Cost Optimisation by using Ultra High-Pressure Reverse Osmosis Membranes in ZLD plant

Manikandan Vasudevan*, Richard Franks, Dr.Yasuhiro Tomi***, Ravindra Yeleswarapu******

*India Branch, Hydranautics Inc., Mumbai, 400059, India, manikandan.vasudevan@nitto.com
** Hydranautics Inc., Oceanside, CA- 92058, USA, rich.franks@nitto.com
***Membrane Division, Nitto Denko Corporation, Shiga, 5250042, Japan, yasuhiro.tomi@nitto.com
****India Branch, Hydranautics Inc., Mumbai, 400059, India, ravindra.yeleswarapu@nitto.com

Abstract: For more than 30 years, using membranes to reclaim municipal waste waters has been a well-established and widely accepted practice. But using membranes for the reclamation of industrial waste waters is more challenging. Because of their composition and variability, industrial waste waters are some of the most challenging waters to treat for reuse. But in regions experiencing extreme water stress, industries that had previously performed minimal treatment for discharging their wastewaters are now being forced to use membranes to reclaim and reuse 100% of their wastewaters. Most of the industries are being forced to choose between achieving zero liquid discharge (ZLD) or shutting down their operations. However, achieving ZLD requires costly in thermal processes. To reduce the cost of these thermal technologies, ultra-high-pressure RO membranes, the PRO-XP1 used, to further concentrate the waste streams beyond that of standard RO. This reduces the flow of waste going to the thermal process and therefore reduces the cost of the thermal process

Keywords: Zero-liquid discharge; Energy saving; Optimise the capital and operating cost

Introduction

Today water is free for neither people in society or industry due to water scarcity because of climate change, urbanization, and industrialisation. The Government has enacted stringent laws and regulations that mandate in-house effluent treatment plant (ETP) or jointly setup a Common Effluent Treatment Plant (CETP) by industries for treat their effluent to achieve Zero liquid discharge (P.R.Kavitha and G.P.Ganapathy) .

The wastewater entering to an ETP/ a CETP will undergo numerous pre-treatment steps before going to the multistage RO (Kuppusamy Ranganathan, Shreedevi D. Kabadgi). After the multistage RO and other membrane-based processes recover 65% to 90% of the wastewater, the remaining 35% to 10% will be treated through an evaporator and crystallizer to convert to solids and disposed in secured land filling(Metcalf & Eddy). Evaporator operating cost is more than 6 to 8 times higher than RO membrane operational cost (Tiezheng Tong and Menachem Elimelech).

The challenges associated with using membranes to treat these highly contaminated effluents to achieve ZLD include heavy fouling, frequent cleaning, and solids disposal. But one of the most significant challenges is the high operating and maintenance cost associated with the final evaporative steps. Unfortunately, the current technology for treating the last portion of the RO brine before the evaporator is limited, costly, and requires high maintenance. A more efficient ultra-high-pressure RO option, based on standard RO technology, was developed to bridge the gap between existing standard RO and the final, thermal steps.

Standard SWRO elements are limited to a maximum feed pressure of 83 bar (1200 psi) at 25 C. It is this pressure-temperature limitation that limits standard RO elements from concentrating the TDS to about 60,000 mg/l. To operate at high pressure-temperature limits and therefore concentrate to higher TDS levels, the ultra-high-pressure membrane, PRO-XP1, that can operate up to 124bar (1800psi) at 25•C (Table.1). This allows the RO system using the PRO-XP1 to concentrate the TDS up to 130,000 mg/l or higher.

Material and Methods

To demonstrate the feasibility of this new ultra-high-pressure RO technology (Table 1) for further concentrating the brine from the existing RO before going to the evaporators in the Tannery CETP, a pilot study was done using six ultra-high-pressure RO membranes (PRO-XP1-4"elements) installed in two pressure vessels in series (Figure 1). Positive displacement high pressure pump was used for the pilot study and pump was controlled by VFD through PLC. The pressure vessel skid was enclosed with MS plate for safety purpose. UHPRO plant was operated through PLC and data was stored in the PLC and Plant can be monitored remotely and data can be accessed remotely(Figure 1).

Existing RO reject is currently treated to multiple effect evaporator to achieve the ZLD. Partial quantity of RO reject water diverted to pilot plant and used as feed for the pilot plant . The pilot plant has a recirculation arrangement to operate at different the recovery by adjusting the recirculation flow. The Reject valve was automatic control valve which was controlled based on the flow setting. The pilot container has two tanks for collect the feed and permeate water with level switches.

