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Improve the ZLD plant performance and optimise the cost by innovative membrane technologies

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Abstract:
Industrial wastes are often characterized as having high organic content that can come from solvents, oils, fats, greases, salts, and other materials used or derived in industrial processing. These wastes can also have a variety of dissolved salts and metals, which make treatment difficult due to issues with scaling, fouling and high osmotic pressure. 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 ZLD process, require incorporating the advanced technologies. The current challenges are frequent membrane replacement, Solid waste disposal, higher energy consumption in thermal process for achieve the ZLD. The new membrane technologies address this issue in the ZLD process to improve the performance and optimise the cost and generate the wealth from waste.

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

Introduction:

Typical treatment processes utilize particle filtration technology, softening, RO, evaporation, and crystallization to achieve ZLD. However, this can be a very complex treatment process and the evaporation and crystallization processes are very expensive (Tiezheng Tong and Menachem Elimelech). Also, the resulting solid waste will have a mixture of salts and may not be easily disposed in a landfill.

The RO Systems concentrate salts and dissolved organic contaminants which cause fouling and scaling on the RO membrane due to the interaction between the membrane surface and the foulants, which affects the membrane performance and shortens the membrane life. These interactions are strongly related to the surface hydrophilicity, charge, and roughness of the membrane. Therefore, the membrane surface modification has been used to improve the antifouling characteristics of RO membranes to mitigate their fouling. PRO-XR1 and PRO-LF1 membrane model having the antifouling characteristics. PRO-XR1 is used for brackish range TDS application and PRO-LF1 is used for sea water range TDS applications. These both membranes have a higher hydrophilicity, a neutral charge, a smother surface which enhance the antifouling characteristics.

In the ZLD process, the high operating and maintenance cost associated with the final evaporative steps(Kuppusamy Ranganathan, Shreedevi D. Kabadgi). 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 (PRO-XP1) option, based on standard RO technology, was developed to bridge the gap between existing standard RO and the final, thermal steps.

The recovered solids from evaporator is disposed in secured land filling because of high colour, mixed salts, and other contaminants (Metcalf & Eddy) . The sludge disposal is very expensive. It can be recovered the salts by using Nano membranes

(PRO-XS1) and minimise the load to the evaporator if reuse the brine solution or separated salts can be used for other industries as raw material (Mona A. Abdel-Fatah).

Concise details of methods and results:

The new innovative membranes are installed and reviewed the performance in Textile and Tannery industries effluent. The Low fouling characteristics membranes and ultra-high-pressure membranes are installed in the Tannery and textile common effluent treatment plant (CETP) performance data has been reviewed.

Tannery based ZLD plants having standard RO membranes in 2~3 stage RO plants and feed TDS from 15000 to 23000 ppm and COD is in the range of 4000 to 5000 ppm and its treated thru primary clarification, Anoxic, Aerobic treatment, hardness removal, dual media filter then followed by Ultra filtration. After treatment COD range is from 500 to 1000 ppm before feed to the RO, So the fouling tendency is more and weekly once required chemical cleaning and average replacement rate is two years once, so the operating cost also increased. To review the performance of the fouling potential in RO membranes, customer has replaced the existing RO membranes to PRO-LF1 in one train and another train SWC5-LD membrane in first stage RO and both train was operated parallel with same quality of effluent feed to the both train at same period. 1st Stage RO plant is having six elements long 2 vessels with 13 m3/h ad feed flow rate

This plant operated continuously for three months to study the SWC5-LD and PRO-LF1 trains. Both trains are operated simultaneously to monitor the membrane performance and fouling rate shall be measured based on the cleaning frequency , so initially cleaned both RO trains to see the performance and found that after cleaning PRO-LF1 flow (Figure.1.1) is better than SWC5-LD which means cleaning effectiveness is better even though Same chemicals concentrations and duration used for both cleanings and then cleaning was carried out based on the flow drop and noticed that SWC5-LD flow drop is faster than PRO-LF1. Salt passage is almost same (Figure.1.2) So conducted chemical cleaning weekly once but PRO-LF1 RO train permeate flow was not reduced than decided flow due to the low fouling nature of the membrane surface.

