POWER PLANT RO BRINE WASTEWATER RECYCLE

Michael Chan, P.E., Duraflow, Tewksbury, MA

Abstract

Reverse Osmosis (RO) is the most common filtration technology employed in power plants for production of high purity water. Due to the large volume and complex chemical characteristic of the RO brine wastewater produced, in the recent years, the power industry faces major regulatory, environmental and economic challenges in the management of this by-product. The ever-increasing demand for clean water coupled with the limited RO brine disposal options led to the improvement of membrane technology for recycle and reuse of this wastewater stream.

This presentation shall explore the dilemma and challenges that need to be recognized and overcome by the power industry in managing brine wastewater generated from the desalination process. The discussion will outline the role of tubular membrane microfiltration and the associated pre-treatment chemistry as a viable approach to address the RO brine management concerns. A case study with detailed design and operation data is presented for a combined-cycle power station on the west coast where a membrane based ZLD system for RO brine recycling has been in operation for 5 years.

INTRODUCTION

Steam from water is the primary driving force for every power station. Electric power plants using different fuels including coal, gas, oil or nuclear create steam that turns a turbine to produce electricity. The electricity generation process requires and consumes large volumes of high-purity water for boiler make-up and for cooling. Sources of water supply can vary from the local water treatment plants to effluent from a local POTW to ground water to a nearby river or lake or a combination of above. Each water source has unique characteristics, including organic matters, dissolved minerals, microorganism growth and chemical contaminants. Each of these inherent characteristics can cause difficulties in a power plant. Therefore, the water has to be treated to minimize potential problems, since these problems could often result in either reduction of plant efficiency or large capital costs. Those challenges are further compounded by the more and more complicated contaminants found in raw water from various sources.

CHALLENGE

Reverse Osmosis (RO) is widely adopted by power producers for purifying boiler feed water, makeup water and in zero-liquid discharge (ZLD) applications. RO produces a clean stream of high-purity water, and a smaller stream of concentrated waste, referred to as reject or brine. The process concept is illustrated in Figure 1. Brine is a highly concentrated solution of the salts and contaminants separated from the water with the reverse osmosis membranes. Injection of high quality water into a gas turbine can improve operating efficiency and increase energy output. However, the desalination applications have always been limited by the disposal costs of RO brine and the adverse impact of brine on the receiving environment. In most power plant locations, where water resources are scarce, no surplus water is available and the local regulatory authorities will not allow power plants to place additional demands on the already scarce water supply, water losses must be minimized during production processing while maximizing water recycling. These requirements are driven by the increasing awareness of water scarcity and on the subsequent regulations for water conservation and discharge.

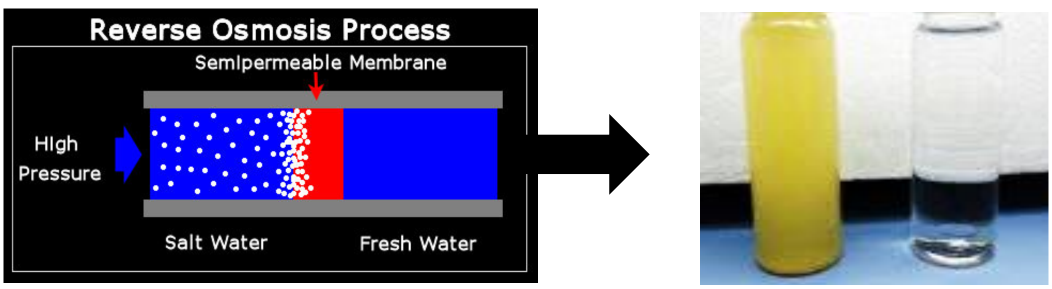

Figure 1 – RO process producing brine (brown solution) and permeate (clear solution)

SOLUTION

The RO brine contains a wide variety of inorganic and organic dissolved solids with TDS concentration up to several thousand mg/L. For some plant locations, RO brine can either be disposed of without any additional treatment or minimized prior to disposal. The following are basic brine disposal methods each with different environmental and capital cost: (1) Surface water discharge, (2) sewer discharge, (3) deep well injection, (4) evaporation pond, (5) land application. Most of these methods are limited by disposal volume, stringent permit requirement, and rigorous site evaluation and monitoring.

