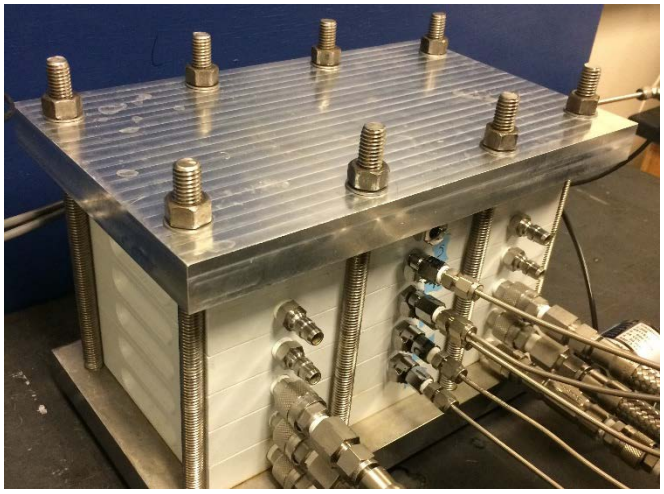
Executive Summary

THE Water Research FOUNDATION

Understanding removal of organics for potable reuse applications using reverse osmosis

Predicting Reverse Osmosis Removal of Unique Organics (Reuse-14-19/4769)

The Laboratory Experimental System.



Custom Made Reverse Osmosis Membrane Test Cell.

The Central Issue

Interest in potable reuse of municipal wastewater has increased as adequate freshwater resources have become limited for some communities. Due to improvements in measurement capabilities, as well as the increase in toxicological assessments of pharmaceuticals, personal care products, industrial chemicals, and compounds of emerging concern, the removal of individual trace organics from municipal wastewater has become an important concern.

Context and Background

Reverse osmosis (RO) is effective at removing many trace organics, but is known to be less effective for neutral, low-molecular-weight organics. It is important to understand the factors that influence the removal of compounds when new trace organics of concern are identified. RO removal efficiency can be affected by many factors, including the functional chemistry of the compound of emerging concern, membrane properties, process operating conditions, and feedwater characteristics.

The objective of this research was to provide additional insight into the removal of individual organics for potable reuse applications using reverse osmosis, with the ultimate goal of developing a model that can predict the rejection of any neutral trace organics through any reverse osmosis membrane products. In this research, laboratory experiments were combined with molecular modeling to provide new insight into the rejection of organics through RO membrane

Findings and Conclusions

The results of this study and full-scale data from the Orange County Water District suggest that disinfection by-products and industrial chemicals may be of greater concern for poor rejection through reverse osmosis membranes than pharmaceuticals and other more complex molecules. This is particularly true for disinfection byproducts and industrial chemicals that contain halogen substituents and carbon-carbon double bonds. Unfortunately, many of these same compounds also have poorer removal by advanced oxidation with UV/H_2O_2 and adsorption with granular activated carbon. An examination of functional chemistry and formation mechanisms suggests that the precursors to these compounds will have higher rejection than the byproducts. This result suggests that a possible strategy to reduce disinfection byproducts in the product water from a potable reuse system would be to perform disinfection after an reverse osmosis system instead of before, if possible. Specific findings included the following:

- Hydroxyl, ether, and methyl groups increase rejection, whereas carbonyl and halogen groups decrease rejection. Carbon-carbon double bonds decrease rejection.

• Benzene rings have lower rejection than corresponding straight-chain carbon compounds.

• Compounds with multiple functional groups close together have higher rejection than similar compounds with the functional groups farther apart.

• *Ab initio* and density functional theory quantum mechanical calculations provide insight about the importance of solute-membrane interactions on organics rejection.

Management and Policy Implications

This research provides insight into the removal of individual organics for potable reuse applications using reverse osmosis and includes an Excel-based process model tool to predict the rejection of organic compounds for user-specified conditions. The results of this technical report and the modeling tool will be of interest to utilities, consultants, engineers, and scientists that are working to determine the most effective treatment strategies for potable reuse systems.

Related WRF Research

Project Title	Research Focus
Testing and Refinement of the Trace Organics Screening Tool (CEC6R12/6R12a)	Provides a useful and usable screening framework to assess the potential risk to aquatic life from discharges that may contain TOrCs. The knowledge gained using a weight-of-evidence approach sheds light on the roles of TOrCs and other stressors and will allow managers to determine needs for future monitoring and/or treatment technology investments.
Identification of the 'Active' Fraction and Metabolic Pathways in Trace Organic Compounds Removal Using Stable Isotope Probing (U2R12)	Examines the fate of TOrCs that can guide research and implementation efforts through identification of microbial communities involved in TOrC assimilation and elucidation of metabolic pathways contributing to TOrC biodegradation. Results can help guide the design and development of specific biomarkers to evaluate the potential for primary BPA assimilation and secondary assimilation, for example, through cross feeding in engineered and natural environmental systems.
Assessment of Techniques for Evaluating and Demonstrating Safety of Water from Direct Potable Reuse Treatment Facilities (4508)	Provides a DPR guidance framework that water utilities and regulators can use to evaluate the safety of existing or potential future DPR scenarios and help facilitate a proactive DPR monitoring process that is protective of public health. Includes practical guidance for selecting and implementing monitoring and control tools for DPR.

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