Membrane Distillation: Effect of salinity on membrane wetting

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Abstract

Membrane distillation (MD) is a thermally driven process that can be used to obtain pure water from wastewater streams [1]. MD membranes are thin, polymeric materials that can filter out unwanted materials, including dissolved salts, by only allowing water vapor to pass through the membrane [2]. It is crucial that the membrane has high hydrophobicity, or strong repulsion against liquid water, to prevent the membrane from getting wet. The process starts with heating of the feed water which evaporates and passes through the hydrophobic membrane which separates salts impurities from the feed water to clean the water. After the feed water passes through the membrane it condenses as a result of the cool distillate stream that it contacts. Condensed water that is collected by the distillate stream now clean distillate water. Throughout this whole process, water is moved through the tubes in the system thanks to a pump.

Materials & Methods

For the turbidity experiments, NaCl, $CaCl_2$, and Na_2SO_4 were used. We made measurements for 12 Concentration factors (CF) levels for this experiment and tested out CF levels 12 and 10. CF level 12 contained 3.5 g of NaCl, 9.5 g of $CaCl_2$, and 12.1 g of Na_2SO_4. CF level 10 contained 2.9 g of NaCl, 7.9 g of $CaCl_2$, and 10.1 g of Na_2SO_4. We mixed each respective measurement of salts of both CF levels into one liter of water each. We tested them one at a time to ensure more accurate results. We used liter beakers to hold the solutions and put them on stirring plates with a magnet inside to make the salts dissolve completely. After starting the stirring plate we waited for the water to look cloudy to start our turbidity testing. Once the water turned cloudy, we would take water samples and test them on the turbidity meter to measure their turbidity levels. We continued to do this until we saw the turbidity levels go down, so when they started to drop, we stopped the experiment. We tested CF level 12 three times and CF level 10 once. We then conducted a similar turbidity test with CF level 12, but after mixing we put the solution into a water bath, to see how temperature affects turbidity levels. We conducted this test two times.

Figure 1
The Turbidity Meter that we used for the turbidity testing.

For our MD experiment, we used NaCl, $CaCl_2$ and Na_2SO_4 to make our solutions. We calculated the amount in grams of each salt needed for the solution by dividing their molar mass by 10. We would then add the measurements calculated into a 1,000 ml beaker (a liter of water) and dissolve it. We prepared 4 liters of solution for each experiment. While waiting for the salts to dissolve we would start setting up the MD system by giving it a thorough clean before use. Part of setting up the MD system meant cleaning the module and removing the membrane that was being used and adding a new one. After the MD system was clean, we would set it up by connecting all pipes to their corresponding places, adding our solutions to the feed bucket, adding distillate water to the distillate bucket, and turning on the heater and cooler. When it was all ready, we would start the system and open the feed water valve and start the pump as well. We conducted 3 experiments with this system.

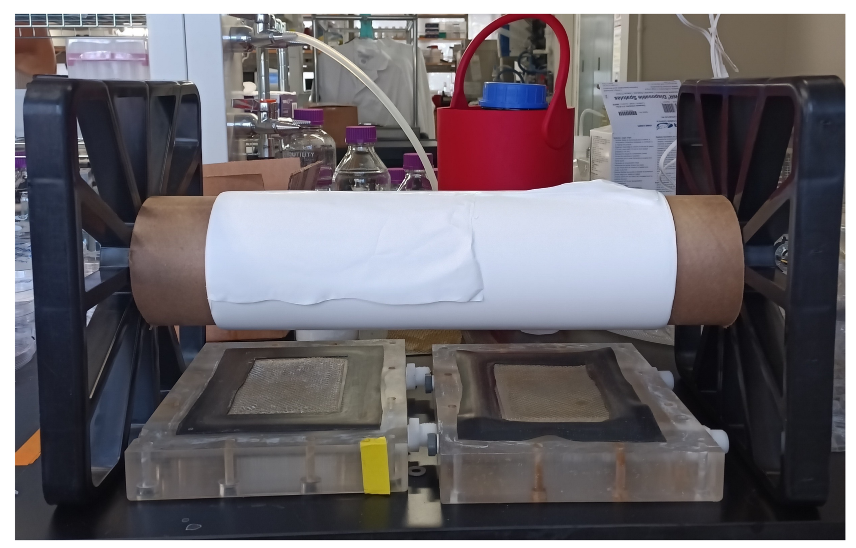

Figure 2
The hydrophobic membrane used for our MD experiment.

