Shale Water Desalination: Multistage membrane distillation considering different configurations and heat integration

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Unconventional shale gas resources are currently changing the global energy market. Nevertheless, shale gas production consumes huge amounts of water for hydraulic fracturing. Part of the injected fracking fluid returns to the surface as a flowback or produce water, containing high levels of total dissolved solids (TDS). In order to protect the environment and health, flowback water must be treated [1-3]. Thermal membrane distillation is an emerging desalination technology which involves mass and heat transfer across a hydrophobic semipermeable membrane.

This work introduces a simultaneous synthesis of membrane distillation systems with heat exchanger networks (HENs) for desalinating shale gas flowback and produce water. The direct contact and vacuum membrane configurations are the best options for desalination [4,5]. Moreover, multistage membrane distillation systems usually have higher efficiencies than single-stages processes [6]. For this reason, two different mathematical models for synthetizing multistage direct contact membrane distillation (MSDCMD) and multistage vacuum membrane distillation (MSVMD) are developed and optimized to achieve zero liquid discharge (ZLD) conditions. To this aim, brine discharges are considered to be near to the salt saturation conditions. The multi-stage superstructures are implemented in GAMS and optimized by SBB solver. The mathematical model is formulated via generalized disjunctive programming (GDP) and mixed-integer nonlinear programming (MINLP), to minimize the total annualized cost.

Sensibility analysis are performed to evaluate the best design parameters and behaviour of the systems under different feed water salinities. A comparison between MSDCMD and MSVMD with and without thermal integration shows cost reductions of ~40%. Hence, the results highlight the capability of the models to obtain freshwater reducing the energy requirements.

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