Executive Summary

WERF

What innovative technologies are available for membrane concentrate management?

Demonstration of Membrane Zero Liquid Discharge for Drinking Water Systems: A Literature Review (WERF5T10a)

The Central Issue

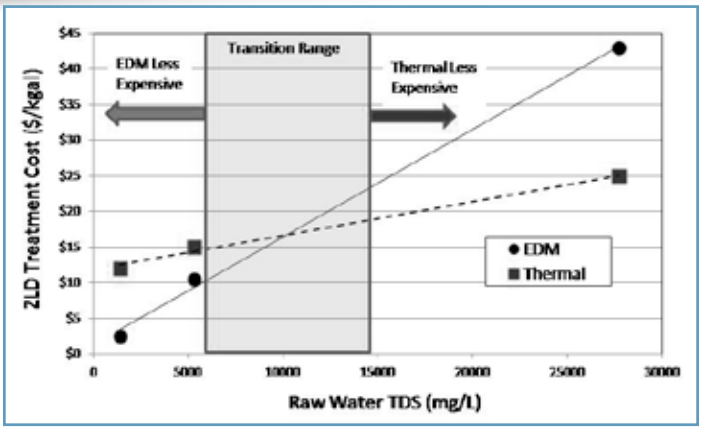
At present, water utilities have been reluctant to undertake high-pressure (reverse osmosis or nanofiltration) membrane projects due to the uncertainty surrounding the availability of feasible disposal options for the concentrate produced by high-pressure membrane systems. Zero liquid discharge (ZLD) is a sustainable disposal option that may represent a long-term solution to concentrate disposal for utilities that need to implement membrane treatment to produce reusable water. It may also help alleviate the pressure wastewater treatment plants are under to accept membrane concentrate streams.

Utilities looking for concentrate solutions need to know: What innovative ZLD technologies are available? How proven are the technologies? What technologies need further demonstration and evaluation? This literature review synthesizes the state of the knowledge of ZLD technologies and presents the information in a readily understandable format. A candidate ZLD technology is being field tested at two sites as the next step for this project.

Context and Background

Increasing demands for potable water have forced drinking water utilities to consider using water from lower quality sources. These lower quality sources may include brackish groundwater or surface water sources impacted by industrial or municipal discharges. Lower quality sources require the use of advanced treatment technologies such as reverse osmosis (RO) or nanofiltration (NF) membranes to treat the water to a level suitable for human consumption.

These membrane systems produce a brine concentrate which provides challenging disposal options, particularly for inland areas. Existing concentrate disposal options that can potentially be implemented include surface and sewer discharge, deep-well injection, evaporation ponds, and land application. However, environmental concerns, high costs, or hydrogeologic conditions often limit the applicability of these options for the disposal of concentrate from large-capacity membrane plants. ZLD technologies are gaining interest as a potential disposal option. ZLD systems separate concentrate into water and solids. The water can be reused and the solids disposed of as a waste or reused in a way that no liquid waste leaves the boundary of the facility. These technologies have not been implemented in municipal applications to date.



Comparison of EDM treatment costs with thermal processes (adapted from Bond et al, 2011).

Findings and Conclusions

To assist in the selection of appropriate ZLD technologies for pilot testing at two sites in Colorado in a later phase of this research effort, a comprehensive literature review of existing ZLD technologies was performed. The literature review examines and compares the design, performance, and costs of various ZLD technologies.

The categories of ZLD options considered by this literature review include:

- Intermediate Treatment
- Thermal-Based Technologies
- Pressure-Driven Membrane Technologies
- Electric Potential-Driven Membrane-Based Technologies
- Alternative Technologies

Intermediate treatment is used to remove sparingly soluble salts from treated water to increase recovery. As the name implies, these technologies are used in between the primary RO step and the final brine minimization technology. The intermediate step can be accomplished with multiple technologies including lime softeners, pellet softeners (also known as fluidized bed crystallizers), nanofiltration, and activated alumina.

Thermal-based technologies use heat to separate water from the concentrate stream, in order to reduce overall volume of the concentrate stream. Some technologies, such as brine concentrators and crystallizers also provide additional recovery. With other technologies (wind aided intensified evaporation, solar ponds, spray dryers, evaporative reduction, and solidification), the water is not

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captured and therefore does not increase the system recovery. The maturity of these technologies varies widely. Brine concentrators and crystallizers have been successfully implemented in industrial settings and their performance and costs are well understood. Other technologies, like solar ponds are developmental in nature. Capital costs, energy, and footprint requirements must be considered while selecting a thermal-based technology. Reducing RO brine volume will be critical for reducing the costs of thermal-based technologies.

Pressure-driven membrane-based technologies use several strategies to increase recovery. The first approach is to reduce the scaling potential of the concentrate, allowing the use of secondary membranes to operate at high recoveries. Alternatively, raw water quality is substantially modified to reduce scaling potential of the source. A final approach is to use nonspiral wound membrane configurations that are less susceptible to scaling, often in conjunction with spiral wound membranes. Several technologies use a combination of these strategies. Many of these technologies are proprietary and have been demonstrated at small scale.

