Coupled Solar Pond/Direct Contact Membrane Desalination Systems: Innovative Use of Waste Heat for Freshwater Production

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While the equipment and operational costs of desalination have declined significantly in recent years, traditional desalination continues to require large sources of energy, typically from fossil or nuclear. Cogeneration, in which waste heat from other industrial processes is used, can reduce the economic and environmental costs, however most desalination processes require still large temperature differences, i.e., "high quality" heat. As a result, the use of desalination is generally considered to be limited to producing drinking quality water in energy or economically rich regions. Recent advances in direct contact membrane distillation, in which the vapor is passed across hydrophobic membranes, have gained attention as it can use small (<30 ^{o}C) temperature differences between the permeate and feed water, as well as operate at low pressures to produce significant quantities of fresh water. As a result, direct contact membrane distillation can take advantage of "low quality" or waste heat to desalinate sea water, brackish water or wastewater. Figure 1 shows the major components of a direct contact membrane distillation system.

For many arid regions of the world affected by increasing surface water salinity or shortages in potable water, development of large-scale desalination facilities are limited by the sources and cost of available energy. As direct contact membranes can utilize low quality thermal sources, a much broader selection of energy sources can be considered, including solar ponds. Solar ponds capture solar radiation and trap this energy in dense brines at the bottom of the pond, with conduction through an insulating blanket of cold, brackish water limiting heat loss. Figure 2 shows the thermal evolution and double diffusive convection of a solar pond, with strong mixing in the upper and lower layers of the pond, and stable stratification in the middle depths of the pond due to counteracting gradients in salinity and temperature. In this presentation, a coupled direct-contact membrane/solar pond distillation system is modeled and tested using a laboratory, pilot scale system. Distillation rates of ~2 L/m^2/day of solar pond can easily be obtained with minimal operating cost and under low operating pressures. While these rates are modest, the systems can be operated for much lower cost than traditional desalination systems, and can even be applied for environmental remediation. An example using Walker Lake, a terminal lake in the western United States experiencing ecosystem collapse is presented, demonstrating that the systems can become a cost-effective component of the lake's water quality remediation.