For those plant locations where water supply is limited and disposal is not a viable option, recycle of RO brine will have to be implemented. The main driving factors will consist of:

- Availability & quality of water supply
- Effluent discharge quality standards
- Discharge volume restrictions
- Reliability of water resource
- Price of water
- Operating cost for process water treatment
- Operating cost for wastewater treatment
- Net saving for brine minimization

A membrane based RO brine wastewater recycling process is schematically illustrated in Figure 2. The process starts with chemical softening followed by tubular membrane microfiltration filtration for hardness and RO foulant removal and RO desalination.

Based on the types and quantities of fouling substances identified in the brine solution, a chemical treatment process is developed to counteract each of the fouling factors. The chemical treatment may take the form of precipitation, adsorption, pH adjustment and microbial control. The chemistries are evaluated for their compatibility and combined effect. The treatment process is carried out in a two- or three- stage chemical reaction. The chemical treatment will typically include one or more of the following processes:

- Chemical Softening - Hardness precipitation for scaling control
- Magnesium Salt – Silica colloid adsorption for fouling prevention
- Activated Carbon - Organic reduction & oxidant destruction
- pH Adjustment – pH optimization for the integrated chemistries

After chemical reaction, the pre-treated brine solution from the process water RO system is processed through the microfiltration membrane filters designed for separation of the incompatible precipitates from water. The waste solution is pumped at a high velocity through the membrane modules connected in series with a low inlet pressure of 50 – 60 psig. The turbulent flow, parallel to the membrane surface, produces a high-shear scrubbing action which minimizes deposition of solids on the membrane surface. During operation, clear filtrate permeates through the membrane, while the suspended solids retained in the re-circulation loop are periodically purged for further de-watering. The filtrate is directed to a brine recycle RO system designed for processing of high TDS solution.

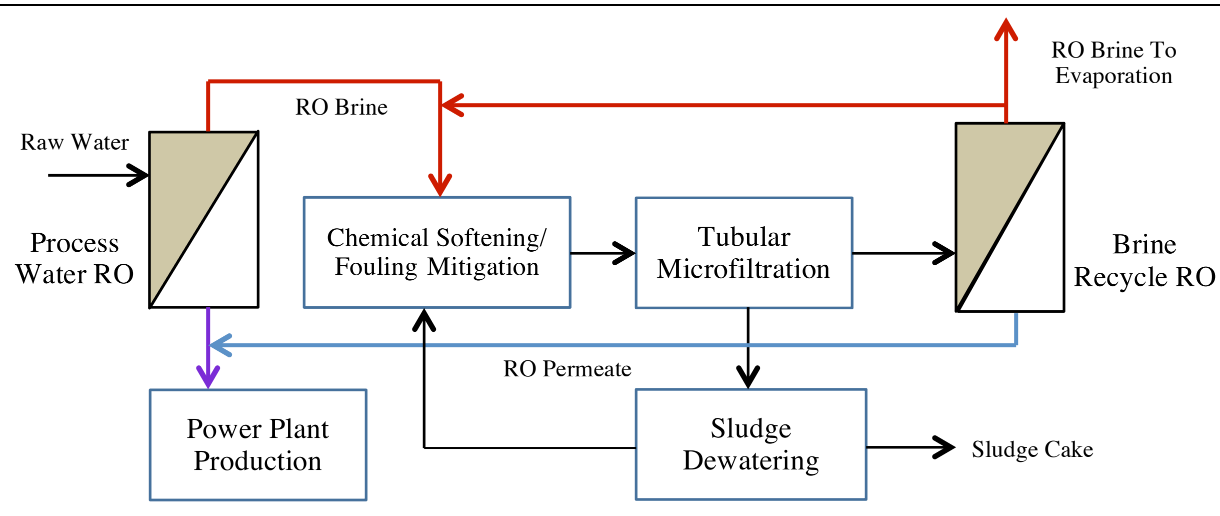

Figure 2 – RO Brine Wastewater Recycle Process Flow Diagram

CASE STUDY SUMMARY

Plant Type/Location: Combined cycle power station in west coast, U.S.A.

