Balaban Desalination Publications

مؤتمر الخليج الخامس عشر للمياه
The 15th Gulf Water Conference

(2025) 275–276
doi: 10.5004/700111

WSTA 15th Gulf Water Conference
Water in the GCC, The Role of Technology in Effective Water Management
28–30 April 2024, Doha, Qatar

Advanced wastewater treatment using functionalized membranes

Mohammed Z. Al-Abri[1,2]

[1]*Nanotechnology Research Center, Sultan Qaboos University, Oman*
[2]*Petroleum and Chemical Engineering Department, College of Engineering, Sultan Qaboos University, Oman*
email: alabri@squ.edu.om

ABSTRACT

Membranes play a crucial role in water treatment and desalination, offering an essential solution to meet the increasing global demand for clean water. The versatility of polymeric membranes in terms of fabrication processes, membrane properties, and applications makes them incredibly well-suited for various wastewater treatment applications. Their adaptability allows for tailored designs and optimization to specific water treatment challenges. Moreover, the recent advancements in electrospun nanofiber polymeric membranes (ENMs) have revolutionized membrane technology, presenting exciting opportunities to enhance the performance of membranes in produced water treatment greatly. The development of ENMs has opened up new avenues for improved filtration efficiency, enhanced water permeability, and increased resistance to fouling, addressing the unique challenges posed by wastewater treatment. These innovative membranes hold significant promise in overcoming the limitations of conventional membrane technologies and advancing the field of water treatment.

Oil and gas-produced wastewater, or oilfield wastewater, is the wastewater generated during oil and natural gas extraction and production. It is a byproduct that emerges alongside the hydrocarbons during drilling, well stimulation, and production processes. Oil and gas-produced wastewater is a complex mixture that contains various contaminants, including hydrocarbons, heavy metals, salts, suspended solids, organic compounds, and naturally occurring radioactive materials (NORMs). The composition of produced water can vary depending on the characteristics of the oil or gas reservoir, the extraction methods used, and the geological formations in the area. Due to its composition and potential environmental impact, the treatment and disposal of oil and gas-produced wastewater present significant challenges for the oil and gas industry. Effective treatment methods must remove or reduce contaminants before safe disposal or potential water reuse.

Additionally, conventional water treatment infrastructure is confronted with a growing challenge stemming from higher living standards, an expanding pharmaceutical industry, and the proliferation of personal care products, micro and nano-plastics, and various human-made chemicals. These persistent contaminants pose a serious threat to water systems as they find their way into natural water bodies, necessitating advanced treatment strategies beyond the capabilities of conventional methods.

ISBN 0-86689-078-5

Nanotechnology, with its precision in manipulating matter at the atomic and molecular levels, emerges as a transformative force in overcoming these challenges. It offers modular and efficient solutions for general wastewater treatment. Nano-adsorption, photocatalysis, and functionalized membranes are key processes targeting diverse contaminants. This multifaceted approach ensures high wastewater treatment efficiency, modularity, and cost-effectiveness.
The utilization of nanofiber membranes incorporating nanomaterials for produced water treatment has gained considerable attention. Specific emphasis has been placed on nanofiber membranes with surface characteristics exhibiting superhydrophobic/superoleophilic or superhydrophilic/superoleophobic properties. Generally, nanoparticles such as iron oxide (Fe_3O_4), titanium dioxide (TiO_2), and silica (SiO_2) have been employed to improve the properties of ultrafiltration (UF) membranes. Incorporating nanoparticles can significantly enhance the hydrophilicity of the membrane surface, thereby improving water permeability and resistance against fouling when treating domestic or industrial wastewater. Nanomaterial-enhanced membranes possess not only superwetting properties but also exhibit photocatalytic capabilities. Commonly used metal oxide nanoparticles like TiO_2 and ZnO are photocatalysts for various water applications. Photocatalysis utilizes visible light or UV to degrade organic contaminants and disinfect bacteria through oxidation or reduction reactions.
Despite nanotechnology's promise, translating these advancements into large-scale industrial applications has encountered hurdles, primarily due to the complexity of system design. Bridging the gap between cutting-edge research and practical implementation is essential for the widespread adoption of nanotechnology in water treatment. This study provides valuable insights into the latest developments, challenges, and opportunities in nanotechnology-based approaches, paving the way for sustainable and responsible water management practices amid evolving environmental concerns.

Keywords: Membranes; Nanofibers; Functionalization; Produced water; Emerging contaminants; Water treatment