

Book Review **Application of Membranes in the Petroleum Industry**

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ABSTRACT

This book [1] provides a comprehensive overview of the roles of membrane technology in the petroleum industry, covering membrane selection, materials, challenges, and applications across the upstream sector in oil and gas production and midstream refining. It includes applications for enhanced oil recovery, midstream refining processes for hydrocarbon separation, and contaminant capture, especially for environmental remediation, focusing on the treatment of byproducts like hydrogen sulfide from petroleum processing. It encompasses three main areas: a general conceptualization of membrane technology, core topics on membrane applications in various sectors within the petroleum industry, and future perspectives along with modeling.

The first two chapters introduce membrane development, explaining how membranes work, their classifications, and the current challenges of membrane technology, including fouling and solute transport modeling. Chapter 2 provides insights into novel membrane materials, categorized as synthetic polymers, biopolymers, and inorganic materials, as well as the use of nanomaterials to nanocomposite membrane for enhancing membrane performance. The following chapters explore membrane applications across the petroleum industry, discussing the importance and challenges in separating compounds with similar physical properties, such as the selective separation of gas mixtures containing carbon dioxide (CO₂), hydrogen sulphide (H₂S), and liquefied petroleum gas (LPG)-range hydrocarbons. For instance, Chapter 3 on natural gas processing recommends different types of membranes depending on the target gas to be removed, focusing on enhancing gas transport selectivity and permeability.

Subsequent chapters delve into complex hydrocarbon separations, which traditionally require energy-intensive cryogenic distillation but can be addressed with membrane technology. Chapter 4 details the selective separation of olefins from paraffins produced after catalytic cracking, using various membrane types, such as polymeric, supported liquid, carbon molecular sieve, and mixed matrix membranes. The importance of separating olefins, vital for the petrochemical industry, is highlighted. Chapter 5 discusses the separation of benzene-toluene-xylene (BTX) from aliphatic paraffins in naphtha, emphasizing the solution-diffusion mechanism via selective aromatic absorption and noting that nanocomposite membranes mitigate the

swelling issues common in polymeric membranes. Chapter 11 shifts to upstream processes, detailing how nanofiltration can produce ionically modified water with controlled hardness and reduced sulfate, useful for enhanced oil recovery (EOR) in creating smart water for flooding applications.

The book then addresses the capture of pollutants produced in the petroleum industry. Produced water, a wastewater stream containing salts, minerals, and emulsified oils generated during oil and gas extraction, presents persistent environmental challenges if untreated. Chapter 6 provides a summary of produced water characteristics, including compound composition and wastewater metrics like total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and gases. Chapter 7 reviews conventional treatment techniques, highlighting the need for hybrid processes to handle its complex composition. Chapter 8 details how membrane properties like pore size, surface wettability, and roughness affect oil-water selectivity, which can be tuned by modifying membrane hydrophilicity, resulting in either superhydrophilic or superoleophilic membranes. In Chapters 9 and 10, phenolic and heavy metal removal from refining wastewater is explored, detailing size exclusion and adsorption mechanisms, with innovative methods like pervaporation and photocatalytic membranes for the removal of phenolic compounds. Heavy metals can be removed using multiple types of membranes, including ultrafiltration, nanofiltration, reverse osmosis, micellar-enhanced ultrafiltration, and forward osmosis. Chapter 12 highlights the role of pervaporation membranes in removing organosulfur compounds from gasoline, noting polyimides as a common membrane material, with alternatives such as polydimethylsiloxane and ceramics. The book also emphasizes simulation tools that enable molecular and fluid dynamic predictions, including molecular dynamics, density functional theory, Monte Carlo simulations, and computational fluid dynamics. The final chapter briefly discusses fouling mitigation, membrane reusability, and greener fabrication approaches.

Overall, this book serves as an extensive resource on membrane technologies across various sectors of the petroleum industry, including enhanced oil recovery (EOR), selective hydrocarbon separation, gas sweetening, and waste stream treatment. It provides a solid foundation in material science, separation mechanisms, and solute transport modeling. The book covers a wide range of current research and briefly highlights potential applications of membrane technology in the petroleum industry. For instance, it mentions emerging applications such as supported liquid membranes (SLM) for olefin-paraffin separation in Chapter 4 and Liqui-Cel membrane contactors for polyphenol extraction in Chapter 9. However, challenges like the trade-off between permeability and selectivity, fouling, and the declining mechanical stability of membranes during extended operations remain barriers to broader implementation of membrane technology in the petroleum industry. The book addresses issues such as the physical aging of polymeric membranes in separating multicomponent gas mixtures, which leads to reduced selectivity over time.

The book could benefit from greater emphasis on commercially available membranes and prototype systems, with a focus on scalability, durability, and performance, which are the key considerations for industry adoption. Additionally, it would be valuable to include more recent updates on the adaptation of membrane technology in the industry. For example, Honeywell UOP's Separex™ system is used for natural gas sweetening, removing contaminants such as water, carbon dioxide, and hydrogen sulfide, as highlighted on their official website. Air Products Membrane Solutions' PRISM membrane separators, featuring polymeric hollow fibers, are utilized in offshore drilling to separate gases like methane, nitrogen, or hydrogen. Similarly,

MTR Corporation's VaporSep® system has been successfully employed for olefin-paraffin separation, enhancing hydrocarbon recovery. These are just a few examples of successful commercial applications of membrane technology, though a comprehensive list is beyond the scope of this review. Notably, the book lacks sufficient coverage of hydrogen recovery from hydroprocessing using membrane technology, an area of significant industrial interest. Including detailed techno-economic feasibility studies would further enhance the book's practical relevance, fostering wider adoption of membrane technologies in petroleum processes.

Keywords: Membrane, Petroleum Industry, Enhanced oil recovery, Membrane contactor

REFERENCES

- [1] Swapnali Hazarika, Achyut Konwar and G. Narahari Sastry. (2024). *Application of Membranes in the Petroleum Industry*. First Edition. CRC Press.