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Book Review
Nanofiltration for Sustainability: Reuse, Recycle and Resource Recovery

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ABSTRACT

The application of nanofiltration (NF) for sustainability in various industries was discussed in this recent published book. The sustainability of the NF was reviewed in terms of potential reuse, recycle, and resource recovery in the respective industry. Wide range of industries were covered in this book ranging from desalination, landfill leachate effluent, textile effluent, food industry effluent, agriculture effluent, heavy metals, and emerging organic contaminants. In addition, the book also considers the application of NF integrated with other technologies such as biological degradation, adsorption, Fenton, electrodialysis, ozonation, coagulation, and flocculation. The book could further explore the application of NF in energy sectors such as water treatment for power plants, carbon capture and sequestration, fuel cell technology, hydrogen purification, and energy storage. In short, the book offers a thorough discussion on the fundamentals of NF technology and its application towards sustainable developments.

Keywords: Nanofiltration; sustainability; water reuse; resource recovery

1.0 BOOK SUMMARY

The book contains 17 chapters contributed by several membrane experts covering on the fundamentals of nanofiltration (NF) technology, mechanism of separation, combination of NF and other technologies to advance circular economy, modification of NF membranes, application of NF in a wide range of industries, and challenges of operation. Chapter 1-3 mainly discuss the fundamentals of NF, general application of NF for various industries and development of NF membranes. Meanwhile, the remaining chapters focus on the application of NF in respective industries in-depth. The industries include desalination, landfill leachate, textile, agricultural and food, organic solvent, ammonia contaminants, geothermal fluid, heavy metal and pharmaceutical and biotechnology. Some of the emerging processes of NF membrane is the lithium recovery, alkaline chemical recovery, removal of pharmaceutically active chemicals (PhACs), and endocrine-disrupting compounds (EDCs), membrane modification for low-pressure filtration, integration of NF processes, inkjet printing NF membrane [1–4]. Table 1 summarizes the chapters and scope of discussion in this book.

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Table 1 Summary of the chapters [10]

Chapter	Summary
1	• Role of NF for resource recovery and reuse. • Sustainability assessment
2	• Case studies in various industries
3	• Transformation of pristine NF membrane into nanomaterials-modified NF membrane
4	• NF fundamentals • Application of NF in desalination
5	• Mechanism of separation • Application of NF in removal of trace organic contaminant • Challenges
6	• Characteristics of landfill leachate effluent • Application of NF in landfill leachate effluent treatment • Hybrid membrane process for landfill leachate effluent treatment
7	• Characteristics of textile effluent • Application of NF for water reclamation • Application of NF for resource recovery
8	• Development of draw solution for the hybrid NF-FO process • Industrial application of NF-FO system
9	• Characterization of agricultural and food industry wastewater • Single NF and Integrated NF treatment • Challenges in NF operation
10	• Characterization of palm oil mill secondary effluent • Application of membrane photocatalytic reactor • Effect of pH and light intensity on MPR
11	• Organic solvent NF • Membrane materials • Transport modeling
12	• Sugar separation from oil palm frond biomass • Application of commercial spiral-wound NF membrane
13	• Treatment of ammonia wastewater • Modification of adsorptive membranes
14	• Principles of NF • Application of NF in agricultural water, process water and geothermal water • Fouling in NF
15	• Sources of wastewater containing heavy metals • Application of NF in heavy metal removal • Challenges • Design and operation of NF system
16	• NF for desalination and wastewater treatment • Hybrid NF membrane technology
17	• Application of NF in food, pharmaceutical and biotechnology industry • Challenges

Chapter 1 outlines the role and benefits of NF in achieving sustainability across various industry. This involves resource recovery and

reuse and adoption of alternative sustainable operation and process. This can be illustrated in Figure 1. Besides, this chapter reviews four sustainability categories for assessing wastewater treatment plants using NF including 1) technical category 2) environmental category 3) economic category, and 4) social category. In Chapter 2, the focus shifts to the application of NF for the reuse, recycling, and recovery of resources in diverse industries including agriculture, domestic, and industrial wastewater. Numerous case studies presented that NF technology enhances permeate quality to meet reusable water standards and facilitates the recovery of valuable resources. The integration of NF with other technologies further reduces fouling, prolong membrane lifespan, and improve membrane performance. Moving on to Chapter 3, the discussion centers on the development of NF membranes from pristine NF membrane into nanomaterials-modified NF membrane to improve membrane transport or alter permselectivity. The chapter delves into the incorporation of various types of nanomaterials including 0-, 1-, or 2-dimensional nanomaterials and metal-organic frameworks (MOFs). Further integration of nanoparticles and NF especially for wastewater treatment were reviewed by Joseph *et al*. [5].