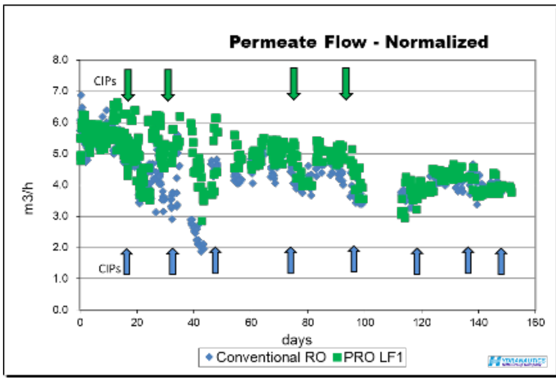

Figure.1.1

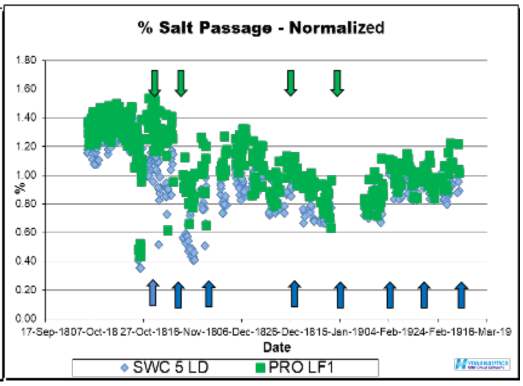

Figure.1.2

During the simultaneous operation of both trains, found that PROLF1 RO train chemical cleaning frequency is less from 50% to 75% than existing conventional SWC5-LD RO membrane, so plant availability 8% increased to treat more effluent as well as cleaning chemical cost also reduced(Table.2) . Thus, membrane life will increase more than conventional RO due to less chemical exposure and less solid abrasion on the surface of the membranes due to affinity of the membrane surface.

Existing RO reject would then be dewatered by evaporation and crystallization. However, these are very expensive processes and thus, there has been a growing application of ultra-high-pressure RO (UHP RO) which can operate above the 83 bar (1200 psi) limit of conventional SWRO membranes. These membranes may operate up to pressures as high as 120 bar (1750 psi)

Ultra-high-pressure RO membranes (PRO-XP1) installed in one of the Textile common effluent treatment and after 5th stage reject is treated through the UHPRO. Its installed in 3 pressure vessels and each 6 elements long. Designed to operate maximum 100bar and operated 80bar pressure (Figire.1.3) at the wastewater's temperature of 43 C based on the feed temperature and feed TDS. The TDS in the feed to was 1,00,000~1,10,000 mg/l and the COD level was 2,850 mg/l. noticed the stable performance and the system was flushed daily and received a clean in place every 5 to 8 weeks once. TDS was consistently reduced to 300~450mg/l (Figure.1.4).

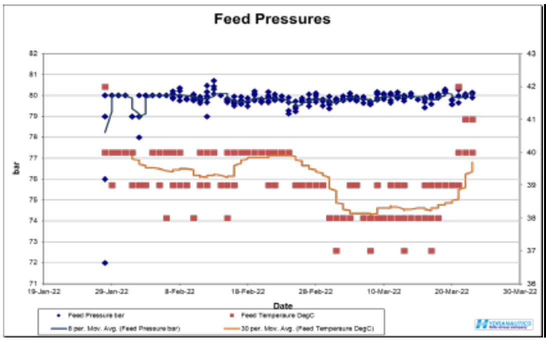

Figure.1.3

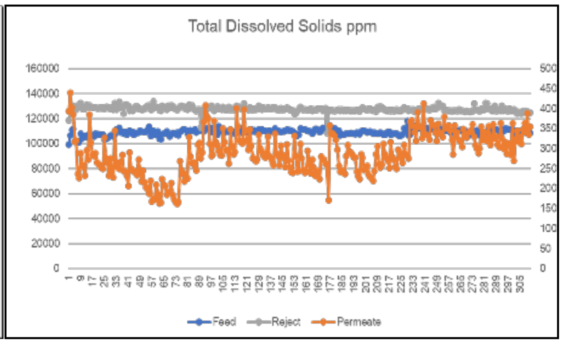

Figure.1.4

Due to the high-power consumption and maintenance, evaporator operational cost is very high, and UHPRO power consumption is 8 kwh/m3. The return of the investment is within four months. Thus, increase the overall recovery because of UHPRO, significant cost saving in the ZLD plant (Table 3).

Recovered the salt from evaporator is disposed in secured land filling and its very expensive. Textile Industries are used sodium sulphate or sodium chloride for dying process, so any one of this salt is in high concentration in the effluent.

One of the Textile industry installed NF membrane (PRO-XS1) to recover the sodium sulphate, so they installed in 5th stage and having five elements long 3 vessels with 20m3/h feed capacity of plunger pump system and operated maximum 25 bar.

This plant operated continuously at 50% recovery because of single stage system and achieved 95,000mg/l of TDS in the NF reject which is more that 95% of sulphate salt contribution. The Dying process is required 140,000mg/l solution for better colour absorption, so partially treated in MEE to increase the concentration as per the dying process requirement and reduced the treatment cost around 20% of earlier treatment cost.

PRO-XS1 at Recovery 75%			
[ppm]	Feed	Perm.	Conc.
TDS	65.4k	22.2k	157 g/l
TH	140	8	560
Cl	8933	9926	4963
SO4	31860	2400	96 g/l
COD	2620	400	9600

Figure.1.5

Arranged the reject recirculation line to demonstrate to operate at 75% recovery. 65,000 mg/l of TDS of RO reject water concentrated to 1,57,000 mg/l of TDS at 75% recovery (Figure.2) and recommended to install second stage of NF system for continuous operation to save 85% of exiting treatment cost by reduce the evaporator operational hours(Table 4), reuse the salt solution and avoid the raw material cost of buying Globar salt.

