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# Integration of membrane distillation into heat paths of industrial processes

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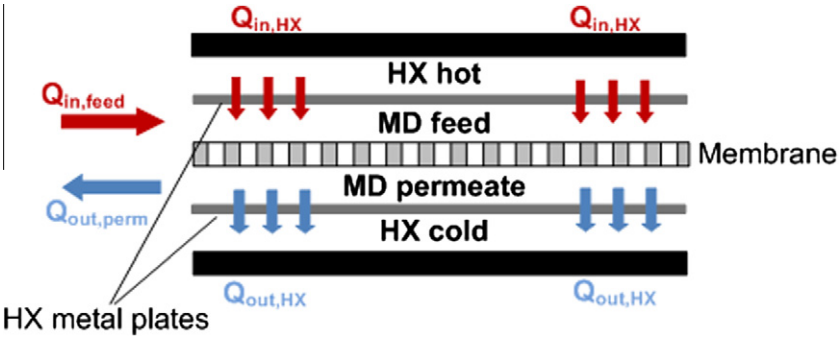
## HIGHLIGHTS

- Merging MD with heat exchangers (MDHX) has new potential for industrial integration.
- Modelling and experimental testing verify performance improvements of MDHX.
- Various parameters were explored including temperature, flow rate and energy use.
- The MDHX module requires <0.01 k Wh/m$^3$ electricity to operate.
- Benefits of MDHX stem from increase single pass recovery from 4% to above 14%.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Membrane distillation (MD) is a process emerging commercially which offers potential as a low cost, low energy desalination process. However single pass recovery in MD is typically limited by thermodynamic constraints to less than 10% thus leading to the need to increase recirculation to achieve practical water recoveries, which costs electricity and produces more greenhouse gas emissions. This work reports on heat and mass transfer modelling and experimental results for a novel MD design, known as the MD heat exchanger (MDHX), which facilitates the addition and removal of heat into the MD hot and cold channels respectively. The modelling and experimental results showed that the MDHX system greatly enhances the single pass recovery at low flow rates. At the proposed experimental conditions, the MDHX process was demonstrated experimentally to increase single pass water recovery from 2% to 14%. This promises to reduce the electrical pumping costs to less than 0.01 kWh for every m$^3$ of water produced. Much higher recoveries are theoretically possible. The novel MDHX concept and module therefore offer new opportunities for heat sourcing or improved system performance for desalination and liquids processing over conventional MD.



## 1. Introduction

Membrane distillation (MD) is an emerging membrane-based purification and concentration process [1–3]. It can be used as an alternate to reverse osmosis (RO), or a unique process for recovering more water from RO brine. One of its main advantages is the capacity to use low-grade heat to drive the process, thus solar energy and waste heat are possible energy sources for this technology [4–6]. Solar thermal is a convenient source of renewable energy, but panels with the required efficiency are costly [7]. On waste heat sources, industries recycle as much heat as possible such that waste heat sources are often diffuse and hard to access and/or low in temperature. Meanwhile, process industries transfer enormous

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