RESEARCH PAPER | Environmental Science | Volume : 6 | Issue : 5 | May 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

Membrane Bioreactor Filtration to Minimize Evaporator Operation in ZLD System

KEYWORDS: MBR, API effluents, Evaporator, ZLD, Operation cost, Water recycle.

Mr. Srinivasarao Gangavarapu	Dr. Uma Maheswara Rao Ganguru	Dr. Narasimha Murthy Brahmandam
Mylan Laboratories Limited, Hyderabad, India.	Mylan Laboratories Limited, Hyderabad, India.	Aurobindo pharma., Hyderabad, India.

ABSTRACT *A study was conducted to assess the MBR (Membrane Bio-Reactor) benefits in ZLD (Zero Liquid Discharge) system. Effluents, used in the study was collected from API manufacturing unit operations, contained COD (Chemical Oxygen Demand) and TDS (Total Dissolved Solids) <1500 mg/l. The ZLD system consist of Bio-ETP (Biological Effluent Treatment Plant), MBR (Membrane Bio-Reactor), RO (Reverse Osmosis) and Evaporator. In ZLD, biological ETP outlets are fed in MBR followed by RO. The permeate generated in operation recycled to utilities for reuse and rejects generated send to Evaporator for further treatment. To assess the benefits of MBR, ZLD system was also operated by bypassing MBR (i.e., Bio-ETP outlet was directly fed to RO plant). The result in experimental study indicated that, without MBR affects the performance of ZLD system. MBR operation in ZLD system increased the RO permeate recovery from 68 to 83 percent, and daily average Evaporator feed (i.e., RO rejects) generation reduced almost by 50%, which resulted in significant reduction of operation cost of ZLD system.*

1. Introduction:
Achieving ZLD (Zero Liquid Discharge) is one of the main objective for any corporate water management system. The other objectives being reducing pollution at source, reducing water consumption (or) reducing overall water usage in the industry and fulfilment of statutory requirements (CPCB, 2015).

Cost of wastewater treatment depends on technology employed and source of energy consumed. In API (Active Pharma Ingredients) manufacturing industries, operation cost per KL (Kilo Liter) typically runs as ₹150.00 for Bio-ETP (Biological Effluent Treatment Plant), ₹60.00 for RO (Reverse Osmosis) and ₹2000.00 for Evaporator. Hence, it is important to minimize the feed to Evaporator as much as possible (UN, 2003).

Settling of suspended solids in outlet of API Bio-ETP is very difficult. Therefore, it is very hard to operate UF (Ultra Filtration)/RO Membrane systems with Bio-ETP outlets, as UF/RO plants designed to feed less than 10 NTU. However, the Turbidity after treatment in Conventional Aeration system is more than 800 NTU (Kenna and Zander, 2000; Fernando, 2011).

It has been found that increase in the suspended solids to UF/RO Plant decreases the recovery percentage. Feeding high NTU water to even disc UF/RO will reduce the recovery as low as 30-40%. Hence, it is important to reduce the suspended solids in the feed to UF/RO Plant as much as possible.

MBR (Membrane bio-reactor), is a modern wastewater treatment technology, which is having several benefits over other methods of wastewater treatment. Flat sheet MBR technology is conventionally used in Sewage Treatment Plants (Judd et al., 2010). The main purpose of MBR is to reduce foot print of the treatment system and achieving very low turbidity water (or) clean water for discharge to gardening or cooling tower (Jianwen et al., 2010; Visvanathan et al., 2000).

The application is now experimentally employing in API manufacturing industry to reduce the turbidity in the feed to RO and improving recovery percent in RO plant. Increase of RO recovery shall reduce Evaporator feed. Besides these applications, fouling shall be reduced in Evaporator, which resulted (i) reduction of clearing frequency of evaporator, (ii) increase of evaporator life, and (iii) reduction of down time. This novel application, first time in the API industry has proved to be the big step towards achieving Zero discharge.