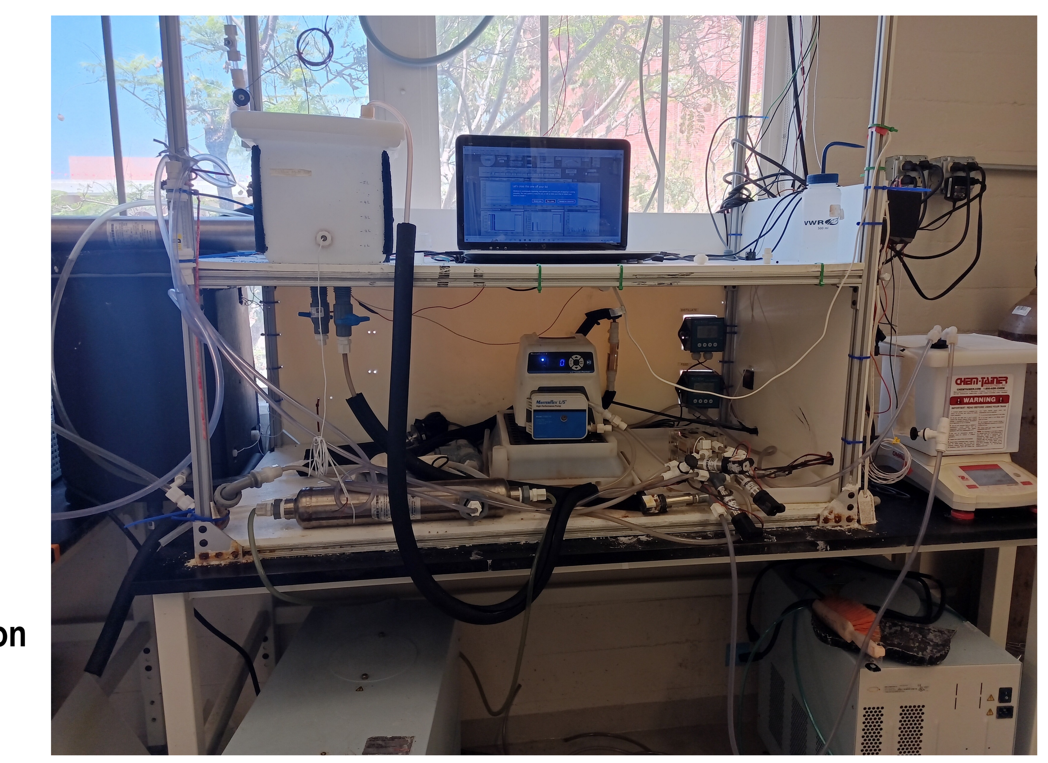

Figure 3
Our membrane distillation system for the MD experiment.

Results & Discussion

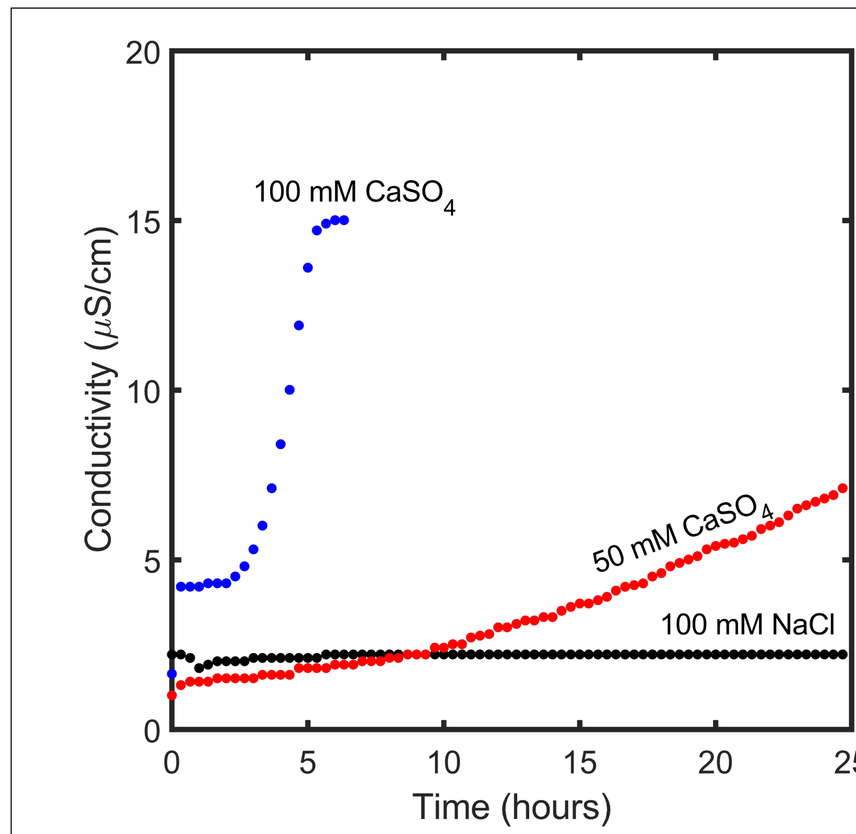

Figure 4
The levels of conductivity of each MD experiment. The levels were measured every hour.

