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TOWARD SUSTAINABLE BRINE MANAGEMENT IN ARID REGIONS: CHARACTERIZATION, SCALING POTENTIAL, AND A TIERED FRAMEWORK FOR JORDAN'S BRACKISH WATER DESALINATION INDUSTRY

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Abstract

Brackish water reverse osmosis (BWRO) desalination is vital for addressing Jordan's severe water scarcity, but its sustainability is constrained by the environmental risks associated with brine disposal. This study employs an integrated approach that combines physicochemical and mineralogical characterization of brines from 11 BWRO plants with field surveys of disposal practices. Quantitative analyses, including X-ray fluorescence (XRF) and X-ray diffraction (XRD), reveal that the brines are complex hypersaline concentrates with elevated scaling potential due to high concentrations of calcium, sulfate, and bicarbonate. These characteristics, together with field-documented practices of direct discharge into valleys, pose clear risks of soil salinization, groundwater contamination, and reduced agricultural productivity. To address these challenges, the study proposes and justifies a tiered management framework grounded in brine quality, plant location, and local environmental conditions. For most inland plants, engineered evaporation ponds successfully demonstrated at the Hashemite University photovoltaic-BWRO facility represent the most practical disposal option under Jordan's arid climate. Increased recovery rates and selective reuse of low-salinity brine can further reduce environmental impacts. We conclude that sustainable brine management in Jordan requires strengthened regulations, investment in containment infrastructure, and proactive stakeholder engagement. Implementing this evidence-based framework is essential to ensure that BWRO desalination contributes to Jordan's water security without compromising its soil and groundwater resources.

Key words: brackish water reverse osmosis (BWRO), brine management, desalination sustainability, public-private partnerships (PPP), soil salinization

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