

BACKGROUND

Water scarcity is a critical issue facing populations everywhere. To combat this problem, the use of alternative water treatment methods such as desalination has been increasing. One of the leading forms of desalination water treatment is Reverse Osmosis (RO) membrane technology for its high efficiency. However, many issues reside in the optimization of this technology, such as biofouling, which is depicted as the accumulation of microorganisms on the membrane surface.

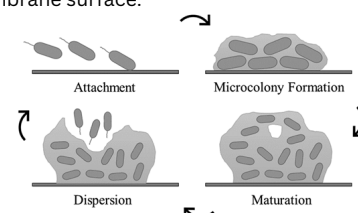


Fig. 1: Biofouling in Reverse Osmosis Water Treatment Systems [1]

Biofouling is currently one of the largest obstacles faced in these systems, and is currently controlled by different chemical and physical cleaning methods. Current methods are ineffective, and only delay biofouling. Therefore preventative methods, such as inhibitory biocide dosing to prevent the presence of biofouling altogether are required, and the development of safe, non-oxidizing, green biocides is essential.

This project has been working in optimizing reverse osmosis technology, specifically by developing a safe, green biocide for use in RO systems [2]. Initially this project looked at 6 possible biocide candidates MIT, DBNPA, SB, PE, SBS, and LAE, (see abbreviations) by analyzing their efficacy against simple, single species *P. aeruginosa* biofilms, and safe for the public and environment [1].

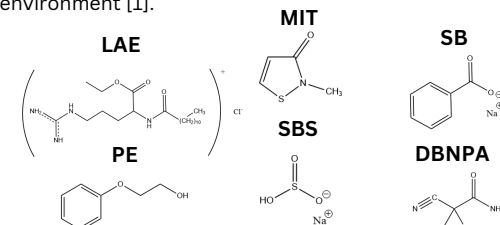


Fig. 2: Potential Biocide Candidates [2]

LAE was the only candidate that was low hazard, and highly efficacious against simple single-species biofilms. Therefore, LAE was the primary focus moving forward into the next step of determining the short-term and long-term compatibility of the biocide with RO polyamide membranes. The polyamide membrane compatibility of LAE with RO polyamide membranes was the primary focus of our research during my assistance.

OBJECTIVES

- To determine the short-term and long-term compatibility of LAE with RO polyamide membranes
- To develop an effective tool for screening the compatibility of biocides to prevent the waste of resources on biocides that are not short-term compatible

MATERIALS AND METHODS

Short-Term Membrane Compatibility

The purpose of short-term testing is to determine if resources should be allocated towards long-term compatibility testing, as long-term testing is more resource intensive. The short-term testing consisted of 8 experimental runs for each biocide candidate. The conditions of each run can be seen in Table 1.

- SBS (a commonly used biocide in membrane storage), and chlorine (an oxidizing biocide known to cause damage to polyamide membranes) used as controls, with deionized water used as an undamaged membrane reference.
- In each run, a RO membrane coupon was soaked in a high concentration of biocide for the listed conditions for each run.
- After soaking, the membranes underwent membrane autopsies via AFM, SEM, and ATR-FTIR (see abbreviations).
- AFM quantitatively observed morphological membrane damage, while SEM qualitatively observed the same. Morphological membrane damage in RO polyamide membranes are typically denoted by either swelling or flattening of the membrane. Damage by swelling is denoted by higher surface roughness, and raised peaks of the typical "ridge and valley" morphology seen on RO polyamide membranes. This is caused by non-oxidizing biocides. Damage by flattening is depicted by the erasure of peaks and valleys altogether. This is caused by oxidizing biocides (such as chlorine).
- ATR-FTIR was employed to examine oxidative degradation of the membrane (denoted by the erasure of the three characteristic peaks shown in Figure 3).

Experimental Run	Biocide Concentration	pH	Duration (h)
1	0.1	7	24
2	50	7	1
3	100	7	1
4	100	4	1
5	100	9	1
6	100	7	8
7	100	7	24
8	150	7	1

Table 1: Short-term Experimental Conditions

Long-Term Membrane Compatibility

Long-term membrane compatibility testing followed the same procedure, with only 3 experimental conditions, and without using chlorine as a control. The 3 experimental conditions each used the same concentration (12x the MBIC, 63 mg/L, found in previous work against *P. aeruginosa* biofilms), and a soak time of 1 month, but each had a different pH (6, 7, 8), to cover the pH range present in RO water treatment membrane vessels.