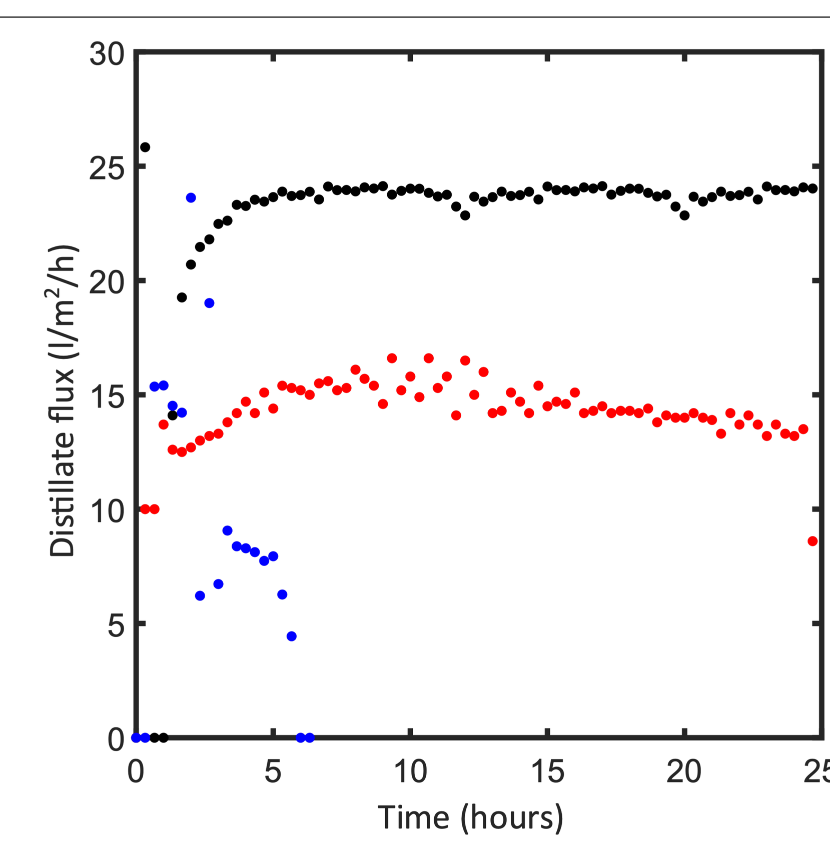

Figure 5
The flux levels that were measured every hour during the MD experiment.

During the SHINE program, we found out that when a membrane wets, it is caused by an increase of ions on the distillate side of the MD system. After testing three different feed solutions, we found that the higher the salinity level, the faster a membrane would wet, resulting in an earlier stop of the experiment. We also found out that when the experiment is ended earlier the distillate flux of water being filtered in the system lowers faster as well. Both of these graphs show the three experiments conducted with the MD system. The first experiment was conducted with 100 mM of NaCl which is represented by black dots on both graphs. The second experiment was conducted with 50 mM of $CaSO_4$ which is represented by the red dots on the graphs. The third and final experiment was conducted with 100 mM of $CaSO_4$ and is represented by the blue dots on the graphs.

