Membrane Distillation

Membrane distillation utilizes vacuum chambers and temperature differentials to promote concentration of product through evaporation and condensation. It can achieve two goals: extraction of water for reuse, and product concentration. Typical product concentration systems will utilize high-energy evaporators to heat the product to the boiling point of water. These systems require input of heat from gas, coal, or other sources, and also require extensive cooling systems to deal with the leftover heat. Membrane distillation can concentrate a product stream while reducing the necessity for cooling towers by absorbing waste heat, and recycling water for use within the plant.

Water containing solute is heated to 50-80 C and then sent to a container that has a hydrophobic membrane separating it from a vacuum. This membrane will allow water vapor to pass through, but will block the movement of liquid water. To maximize efficiency, the heat for this process can come from waste heat from other industrial processes. Alternatively, the heat can also be generated from solar or geothermal sources. Cooling water (20-40 C) is necessary to establish the temperature differential that drives the process. Water evaporates and passes through the microporous hydrophobic membrane. At the opposite end of a vacuum chamber, a thin foil lies between the steam and the next chamber of cooler water. The water on the other side of the foil is slightly cooler, which causes the purified steam to condense and drip to a collection pipe at the bottom of the chamber. The condensation energy released at the foil causes the water in the second stage to heat up, resulting in evaporation and repeating the earlier process. This thermodynamic process is very efficient, and the same heat can be used multiple times for maximum efficiency. At the end, the high concentration solution is collected and disposed of (or further processed to recover valuable products such as whey protein) [46].

- Energy efficient through recycling energy multiple times [47]
- Robust because only clean vapor passes through the membrane
- Low investment cost through the use of plastic materials
- Low operating costs due to efficiency, especially if waste heat is utilized
- Need for chemicals and pre-treatment is low
- Creating a vacuum within the chambers can be energy-intensive

References

[46] A. Hausmann et al., “Direct Contact Membrane Distillation of Dairy Process Streams,” Membranes, vol. 1, no. 1, pp. 48–58, Jan. 2011.
[47] R. Ullah et al., “Energy efficiency of direct contact membrane distillation,” Desalination, vol. 433, pp. 56–67, May 2018.