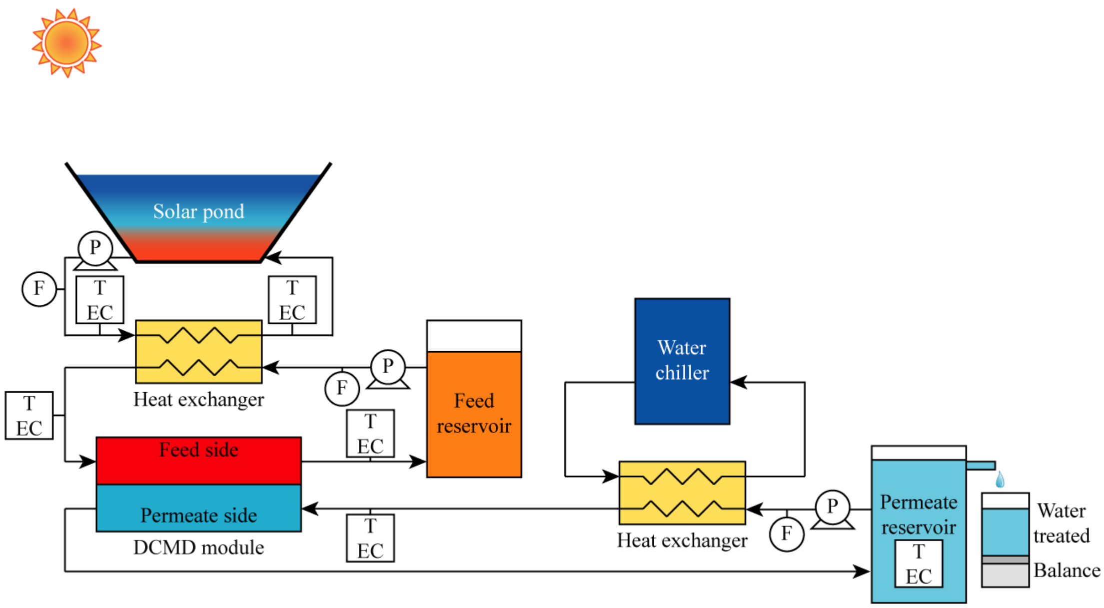

Figure 1. Conceptual design of a coupled Solar Pond/Direct Contact Membrane Distillation plant. The solar pond is used to collect and store thermal energy, which is used to heat the saline water to be treated to ~20^{o}C over the permeate fluid. Water vapor is driven across the membrane via the resulting vapor pressure gradient and condenses on the permeate side. The permeate can be cooled using the thermal mass of the ocean or saline lake.

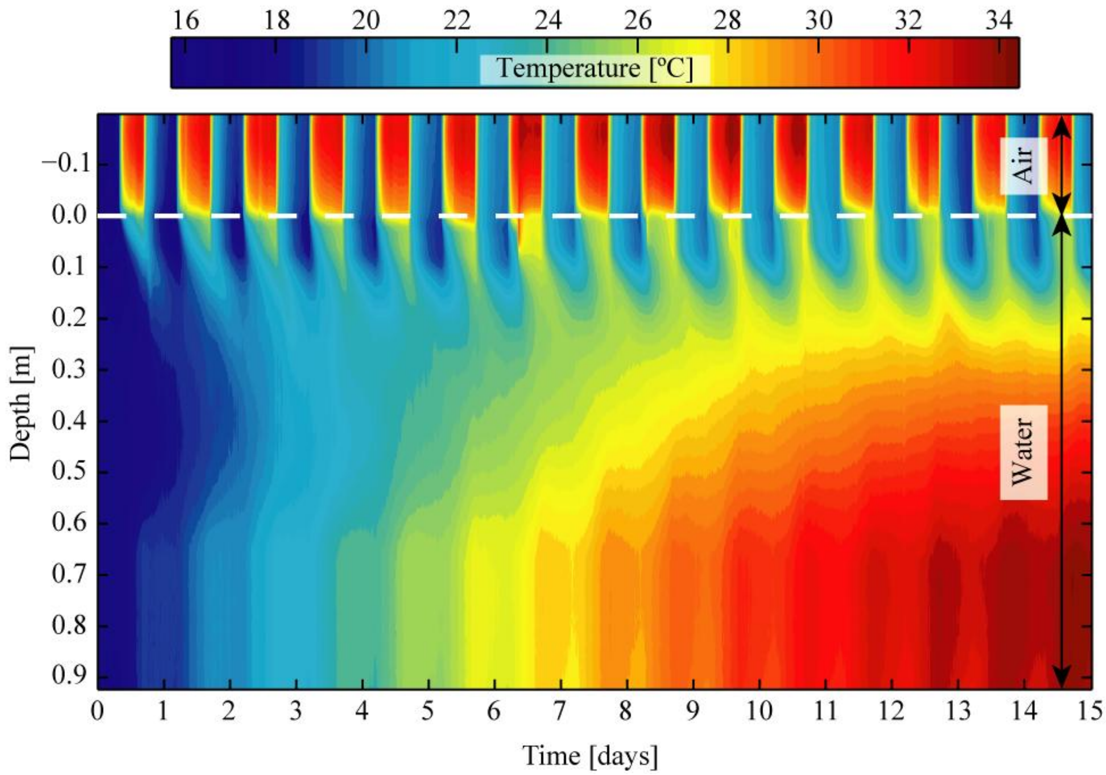

Figure 2. Thermal evolution of the laboratory scale solar pond as measured by high resolution fiber-optic distributed temperature sensing. Over the 14 day experiment, the lower brine layer was warmed ~18 ^{o}C and showed strong internal convection. The upper convecting zone also showed strong stratification and subsequent breakdown at night. However, the non-convecting zone (0.2m to 0.6m) showed only conductive heat transfer and effective isolation of the warm layers below.