The pilot plant was operated around nine months in Tannery CETP to evaluate the UHPRO (PRO-XP1) performance. The pilot trial was run for 8 months at a range recovery between 34% and 40% and a range of fluxes between 7 lmh to 13.4 lmh. PRO-XP1membrane design pressure is 124bar at 30 DegC . During the trial, maximum operated pressure was 119bar (Figure 2) at 25DegC of feed wastewater's temperature. Total dissolved solids in the feed to the pilot was 53,700~70,000mg/l and the COD level was 3,100mg/l (Table 2). To maintain stable performance, the system was flushed daily with RO permeate water and received a clean in place every 2 to 4 weeks. Permeate TDS was consistently achieved 300~450 mg/l (Figure 3).

Due to the high-power consumption and maintenance (figure 4), evaporator operational cost is very high, and UHPRO power consumption is 6 to 9 kwh/m3. Total saving would be 43,200,000/year which is less than six months of return of investment for membrane if this scale up plant is installed in the tannery CETP (figure 5).

Generally, all RO/NF membrane limitations are pressure, temperature and recovery based on the feed water quality. UHPRO was operated based on the feed temperature vs pressure guideline chart (Figure 6).

Results and Discussion

During the pilot study, PRO-XP1 performance was consistent and achieved the permeate TDS was less than 450 ppm which was reused to tannery industry. UHPRO feed pressure was not increased due to higher COD and other contaminants and it was recovered after flushing and chemical cleaning.

Maximum operated at 40% recovery and increased the feed concentration from 55000 ppm to 92000ppm. Availability of the UHPRO system is higher than multiple effect evaporator because evaporator required 2 to 3 days shutdown for cleaning the heat exchangers. Energy consumption was 9 kwh during the pilot study, and it can be reduced further by incorporating the energy recovery device.

The existing RO operational team can be operated the UHPRO plant and not required any skilled operational team because its similar process and footprint also smaller than multiple effect evaporator. The capital cost will be reduced if incorporate the UHPRO system in the ZLD system because of evaporator capacity will be reduced from 30 to 40% based on the feed water quality and operating cost will be reduced due to less volume to be treated at smaller size of evaporator.

Ultra-high-pressure RO (PRO-XP1) reduces the band width of energy between Sea water construction RO and Multiple effect evaporator in the ZLD process(Figure 4). UHPRO can be used wherever required high concentration applications like salt concentrations, increase the recovery of existing desalination plant , etc

Conclusions

The pilot demonstrated that the UHPRO can be used to further concentrate the salts and reduce the flow to the evaporator by as much as 40% while producing a high quality permeate over an extended period of operation. Overall ZLD cost would be reduced significantly by incorporating the UHPRO

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Figures and Tables

Table 1 Membrane details

Parameter	UHPRO(PRO-XP1)
Nominal Salt Rejection*)	99.80%
Nominal Permeate flow*)	30.3 m^3/d
Materials	Composite Polyamide
Membrane surface	Negative
Active area	3.391 m^2
Configuration and size	8-inch Spiral wound
Maximum pressure	12.4 MPa
Manufacturer	Nitto Denko/Hydranautics
*Test conditions	32,000 mg/L NaCl solution; 5.5 MPa;25 Degree C; 10% recovery

Table 2 Feed water quality which is received from existing RO reject.

Feed Parameters	Values	Feed Parameters	Values
pH	7.6	Mg	3000 ppm
Temp	36 DegC	Chloride	33500 ppm
TDS	58800ppm	COD	2640 ppm
Colour	3022 ptCo	Ca	780 ppm
Hardness	3780 ppm	T. Alkalinity	2400 ppm
BOD	213 ppm		