2. Materials and Methods:

2.1 Effluent source:
Effluents used in the study collected from various industrial activities (of API manufacturing unit), which includes; process & reactor washings, utility outlets, cooling tower blowdowns and boiler blowdowns. The feed of Biological ETP contains COD (Chemical Oxygen Demand) and TDS (Total Dissolved Solids) < 15000 mg/l. The outlet of Bio-ETP used in the study to assess the MBR benefits.

2.2 Effluent characterization:
Stage wise effluents are characterized by approved methods, and the effluent characteristics along with methods employed presented in table. 1.

2.3 ZLD system:
As shown in figure 1, ZLD system consists Biological Effluent treatment plant (Activated sludge process), followed by MBR and RO plants. The RO rejects generated in the process is treated in Evaporator.

2.3.1 Biological Effluent Treatment Plant (Bio-ETP):
The Bio-ETP consists of a pre-treatment unit (i.e., screen chamber, grit chamber and oil & grease trap), equalization cum neutralization tanks (2 numbers each capacity 700 KL), flash mixture, primary clarifier, primary aeration tank (with 8 days retention time), secondary clarifier, second stage aeration tank (with 4 days retention time), and final clarifier.

2.3.2 Membrane Bioreactor (MBR):

Volume : 6 | Issue : 5 | May 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

The MBR consists of a membrane case with multiple flat membrane cartridges, which are connected to a manifold with transparent tubes. The diffuser case contains diffuser pipes inside. The MBR flat membrane sheets are made from chlorinated polyethylene, normally the pore size is 0.4μm. Treated water passed through the membrane sheets and inside spacers to come out via the nozzle. The MBR permeate (which is also called as product) can be supplemented to Reverse Osmosis plant for further polishing. The design operational conditions are 3000 to 5000 mg/l MLSS (Mixed Liquor Suspended Solids), Viscosity less than 100 mPa·sec and DO (Dissolved Oxygen) concentration is ≥ 1 mg/l.

2.3.3 Reverse Osmosis (RO):
Reverse osmosis is a separation process that uses pressure to force a solution such as water through a membrane. In RO plant, effluent filtered through sand filters, cartridge filters and finally through disk type polyamide membranes. Entire system was operated in auto mode. The feed pH was maintained between 6.0-6.5 and all other anti-scalents added as per system design. The pressure maintained is 45-60 bar on membranes to separate permeate.

2.4 Effluent treatment in ZLD system:
Effluents collected for experimental studies taken to screen chamber for retaining floating matter, followed by grit chamber to remove grit, and oil & grease trap for free floating oil & grease removal. The outlet of oil and grease chamber collected in Equalization cum neutralization tanks where air provided through grid placed at the base of the tank for appropriate mixing to avoid solids from settling and to avoid anaerobic conditions. The pH of the effluent shall be adjusted (to 6.5 to 8.5) by adding HCl or caustic lye solution.

Neutralized effluents are fed to Aeration tank through flash mixture and primary clarifier. Flocculants/coagulants are added into flash mixer tank along with the neutral effluent as per required dosage based on laboratory results. Overflow of flash mixture by gravity collected into clarifier for clarification. Clarified water send to primary aeration tank at uniform and constant flow rate.

In aeration tanks, aeration is provided with diffused aeration system. In primary aeration tanks, DO maintained more than 0.5 mg/l, MLSS is maintained at 2,000- 4,000 mg/l and sludge recycle performed if MLSS falling below 2,000 mg/l. The overflow of primary aeration tank passed through second stage clarifier to second stage aeration tank, where DO maintained 2 mg/l. The nutrients such as BOD (Biological Oxygen Demand): Nitrogen: Phosphorous at 100:5:1 respectively. The outlets of 2nd stage aeration tank send to final collection tank through final clarifier for further treatment in MBR plant.

The outlet of Bio-ETP collected in MBR feed tank where submerged MBR plant works to separate suspended solids. The filtrate generated from MBR collected in MBR product collection tank and the permeate further polished in RO plant for reuse. The permeate generated from RO is collected in degasser where gasses are removed and final product ready to recycle. Rejects generated from RO plant send to Evaporator for further treatment.