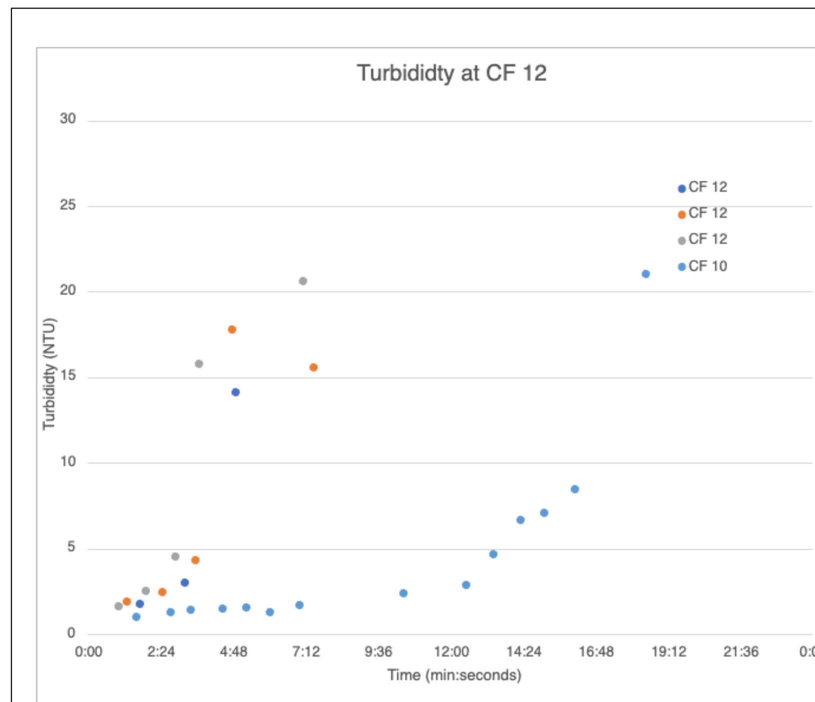

Figure 5
The turbidity levels of our saline solutions over time. Dark blue, orange, and gray dots show the turbidity levels of 3 different CF 12 experiments. Light blue dots show the turbidity levels of the CF 10 experiment.

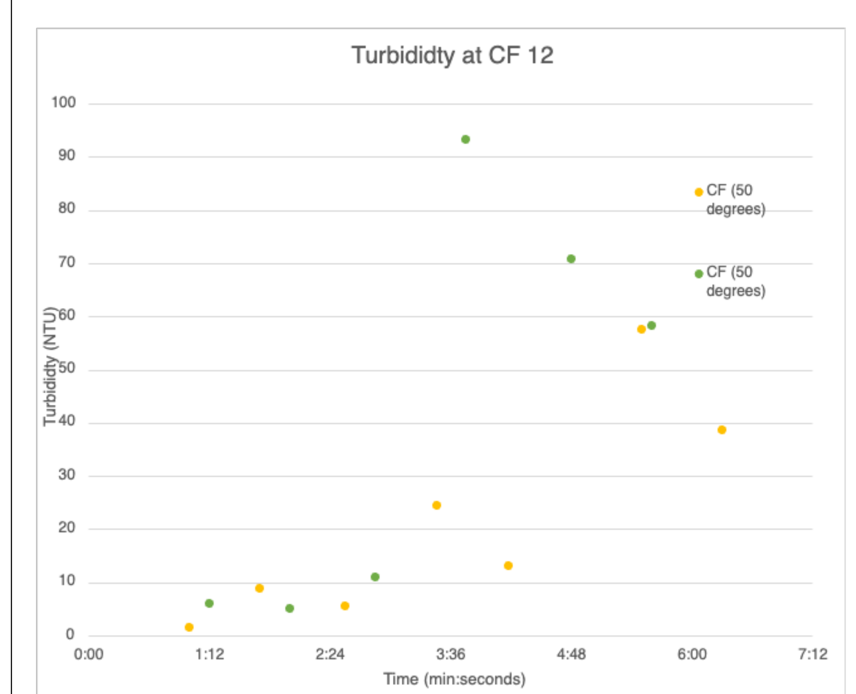

Figure 6
The turbidity levels of 2 CF 12 saline solutions that were tested over time. Both of these solutions were put in a water bath that had water at 50℉.

When measuring turbidity levels, we found out that the higher the concentration of salt, the faster turbidity levels would increase. When testing the turbidity of our saline solutions we noticed that it took less time for the CF 12 solution to become cloudy, which demonstrates a high turbidity level compared to a clear looking solution, than for the CF 10 solution. This comes to show that when a solution has more salt, the turbidity levels take less time to increase. On figure 5 it also shows that it takes less time for turbidity levels to start going down when more salt is used to make solutions. During our temperature related turbidity testing, we found out that with higher temperatures, it take less time for turbidity levels to increase. When we put our mixed saline solutions into the hot water we immediately started our turbidity testing and noticed that the turbidity levels were increasing at a much faster pace than the saline solutions that were not put into the water bath. On figure 6, it shows how in both CF 12 experiments, the experiments were stopped within minutes five and six, which is earlier than the fastest CF 12 experiment of 7 minutes when testing how salinity levels affected turbidity.

Takeaways

- I have learned how to better my understanding of a research paper in a shorter amount of time.
- I deepened my understanding and knowledge of using programs and math with the work I completed in this program.
- I hope to have more opportunities similar to the SHINE program that will allow me to discover more about how the world of research works.
- I have been able to learn a little more about the future career path I wish to take and I now have experience that will help me get there.

Acknowledgments

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