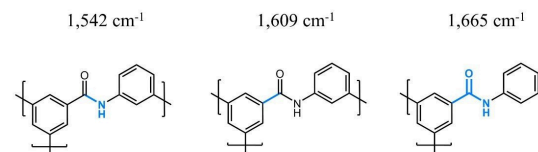
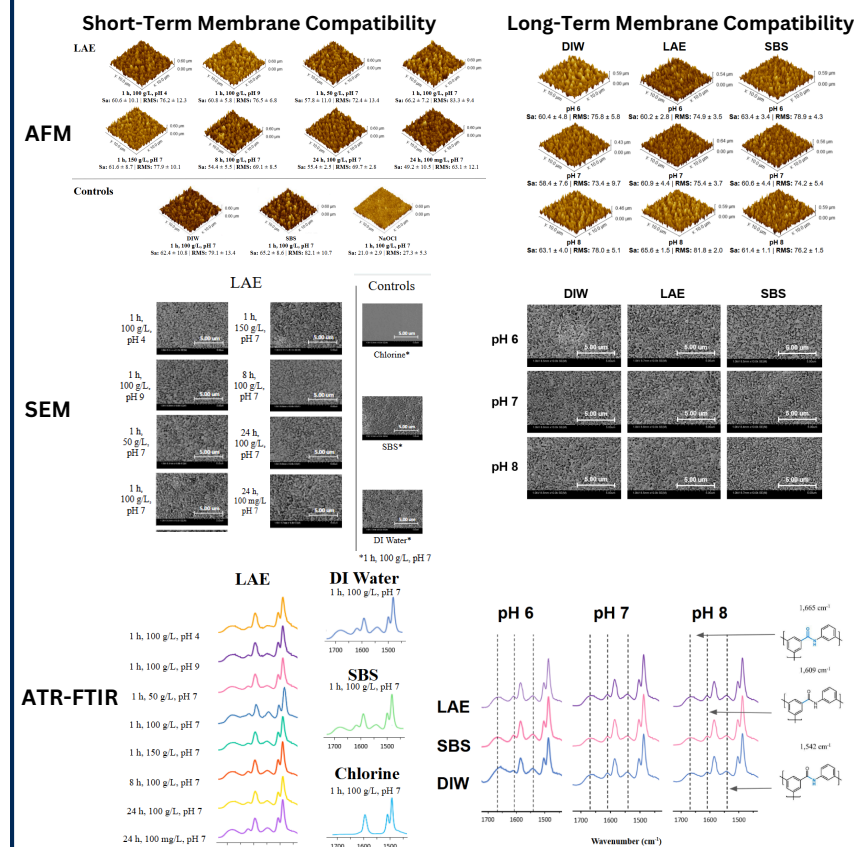


Figure 3: Characteristic Peaks

RESULTS



Summary of Results

The AFM results depict the surface roughness of the membrane samples, with the Sa depicting the average deviation between the low and high points on the membrane, and RMS values representing the standard deviations of the peaks and valleys.

The membrane compatibility was successful in determining LAE as undamaging to RO polyamide membranes, as the range of the values seen in the LAE results fall within the error margins of the undamaged membrane references.

The SEM results show that LAE does not visibly damage the membrane, and that the morphology seen in the AFM results fairly represents the results of the entire membrane (as the area covered by AFM is quite small comparatively).

The ATR-FTIR results display that LAE does not cause oxidative damage to the characteristic peaks of RO polyamide membranes, which is consistent with the non-oxidizing nature of the biocide.

ABBREVIATIONS

- MIT:** 2-methyl-4-isothiazolin-3-one
DBNPA: 2,2-dibromo-3-nitropropionamide
SB: Sodium Benzoate
PE: Phenoxyethanol
SBS: Sodium Bisulfite
LAE: Ethyl Lauroyl Arginate
RO: Reverse Osmosis
AFM: Atomic Force Microscopy
SEM: Scanning Electron Microscopy
ATR-FTIR: Attenuated Total Reflectance - Fourier Transform Infrared Spectroscopy
MBIC: Minimum Biocide Inhibitory Concentration

CONCLUSIONS

- LAE was found to be both short-term and long-term compatible with RO polyamide membranes.
- This research has developed a rapid degradation membrane compatibility procedure that streamlines current membrane compatibility procedures.

FUTURE PROSPECTS

- To further determine the compatibility of LAE with RO systems, the biocide should be applied in a lab-scale RO system.
- Further efficacy testing is required for LAE, specifically against complex, multi-species biofilms.

REFERENCES AND ACKNOWLEDGEMENTS



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- [1] Da-Silva-Correa, L. H., Aasen, K., Gamm, N. E., Godoy, R., Rahmati, N., & Buckley, H. L. (2023). Efficacy testing of non-oxidizing biocides for polyamide membrane biofouling prevention using a modified CDC biofilm reactor. *Journal of Water Supply: Research and Technology-Aqua*, 72(3), 313–328. <https://doi.org/10.2166/aqua.2023.217>
- [2] Da-Silva-Correa, L. H., Smith, H., Thibodeau, M. C., Welsh, B., & Buckley, H. L. (2022). The application of non-oxidizing biocides to prevent biofouling in reverse osmosis polyamide membrane systems: A review. *Journal of Water Supply: Research and Technology-Aqua*, 71(2), 261–292. <https://doi.org/10.2166/aqua.2022.118>
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