2.5 Assessment of MBR benefits:
As shown in figure. 1, ZLD system was operated. Also the system was operating by bypassing MBR (i.e., Bio-ETP final clarifier outlet was directly fed to RO plant). The result obtained in the both the schemes subjected for assessment of MBR benefits.

3. Results & Discussion:
3.1 Effluent Characteristics:
Stage wise wastewater characterized in various intervals, and obtained average values are presented in table. 1. The Bio-ETP feed quality parameters are within the design specification (i.e., COD - 13240 mg/l, BOD - 4246 mg/l, TSS - 726 mg/l, and TDS - 7698 mg/l).

All vales presented in the study was 10 days averages, and the values considered in stable condition of ZLD system.

3.2 Loads movement in ZLD system:
3.2.1 ZLD System with MBR operation:
In ZLD system with MBR operation, average hydraulic loads are 320 KLD (Kilo Liter per Day) to Bio-ETP and MBR, 316 KLD to RO, and 53.72 KLD to Evaporator. The COD loads are 1460.5 KPD (Kilograms Per Day) to MBR, 1036.5 KPD to RO and 1004.7 KPD to Evaporator. The BOD loads are 518.4, 216.1 and 214.0 KPD to MBR, RO and Evaporator respectively. Whereas, the RO permeate contained COD and BOD loads are 31.7 and 2.1 KPD respectively with 262.28 KLD of permeate recovery. The TSS loads are 388.5 KPD to MBR and it is reduced to 0 KPD in RO feed and permeate. The evaporator feed contained TSS of 18 mg/l and it was contributed TSS load of 1 KPD. The TDS load was 2445.8 KPD in MBR feed and almost same as 2398.8 KPD in MBR permeate. The RO permeate TDS was 342 mg/l, which contributed TDS load of 89.7 KPD. The Evaporator feed contained TDS of 49983 mg/l, which contributed TDS load of 2309.1 KPD to evaporator (table 1 and 2).

3.2.2 ZLD system without MBR operation:
The ZLD system without MBR operation contained hydraulic loads of 320 KLD and 101 KLD to RO and Evaporator respectively. The COD loads are 1456.0 KPD to RO and 1426.2 KPD to Evaporator. The BOD loads are 517.8 KPD and 515.1 KPD to RO and Evaporator respectively. Whereas, the RO permeate contained COD and BOD loads of 29.8 and 2.6 KPD respectively with 219 KLD of permeate recovery. The TSS loads are 392.3 KPD to RO and it is reduced to 0 KPD in RO permeate. The Evaporator feed contained TSS of 3854 mg/l and it was contributed TSS load of 389.7 KPD. The TDS load was 2425.6 KPD in RO feed and almost same as 2339.3 KPD in Evaporator feed, which contributed TDS of Evaporator to 23134 mg/l. The RO permeate TDS was 376 mg/l, which added TDS load of 82.3 KPD (table 1 and 2).

Studies conducted by Chang et al. 2008, in Pharmaceutical wastewater by a membrane bioreactor (MBR) process shown 100% suspend solids removal (Chang et al., 2008). As detailed above, no significant removal of TDS loads in MBR. Several MBR based studies carried by Cirja et al., 2007 shown no significant removal of household chemical traces from municipal wastewater (Cirja et al, 2007). An assessment conducted by employing MBR for treatment of activated sludge process outlets has shown significant reduction in TSS and COD by 93 and 99% respectively (Malpei et al., 2003). In other study, an attempt was also made in textile industry to reduce organic load by using MBR combining with aerobic, anoxic and anaerobic systems, where less energy consumed for overall treatment process (Brik et al., 2006; Saima et al., 2015).

3.3 Water recovery in ZLD system:

Volume : 6 | Issue : 5 | May 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

The permeate recovery was 68 % without MBR in ZLD system. Whereas, the insertion of MBR in ZLD system increased the water recovery upto 83 % (i.e., from 219 KLD to 262.28 KLD).

