Title: Application of trimethylamine–carbon dioxide in osmotic heat engine for power generation
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Abstract: Salinity gradient energy were for years touted as a new renewable energy source. Naturally occurring salinity gradients, such as where river water meets seawater, were considered untapped sources energy that could be harnessed with technologies like pressure retarded osmosis (PRO). Unfortunately, operational challenges plague industrialization of PRO. The relatively low osmotic pressure of seawater limits power generation potential. More problematic are the organic and inorganic content of the waters which pose a severe fouling threat to the membranes. Pretreatment to remove these contaminants would be cost prohibitive and could result a substantial loss in energy production [1]. The concept of the osmotic heat engine (OHE), first proposed by Loeb in 1975 [2], addresses these two problems of PRO. The OHE is a "closed loop" PRO process with a thermally regenerable draw solute. By choosing a thermolytic solute with a high solubility, osmotic pressures far in excess of seawater are possible. Furthermore, since the process is close loop (no mass inputs or outputs), the solutions are pristine and contain no foulants. OHEs therefore can produce far more power and with fewer losses than conventional PRO.

The development of the OHE was made possible by the recently developed NH_3-CO_2 thermolytic draw solute. This solute, which in water consists of ammonium salts, can be easily regenerated by conventional steam stripping and was the focus of numerous studies on forward osmosis (FO) [3,4]. The regenerable nature of the solute led to the development of the OHE concept [5]. However, one of the major challenges with the NH_3-CO_2 solute is that ammonia, which is present in the draw solute, can readily cross the membrane because of its "water-like" characteristics. This high flux of the ammonia does not mean that it is lost (the system is close loop and all of the solutes end up recycled in the process, but it does impair the water flux and power density due to lost osmotic pressure and internal concentration polarization.

A newly investigated thermolytic draw solute is trimethylamine–carbon dioxide (TMA–CO_2). Like NH_3-CO_2, TMA–CO_2 has a high solubility in water and can generate high osmotic pressure. It also features comparable volatility to ammonia and low enthalpy of vaporization, indicating comparable or less energy would be consumed for draw solute regeneration. The benefit of TMA–CO_2 lies in its larger molecular size. This makes it less likely to pass through the membrane. In this work, we explore the use of TMA–CO_2 in PRO and compare its performance to other model draw solutes (NaCl) and NH_3-CO_2. Tests were conducted with up to 5 M solutions of TMA–CO_2 using a lab-scale PRO test system with a proprietary Porifera membrane. Estimated power densities of up to 18.6 W m^{-2} were achievable at relatively low pressures (10 bar). Higher hydraulic pressures would yield higher power density if a membrane housing could be made to support a membrane without forming defects. For comparison, NaCl and ammonia-carbon dioxide (NH_3–CO_2) have been evaluated for PRO performance using Porifera membrane. The water flux of TMA-CO_2 was about 20 % lower than that of NaCl and comparable with that of NH_3–CO_2. Reverse solute flux of TMA–CO_2 ranged from 0.5 to 3.5 mol m^{-2} h^{-1} in all experiments. This value was much lower than NH_3-CO_2 (4.0 to 51 mol m^{-2} h^{-1}) and approximately half that of NaCl. Low solute flux was attributed to molecular size differences between solutes. In all, TMA-CO_2 represents an OHE draw solute option with low draw solute flux without substantial sacrifice of power density. This solute, as well as its many derivatives, may therefore represent the "sweet spot" for thermolytic OHE systems.

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