Slovak Society of Chemical Engineering
Institute of Chemical and Environmental Engineering
Slovak University of Technology in Bratislava

PROCEEDINGS

52nd International Conference of the Slovak Society of Chemical Engineering SSCHE 2026

Hotel SOREA TRIGAN
Štrbské Pleso, Slovakia
May 26 - 29, 2026

Editors: Assoc. prof. Mário Mihaľ

ISBN: 978-80-8208-177-3, EAN: 9788082081773

Published by the Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava in Slovak Chemistry Library for the Institute of Chemical and Environmental Engineering; Radlinského 9, 812 37 Bratislava, 2026

Ahmed, A., Hríbik, D., Variny, M., Červeňanský, I.: Performance Analysis of Single to Triple-Stage EvaporationCrystallization Systems for Efficient Brine Processing, Editors: Mihaľ, M., In *52nd International Conference of the Slovak Society of Chemical Engineering SSCHE 2026*, Štrbské Pleso, Slovakia, 2026.

Performance Analysis of Single to Triple-Stage Evaporation–Crystallization Systems for Efficient Brine Processing

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Abstract

Evaporation and crystallization are the most energy-intensive operations in brine processing, and their optimal design is of great importance to the brine processing industry. In this study, single-stage and triple-stage evaporation systems with crystallization were designed, and their energy and economic efficiency were compared and analyzed. In addition, two operation configurations were studied: without a steam ejector and with a steam ejector. Membrane distillation was considered as an alternative solvent removal technology. The models were built in Aspen Plus simulation software. Specific steam consumption, total energy consumption, capital costs, and operating costs were taken as the evaluation indicators. The results showed that the thermal efficiency of evaporation was improved significantly with the increase of evaporation stages, and the three-stage system had the lowest specific energy consumption. However, the capital investment and complexity of the system increased with the increase in evaporation stages. The integration of steam ejectors further reduced steam consumption by partial vapor recompression. The energy-saving effect was obvious in all configurations. The results showed that the relative advantage of the steam ejectors was more obvious in the three-stage system. The economic evaluation results showed that there was a compromise between capital costs and operating costs. The single-stage system had the lowest investment cost, while the three-stage system had the lowest total cost in the long run, especially with the ejectors. The energy cost, feed concentration, and plant capacity had significant effects on the optimal design of the system in all considered cases. The research results provide practical references for the design and selection of evaporation–crystallization systems, with further research to be dedicated to a generalized framework for evaluation and optimization of the brine processing technologies.

This study was supported by the Slovak Research and Development Agency under contract no. VV-MVP-24-0365.