Conclusions

The New innovative membrane technology demonstrated that the overall ZLD cost is reduced because of increase the membrane life by using low fouling membrane(PRO-LF1), increase the recovery by using ultra high pressure reverse osmosis (PRO-XP1) and reuse the salt by high selective salt separation nano membrane (PRO-XS1). The overall ZLD cost is expected to reduce from 40% to 65% by incorporating this new advance membrane technology.

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Figures and Tables

Table 1. Membranes data sheet and its performance at standard test condition

Parameter	low fouling HPRO (PRO-LF1)	UHPRO(PRO-XP1)	High selective NF (PRO-XS1)
Nominal Salt Rejection*)	99.80%	99.80%	99.80%
Nominal Permeate flow*)	29.1 m^3/d	30.3 m^3/d	32.2 m^3/d
Materials	Composite polyamide	Composite Polyamide	Composite Polyamide
Membrane surface	Neutral	Negative	Negative
Active area	37.2 m^2	3.391 m^2	37.2 m^2
Configuration and size	8-inch Spiral wound	8-inch Spiral wound	8-inch Spiral wound
Maximum pressure	8.3 MPa	12.4 MPa	8.3 MPa
Manufacturer	Nitto Denko/Hydranautics	Nitto Denko/Hydranautics	Nitto Denko/Hydranautics
***Test conditions**	32,000 mg/L NaCl solution; 5.5 MPa;25 Degree C; 10% recovery		10,000 ppm NaCl + 10,000 ppm MgSO4 at 15 L/m2/hr, 25C,15% recovery

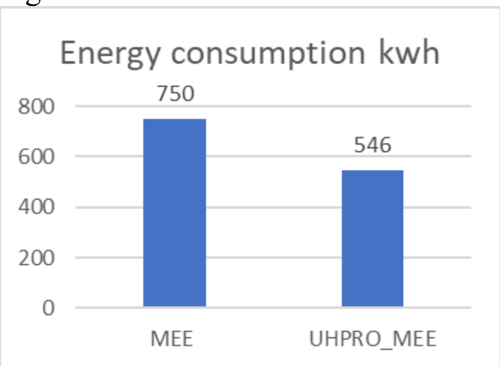
Savings by using PRO-LF1
Table :2

PRO - LF1: Value Proposition			
1 MLD plant - 90 Nos	**SWC5-LD**	**PRO LF1**	Remarks
CIP Frequency (# CIPs/ month)	2	1.0	Once every 3 weeks with PRO LF 1
# CIPs/yr	24	12	
Chemical cost $/ CIP	150	150	
Cost for CIP / yr	3,600	1,800	
Plant Downtime during CIP - hrs	8	8	
Total down time due to CIP / yr	192	96	
Permeate production rate(m3/hr)	41.67	41.67	1000 m3/day
Loss in avg production due to fouling	4		5% - 15%
Total Production / yr	321,326	361,029	
Unit price of the product water ($/m3)	1.00	1.00	
Annual revenue of the product	317,726	359,229	
Savings ($/yr)	**41,503**		

Savings by using PRO-XP1
Table 3.

MEE			UHPRO+MEE		
Descriptions	**Value**	**Unit**	**Descriptions**	**Value**	**Unit**
Reject flow from HPRO	30	m3/h	Reject flow from HPRO	30	m3/h
			Feed to UHPRO	30	m3/d
			Permeate recovered from UHPRO	12	m3/h
Feed to Evaporator	30	m3/h	Feed to Evaporator	18	m3/h
			UHPRO Energy consumption	8	kwh/m3
			UHPRO Energy consumption per hour	96	kwh
Evaporator Energy consumption	25	kwh/m3	Evaporator Energy consumption	25	kwh/m3
Evaporator Energy consumption per hour	750	kwh	Evaporator Energy consumption per hour	450	kwh
Total Energy consumption	750	kwh	Total Energy consumption	546	kwh

Figure 1.



Savings for using PRO-XS1
Table 4

System	Items	Case 1 (HPRO+DTRO+MEE)	Case 2 (NF-30%+MEE)	Case 3(NF-75%+MEE)
5 stages	Feed flow, m3/hr	20	20	20
RO/NF	recovery, %	30	50	75
	Feed pressure, bar	49.3	32.8	30(1st), 70(2nd)
	Pump specific energy, kwh/m3	5.69	2.27	2.08(1st), 4.85(2nd)
	Power cost per day, $	81.99	54.55	108.10
	5th System cost per day,$	90.52	69.41	134.30
DTRO	Feed flow, m3/hr	14		
	recovery, %	35		
	Feed pressure, bar	80		
	Pump specific energy, kwh/m3	7.92		
	Power cost per day, $	79.83		
	DTRO cost per day,$	132.43		
MEE	average energy cost, kwh/m3	25.0	25.0	-
	MEE Feed flow m3/h	9.8	10.0	
	MEE cost per day, $	588.0	600.0	0.0
Total	system cost per day, $	810.95	669.41	134.3

Figure 2