nanoparticle-coated quartz membrane, with an initial oil concentration of 39,567.4 mg/L in the oily wastewater. The results show a significant reduction in oil concentration as the membrane height increased. The residual oil concentrations were recorded as follows: 3,761.5 mg/L at 1 mm, 440.6 mg/L at 2 mm, 78.5 mg/L at 3 mm, and only 1.2 mg/L at 4 mm. These findings indicate that increasing the membrane height enhances oil-water separation efficiency, with 4 mm proving to be the most effective. This research provides valuable insights into optimizing quartz-based membrane housing design for industrial wastewater treatment. By addressing a critical design parameter often overlooked in membrane filtration, this study contributes to the advancement of low-cost, efficient, and scalable oil-water separation technologies.

About Institution:

The University of South Africa (UNISA), located in Florida, South Africa, is the largest open distance learning (ODeL) institution in Africa and a key driver of research, innovation, and technological advancement. As part of the College of Science, Engineering, and Technology (CSET), the Department of Mechanical Engineering, Bioresources, and Biomedical Engineering is dedicated to cutting-edge research in materials science, fluid mechanics, and sustainable engineering solutions. UNISA is inspired by its vision to become "the African university shaping futures in the service of humanity." This vision defines its mission and commitment to serving every country on the African continent and the broader global community while transcending language and cultural barriers. The institution fosters multidisciplinary collaborations with national and international research institutions, industry stakeholders, and government bodies, ensuring that its research contributes to scientific advancements and real-world applications. With a strong faculty of researchers, academics, PhD candidates, and industry partners, UNISA remains a pioneering institution in membrane technology, environmental sustainability, and industrial wastewater treatment.

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