Artificial Intelligence and Environment Mega Data

Optimizing reverse osmosis technology with artificial intelligence for water desalination and reuse

Jungbin Kim[a,b]
[a] Department of Environmental Science, Wenzhou-Kean University, Wenzhou 325060, Zhejiang, China
[b] Department of Environmental and Sustainability Sciences, Kean University, Union 07083, New Jersey, United States

Abstract: Global climate change has intensified droughts, leading to severe water scarcity in various regions. With conventional freshwater supplies proving increasingly inadequate, exploring alternative water resources has become indispensable. Thus, desalination and water reuse have become key strategies for ensuring a reliable and sustainable water supply. In particular, reverse osmosis (RO)-based membrane technology plays a central role in this transition, as it effectively removes bacteria, micropollutants, and dissolved solids, producing high-quality water suitable for urban reuse applications. However, despite its technical advantages, RO faces fundamental barriers to wider implementation, such as high energy consumption and membrane fouling. Energy requirements remain one of the most significant contributors to operating cost and environmental burden, while fouling processes reduce membrane efficiency, shorten lifespan, and complicate system operation. Artificial intelligence (AI) provides new opportunities to address these limitations. AI-based algorithms enable the identification of optimal operating conditions that minimize specific energy consumption while maintaining high recovery and water quality. Also, machine learning enables predictive fouling analysis, allowing early detection of fouling and formulating effective mitigation strategies. Building on such AI-driven insights, identifying fouling mechanisms can further guide system design for improved efficiency. This study highlights the potential of AI integration with RO technology as both a means to lower energy demand and enhance membrane reliability, and as a pivotal pathway toward sustainable urban water management in the face of climate change.

Keywords: Desalination; water reuse; reverse osmosis; artificial intelligence; process optimization.