Figure 1. Pilot UHPRO system - 4” dia X 3 element long two vessels in series

Figure 2 UHPRO feed pressure and operated at different recovery

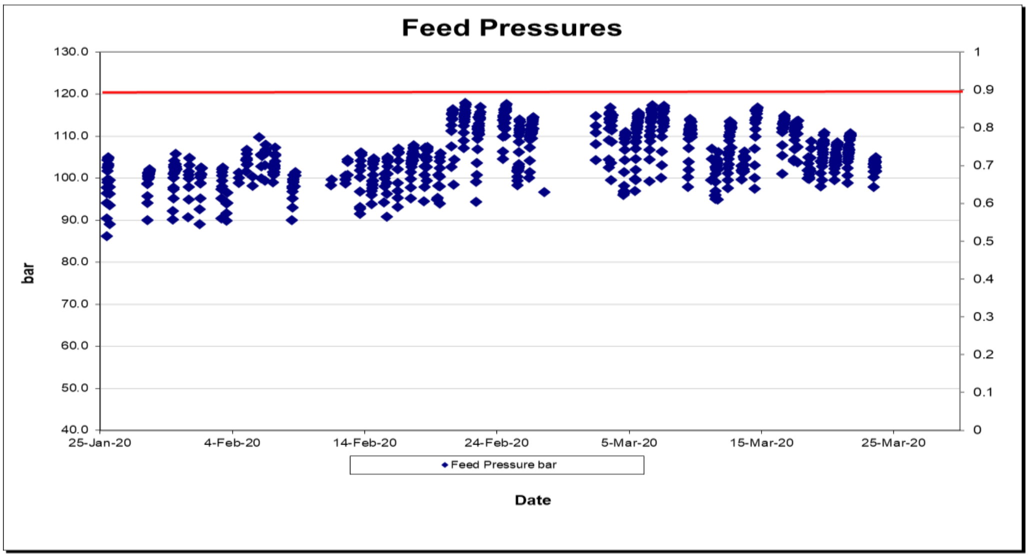

Figure 3 UHPRO feed and permeate concentration

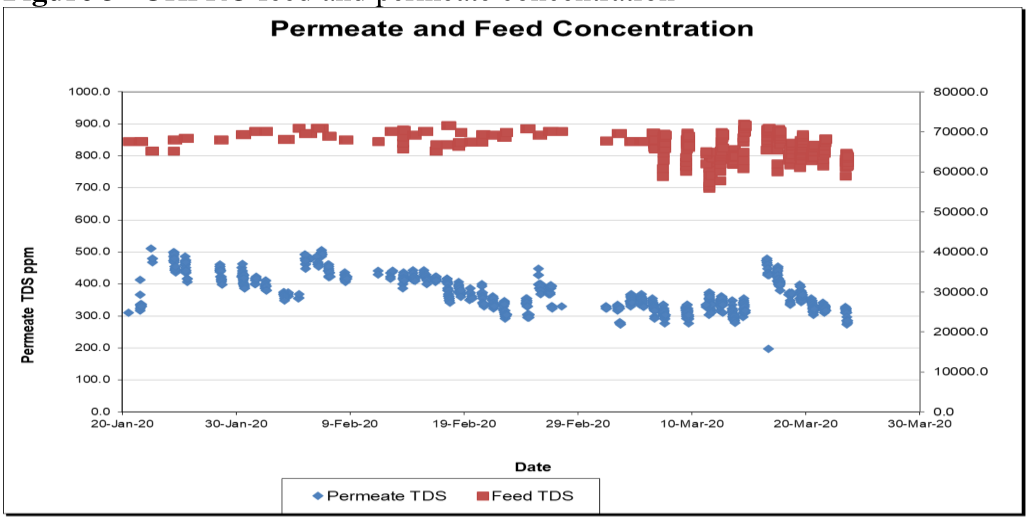

Figure 4 Energy consumption per m3 of treatment

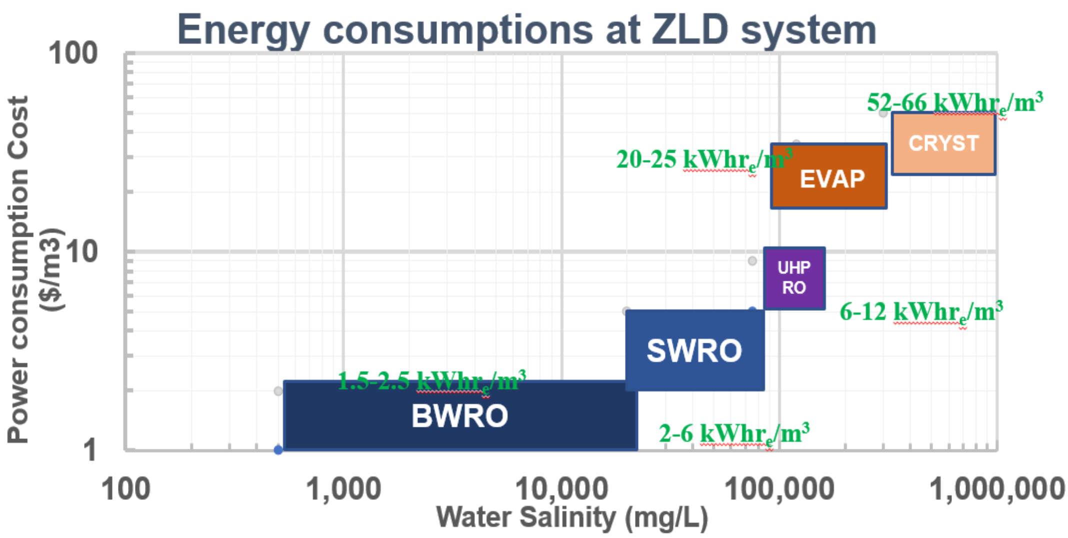

Figure 5 Operating cost of UHPRO vs Multiple effect evaporator

Description	Evaporator	UHPRO
Operating cost INR/kl	700.00	100.00
Total Operating cost before installation of UHPRO per Year INR (40kl/h X 300 days X 20 hrs)	168,000,000.00	
Operating cost after 40% water recovered from UHPRO	100,800,000.00	24,000,000.00
Total Saving per Year INR (40kl/h)	**43,200,000.00**	

Figure 6 Maximum operating pressure for PRO-XP1 based on the temperature