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Advancing Sustainable Seawater Desalination Technologies: Exploring the Sub-Atmospheric Vapor Pipeline (SAVP) and Energy-Efficient Solution for Urban and Industrial Water Management in Smart, Eco-Friendly, and Green Building Infrastructure

Authors : Mona Shojaei

Abstract : The Sub-Atmospheric Vapor Pipeline (SAVP) introduces a distinct approach to seawater desalination with promising applications in both land and industrial sectors. SAVP systems exploit the temperature difference between a hot source and a cold environment to facilitate efficient vapor transfer, offering substantial benefits in diverse industrial and field applications. This approach incorporates dynamic boundary conditions, where the temperatures of hot and cold sources vary over time, particularly in natural and industrial environments. Such variations critically influence convection and diffusion processes, introducing challenges that require the refinement of the convection-diffusion equation and the derivation of temperature profiles along the pipeline through advanced engineering mathematics. This study formulates vapor temperature as a function of time and length using two mathematical approaches: Eigen functions and Green's equation. Combining detailed theoretical modeling, mathematical simulations, and extensive field and industrial tests, this research underscores the SAVP system's scalability for real-world applications. Results reveal a high degree of accuracy, highlighting SAVP's significant potential for energy conservation and environmental sustainability. Furthermore, the integration of SAVP technology within smart and green building systems creates new opportunities for sustainable urban water management. By capturing and repurposing vapor for non-potable uses such as irrigation, greywater recycling, and ecosystem support in green spaces, SAVP aligns with the principles of smart and green buildings. Smart buildings emphasize efficient resource management, enhanced system control, and automation for optimal energy and water use, while green buildings prioritize environmental impact reduction and resource conservation. SAVP technology bridges both paradigms, enhancing water self-sufficiency and reducing reliance on external water supplies. The sustainable and energy-efficient properties of SAVP make it a vital component in resilient infrastructure development, addressing urban water scarcity while promoting eco-friendly living. This dual alignment with smart and green building goals positions SAVP as a transformative solution in the pursuit of sustainable urban resource management.

Keywords : sub-atmospheric vapor pipeline, seawater desalination, energy efficiency, vapor transfer dynamics, mathematical modeling, sustainable water solutions, smart buildings
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