The MBR, is a micro filtration setup, which is designed to remove suspended solids, resulted in reduction of TSS load on RO and Evaporator in ZLD system. Suspended solids typically blocks the membrane pores in RO plant, therefore RO recovery will down, and which leads to increase of rejects percent. Increase of rejects percent shall increase hydraulic loads in Evaporator, so the treatment cost will be increased. As recovery volume increases, decreases the feed volume to Bio-ETP, because the condensate generated in Evaporator need to be fed in Bio-ETP for further treatment.

3.4 Cost of ZLD operations:

Reference to table. 3, the operation cost of MBR is □ 15.00 per KL and it is □ 60.00 and □ 2000.00 for RO and Evaporator respectively. The ZLD system operation cost was □ 221,440.00 per day without MBR operation ((RO-320 KLD x □60 = □19200.00) plus (Evaporator-101 KLD x □ 2000.00 = □202240.00)). With MBR, the operation cost of ZLD was reduced to □ 131,200.00 ((MBR- 320 KLD x □15 = □4800.00) plus (316 KLD x □60.00 = □18960.00) plus (Evaporator- 54 KLD x □2000.00 = □107,440.00)).

The operation of ZLD system with MBR reduced the treatment cost from □221440.00 to □131200.00 per day. One day saving of ZLD system with MBR operation was estimated to □90240.00, and it is □ 2,707,200.00 (□90240.00 x 30 days) per Month. The Bio-ETP operation cost is not included in costing as it is same in both the operational conditions.

4. Conclusion:

Operation of ZLD system with MBR operation reduced the TSS load on RO, which resulted in improvement of permeate recovery from 68 to 83%. Improvement of permeate recovery decreased the Evaporator feed volume by 46.9 %. Reduction of treatment cost with MBR in ZLD system was estimated to 40.8%.

From above result, it is recommended that the MBR operationalization in ZLD system shall provide added value on water recovery and operation cost reduction through Evaporator feed minimization.

Table: 1 Unit wise effluent quality in experimental ZLD system

S.No.	Parameter	Unit	Bio-ETP inlet	ZLD system with MBR operation				ZLD system without MBR operation			Method of Analysis
				Bio-ETP outlet	MBR Outlet/ RO Feed	RO permeate	RO rejects/ Evaporator Feed	ETP outlet	RO permeate	RO rejects/ Evaporator Feed	
1	pH	---	7.31	7.96	7.64	7.23	7.84	7.96	7.31	7.92	pH Electrode method
2	COD	mg/l	13240	4564	3280	121	18703	4550	136	14104	HACH COD track, USA
3	BOD	mg/l	4246	1620	684	8	3984	1618	12	5094	HACH BOD track, USA
4	TSS	mg/l	726	1214	0	0	18	1226	0	3854	Gravimatory, millipore
5	TDS	mg/l	7698	7643	7591	342	42983	7580	376	23134	Gravimatory, watt man

Table: 2 Unit wise loads flow in experimental ZLD system

S.No.	Parameter	Units	ZLD system with MBR operation										ZLD system without MBR operation						
			MBR feed (ETP Outlet)		RO Feed (MBR Outlet)		RO permeate			RO rejects/Evaporator Feed		RO feed (ETP Outlet)		RO permeate			RO rejects/ Evaporator Feed	
			in KLD	Loads in Kgs	in KLD	Loads in Kgs	in KLD	Recovery	Loads in Kgs	in KLD	Loads in Kgs	in KLD	Loads in Kgs	in KLD	Recovery	Loads in Kgs	in KLD	Loads in Kgs
1	COD	mg/l	320	1460.5	316	1036.5	262.28	83	31.7	53.72	1004.7	320	1456.0	219	68	29.8	101	1426.2
2	BOD	mg/l		518.4		216.1			2.1		214.0		517.8			2.6		515.1
3	TSS	mg/l		388.5		0.0			0.0		1.0		392.3			0.0		389.7
4	TDS	mg/l		2445.8		2398.8			89.7		2309.1		2425.6			82.3		2339.3