Electric potential-driven technologies (electrodialysis) use cathodes and anodes to draw ions across ion-exchange membranes, removing ions from the feed stream. This differs from RO membranes which remove water from the feed stream, causing both ionic and non-ionic species to concentrate on the concentrate side of the membrane. With electric potential driven technologies, non-ionic species such as silica are not concentrated and their scaling potential is reduced. These technologies appear to be most suitable when treating low to moderate TDS waters.

Alternative technologies are those which are currently under development and show potential for future use. These include forward osmosis, electrocoagulation, membrane distillation, dewvaporation, and eutectic freeze crystallization. While these technologies have the potential to be more cost effective or environmentally friendly than current technologies, they are not mature enough to warrant testing by this project.

Management and Policy Implications

As water scarcity becomes more prevalent, the need for brine minimization and ZLD technologies grows. New technologies are being introduced and emerging and existing technologies are gaining in acceptance and use. This literature review synthesizes the state of the knowledge of ZLD technologies and presents the information in a readily understandable format. As the field of brine minimization and ZLD evolves, continued tracking and testing of technologies will be needed. The next steps for this project include pilot testing of a selected technology – EDM (Electrodialysis Metathesis) – at two sites: La Junta and Brighton, Colorado. The findings will help provide solutions and inform decision making related to managing membrane brine concentrate in inland areas and the utilization of lower quality water sources to augment water supply in water-stressed regions.

Related WERF Research

Project Title	Research Focus
Survey of High Recovery and Zero Liquid Discharge Technologies for Water Utilities (03CTS17aCO)	Provides a systematic characterization of high recovery performance and costs over a range of size, salinity, and composition. This is an essential reference for utilities considering high recovery processing for desalination projects.
Beneficial and Non-Traditional Uses of Concentrate (03CTS17bCO)	Provides a comprehensive review and evaluation of the full range of potential beneficial and nontraditional uses of concentrate and assesses the feasibility of implementation, economic considerations, and environmental safety.
Impacts of Membrane Process Residuals on Wastewater Treatment (03CTS17cCO)	This report and accompanying CD provide utilities with two types of models for predicting the impacts of membrane concentrate loadings on the collection system and the wastewater treatment plant. Interactive Excel models allow users to predict point source impacts of the discharge of concentrates from a variety of sources such as reverse osmosis and the mass balance model examines the impacts of system-wide concentrate discharges. This is a useful guidance manual for any utility that handles membrane process residuals.
Regional Solutions for Concentrate Management (03CTS17dCO)	Provides an overview of concentrate disposal and management practices and includes a decision methodology that can be used to assess not only what concentrate disposal options are technically feasible, but also what options are viable. The decision methodology is provided in the form of interactive software included on a CD that allows users to enter site-specific data and assess options.
Demonstration of Membrane Zero Liquid Discharge (WERF5T10)	This research conducts pilot tests demonstrating the ZLD technology EDM (Electrodialysis Metathesis) to help address the technical and financial uncertainties which hinder ZLD implementation. Pilot testing occurs at two existing RO plants, La Junta and Brighton, Colorado in 2012 and 2013, respectively.

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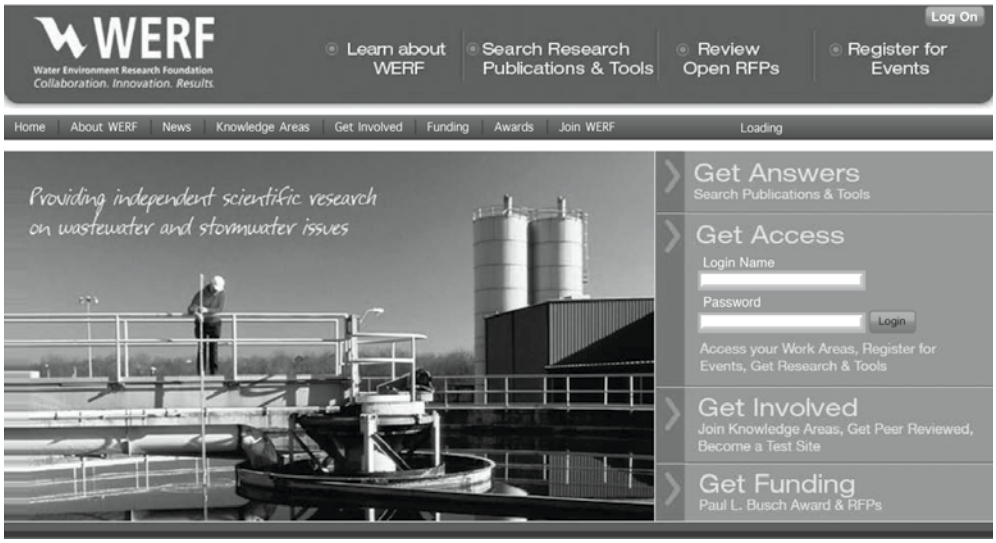

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City of Aurora, CO
City of Brighton, CO
City of La Junta, CO
City of Thornton, CO
Colorado Water Conservation Board (including Metro, South Platte, and Arkansas Basin Roundtables)
East Cherry Creek Valley Water and Sanitation District
Metro Wastewater Reclamation District
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South Adams County Water and Sanitation District

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