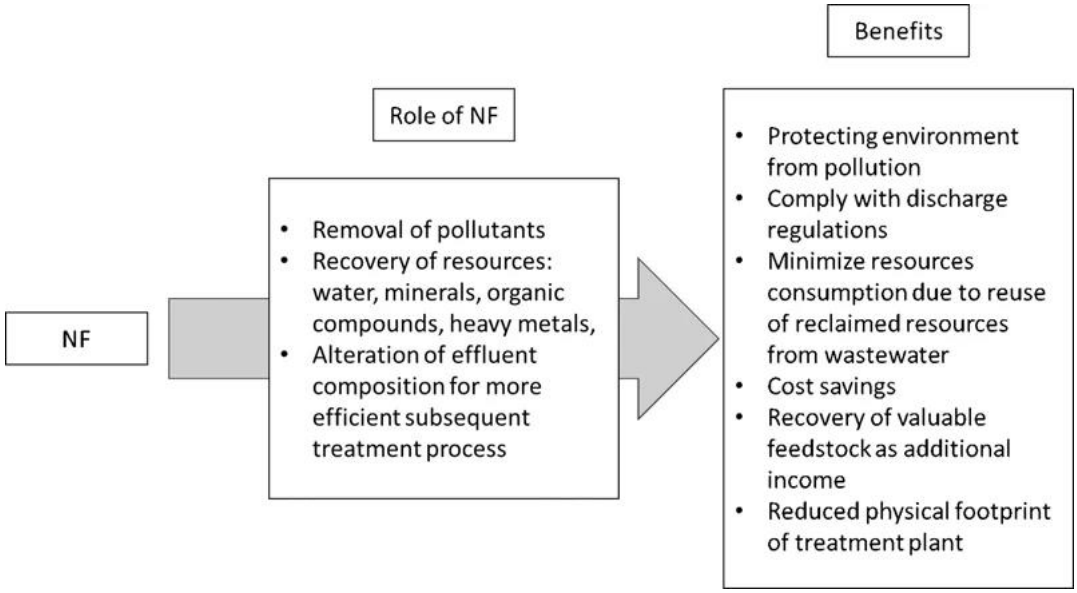

Figure 1 Role of NF and benefits obtained with the utilization of NF in the industry [11]

In the subsequent chapters spanning from Chapter 4 to Chapter 17, a more comprehensive exploration of the application of nanofiltration (NF) in selected industries is provided. This includes the characteristics of water and wastewater produced from industry, development of NF and integrated NF system, as well as challenges encountered during operation. In Chapter 4, it discusses the application of NF membranes for desalination particularly on the membrane fabrication including the incorporation of nanofillers and advancement in interfacial polymerization process. Chapter 5 reviews the application of NF in addressing emerging and trace organic contaminants (TrOCs) such as PhACs, personal care products (PCPs), endocrine-disrupting compounds, pesticides, and organohalogen compounds. A comparative analysis of the performance of reverse osmosis

(RO) and NF in terms of operational costs and water quality is conducted. NF possesses a lower operating cost due to the lower pressure requirement despite the quality of water produced by NF and RO is quite comparable. Chapter 6 explores the application of NF in landfill leachate treatment. Due to the high pollutant concentrations and its toxic nature, combination of NF with other pressure-driven membrane processes (MBR, UF, and RO) and/or treatment techniques (coagulation and advanced oxidation) is commonly used. In Chapter 7, the application of NF membrane for textile industry was discussed in terms of the types of NF membrane either thin-film composite, thin-film nanocomposite, layer-by-layer, and asymmetric membranes. Each type of the NF membranes comes with its advantages and disadvantages, therefore systematic studied are required to explore the cost benefit for its practical application [6].

Chapter 8 explores the integration of NF with forward osmosis (FO) for various industrial application including brackish water desalination, wastewater treatment, chemical and food processing. Such integration allows high water flux and low reverse solute transport as shown in Figure 2. In Chapter 9, the application of NF for agricultural and food industry wastewater by using single NF and integrated NF process is discussed. Based on the case studies, the NF process is integrated with biological degradation, adsorption, Fenton, electrodialysis, ozonation, coagulation, and flocculation for enhanced treatment [7]. Moving forward, Chapter 10 focuses on the treatment of palm oil mill secondary effluent (POMSE) using NF membrane photocatalytic reactor (MPR) as shown in Figure 3. Generally, the POMSE is mixed with photocatalyst such as zinc oxide (ZnO) for the photocatalysis degradation subsequently proceed with membrane separation using NF. This integrated process mitigates the flux decline and membrane fouling. However, the transfer of photocatalyst will lead to the accumulation at the process pipe hence photocatalytic performance. The chapter also reviews the two critical factors that affect the performance of MPR which is pH and light intensity. Further research can look into the recovery of valuable chemicals from the agricultural industry using NF [8].