Plant Water Sources: Ground water

Wastewater Sources: RO brine (>80%), boiler blow-down, oil/water separator effluent, and plant wash-down

Project Objective: 100% recycle of wastewater generated from the power plant to minimize ground water withdrawal

Year Installed: 2011

Average Flow: 220 to 250 gallons/min (GPM)

Treatment Concept: Zero-liquid-discharge (ZLD) design. Treatment process:
Chemical softening/fouling mitigation → Tubular membrane filtration →
RO chemical pre-treatment → RO filtration →
(1) RO permeate recycled to production, and (2) RO brine to evaporation pond

Major Contaminants: Hardness (Calcium and Magnesium), silica, organic matters (COD), dissolved solids (DS) and suspended solids (SS)

Membrane: <u>Tubular Microfiltration (MF)</u>
The MF membranes are manufactured in a tubular configuration designed to handle high solid concentration as shown in Figure 3. The membranes, made of PVDF, are cast on the surface of porous polymeric tubes to produce a nominal pore size of 0.1 micron. Bleach and/or hydrochloric acid are typically used for membrane cleaning. An automatic back-pulse mechanism is an integral part of the operation design to provide physical surface cleaning by periodically reversing the filtrate flow direction. The system is configured into four separate skids with 50% stand-by capacity as shown in Figure 4.

Figure 3 – Tubular MF Module

Figure 4 – Tubular MF Skid (1 of 4 shown)

The tubular MF has been operated with an average flux of >330 GFD. The membrane frequency is about 1 to 2 times a week for 50% of the total membrane area.

<u>Reverse Osmosis (RO)</u>

The RO system utilizes a two-pass design with spiral wound thin film composite membranes (Figure 5). The recovery rate varies from 77% to 82% depending on the TDS concentration in the feed from the tubular MF system and temperature. The RO flux ranges from 13 to 22 GFD. The RO membranes are chemically cleaned once every 12 to 15 months. The skid-mounted brine recycling RO system is depicted in Figure 6.

Figure 5 – RO Module

Figure 6 – Brine Recycling RO Membrane System

Brine Evaporation: The brine from the recycle system is discharged into one of the two lined evaporation ponds (Figure 7). A crystallizer is considered to be installed to provide additional brine handling capacity due to the seasonal changes of the evaporation rate.

Figure 7 – Onsite Evaporation Pond (1 of 2 shown)

System Performance: 12-month (January 1 – December 31, 2015) system performance for removal of various contaminants is presented in Table 1 below.

Table 1 – Twelve-Month Water Quality Analysis

Contaminants	Influent (CTB) (Ave mg/L as ion)	DF Filtrate (Ave mg/L as ion)	RO Permeate (Ave mg/L as ion)
Ca	232	8	<1.0
Mg	82	15	<0.5
SiO_2	47	7	<1.0
COD	301	117	<6.0
Alk (as CaCO3)	305	20	<3.0
TDS	2,020	1,720	<15
pH	8.5 S.U.	10.5 S.U.	6.8 S.U.
SDI	>Max. SDI Test Value	<3.0	----
NTU	Very High	0.2	<0.5

CONCLUSION

After 5 years of operation, the RO brine wastewater recycling plant has demonstrated that a ZLD system with RO desalination coupled with a high-flux tubular membrane filtration process as pre-treatment is a technically viable and economically affordable solution to address today's water scarcity and regulatory requirements in the power industry.

REFERENCE

1. Cheryan, Munir, 1998, Ultrafiltration and Microfiltration Handbook, 2nd edition, CRC Press, Boca Raton, Florida, pp. 237 – 254.
2. Duraflow, 2005 – 2016, Internal Technical Files.
3. EPA, April 1996, Technology Transfer Handbook – Management of Water Treatment Plant Residuals.
4. Hydranautics, January 2001, Pre-treatment, Technical Service Bulletin.

The author of this article, Michael Chan, is Technical Director of Duraflow LLC. Chan can be contacted at mchan@duraflow.biz or 978.851.0447.