Volume : 6 | Issue : 5 | May 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

Figure: 1 Schematic showing ZLD system; consist Bio-ETP, MBR and RO

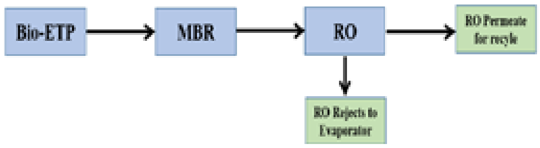

Table: 3. Savings against operation of MBR in ZLD system

Treatment Unit	Units	Treatment cost per Unit	ZLD System without MBR		ZLD System with MBR	
			Feed KLD	Treatment cost	Feed KLD	Treatment cost
MBR	KL	□ 15.00	--	--	320	□ 4,800.00
RO	KL	□ 60.00	320	□19,200.00	316	□ 18,960.00
Evaporator	KL	□ 2,000.00	101	□ 202,240.00	54	□ 107,440.00
Treatment cost per day:			□ 221,440.00		□ 131,200.00	
Savings per day with MBR operation:			□ 90,240.00			
Savings per Month with MBR Operation:			□ 2,707,200.00			

Reference:

1. Brik, M., Schoeberl, P., Chamam, B., Braun, R. and Fuchs, W. Advanced Treatment of Textile Wastewater towards Reuse Using a Membrane Bioreactor. Process Biochemistry, 2006, 41, pp. 1751-1757.
2. Chang, C.Y., Chang, J.S., Vigneswaran, S. and Kandasamy, J. Pharmaceutical Wastewater Treatment by Membrane Bioreactor Process - A Case Study in Southern Taiwan. Desalination, 2008, 234, pp. 393-401.
3. Cirja, M., Zuehlke, S., Ivashechkin, P., Hollender, J., Schäffer, A. and Corvini, P.F., Behavior of Two Differently Radiolabelled 17α-Ethinylestradiols Continuously Applied to a Laboratory-Scale Membrane Bioreactor with Adapted Industrial Activated Sludge. Water Research, 2007, 41, pp. 4403-4412.
4. CPCB (Central Pollution Control Board), Guidelines on Techno-Economic feasibility of implementation of Zero Liquid Discharge (ZLD) for water polluting industries, Circular, 2015, pp. 1-25.
5. Fernando, S.G.E., The Book: Wastewater Treatment and Reutilization. Intech Open Access Publishers, 2011.
6. Jianwen, Bin, S., Hang, F.L., Test Membrane Bioreactor Wastewater Treatment Cephalosporin Pharmaceutical Study. Environmental Engineering, 2010, 28, pp. 65-66.
7. Judd, S., The MBR Book: Principles and Applications of Membrane Bioreactors for Water and Wastewater Treatment. Elsevier, UK., 2010.
8. Kenna, E.N., and A.K. Zander, "Current Management of Membrane Plant Concentrate." American Water Works Association Research Foundation, Denver, Colorado, 2000.
9. Malpei, F., Bonomo, L. and Rozzi, A., Feasibility Study to Upgrade a Textile Wastewater Treatment Plant by a Hollow Fiber Membrane Bioreactor for Effluent Reuse. Water Science & Technology, 2003, pp. 47, 33-39.
10. Saima Fazal*, Beiping Zhang, Zhenxing Zhong, Lan Gao, Xuechuan Chen. Industrial Wastewater Treatment by Using MBR (Membrane Bioreactor) Review Study, Journal of Environmental Protection, 2015. 6, pp. 584-598.
11. UN, Waste-water treatment technologies: A general review, Economic and social commission for western Asia, 2003, pp. 49-77.
12. Visvanathan, C., Aim, R.B. and Parameshwaran, K. Membrane Separation Bioreactors for Wastewater Treatment. Critical Reviews in Environmental Science and Technology, 2000, 30, pp. 1-48.