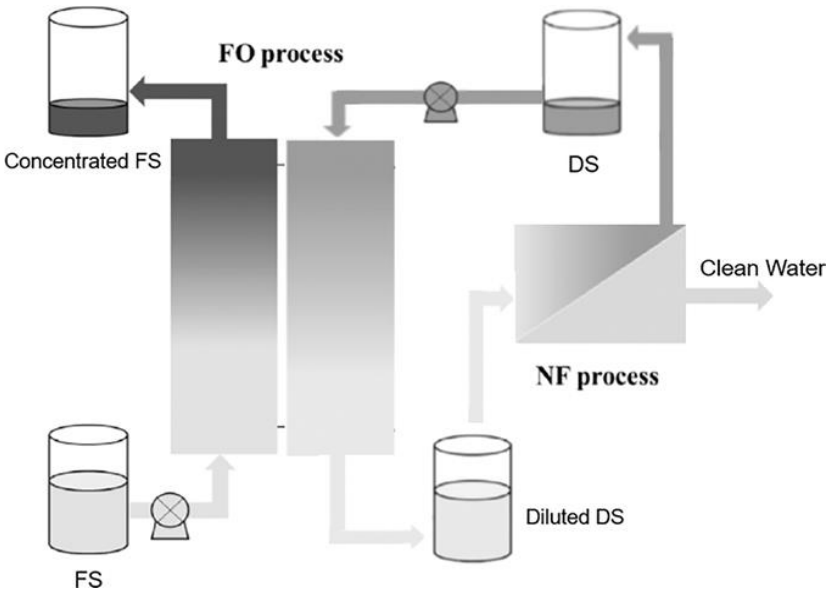

Figure 2 Schematic of a hybridized and continuous NF-FO process [12]

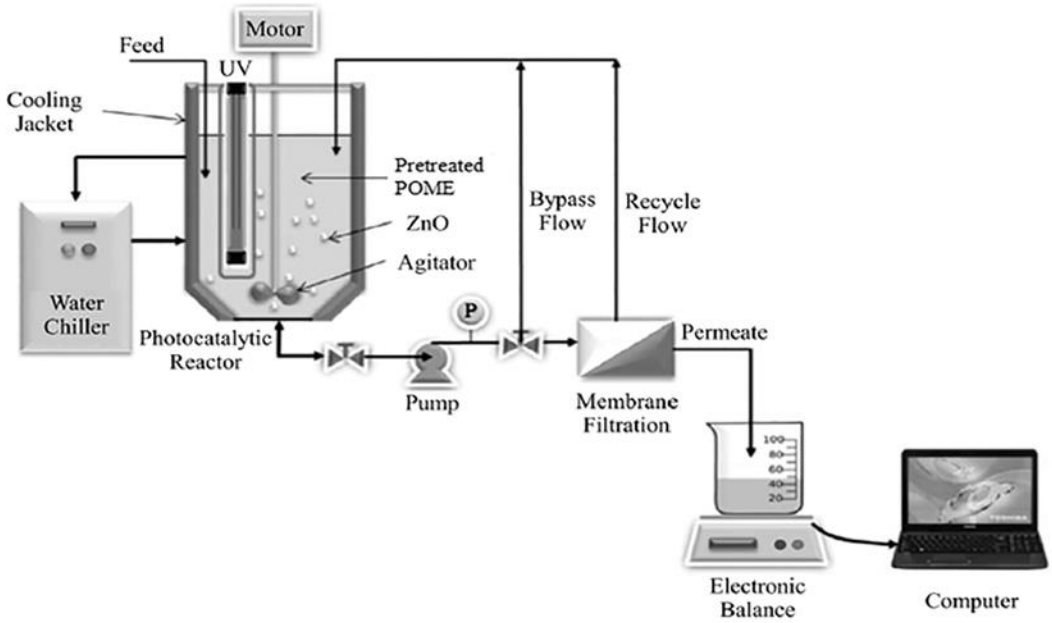

Figure 3 Schematic diagram of split-type MPR with suspended photocatalyst [13]

2.0 FINAL REMARKS

Overall, the book presented thorough review on the fundamentals of NF technology, mechanism of separation, integration of NF and other technologies to promote circular economy, modification of NF membranes, and its application of NF across industries. The book also addresses the challenges associated with NF operation. As emphasized in the book, future research could be devoted towards the development of NF membrane materials, concentrate management, long-term membrane stability, membrane fouling, cost evaluation, and process scaling for a robust and sustainable future. Furthermore, sustainable production of NF membrane from waste biomass should be investigated [9]. To enhance the future publications, the overlapping of topics should be minimized for instance the fundamental knowledge of membrane process and integration NF system was replicated in some sections. Additionally, the book chapter should be more focused on the subject NF over other treatment techniques. This would allow for more in-depth reviews of NF technology and its role in achieving sustainable development.

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