International Journal of Chemical Sciences and Applications ISSN 0976-2590.
Vol 3, Issue 1, 2012, pp 217-222 http://www.bipublication.com

BIOLOGICAL NUTRIENT REMOVAL: MEMBRANE BIOREACTOR

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ABSTRACT

The membrane bioreactor consists of bioreactor (volume 9 L) with reverse osmosis (RO) system placed outside the bioreactor. Bioreactor divides into three zones anaerobic, anoxic and aerobic. Spiral wound polyamide RO membrane module, 0.001 µm pore size and 0.075 m^2 of filtration area used in this study. MBR system is introduced with treat Municipal wastewater collected from the staff colonies at Mahavir Chemical Pvt. Ltd., Nagpur, India. The lab-scale batch experiment were conducted for the period of 12 months to investigate the performance of MBR in terms of organic content, Solid content, Nitrogen content and Phosphorus content. The effect of Sludge retention time SRT (10, 20 and 30 days) and Hydraulic retention time HRT (6-8 hours) on treatment performance was also examined. The results are in good agreement with Indian standards for drinking water. The removal efficiency of COD, BOD, NH_4 and PO_4 were found to be 95 % (average). Total suspended solid (TSS) was below detectable limits (nearly 100 %). The removal efficiency of TN and TP varied between 80-90 %. The contribution of RO system in removing pollutants is found to be 12 – 15 % and that of bioreactor it is 80 – 85 %.It was also found that the effluent quality increased with increased in SRT and HRT.

Key word: *Biological Nutrient Removal, Membrane bioreactor , Pre and post denitrification, Reverse osmosis,*

1. Introduction

Water scarcity and disposal of wastewater from municipal as well as industrial areas are the two most serious problems in the world today. Disposal of wastewater into the river and in the land is not solving the problem; instead, it is contaminating both the ground water and river water. So, in order to reduce the above said problems as well as to meet the drinking as well as water reuse standards, it is necessary to treat the wastewater by means of effective technique [1]. In India, many activated sludge process plants are in operation to treat wastewater, but they are not efficient enough to meet the reuse standards [2]. Therefore, in this survey, the membrane separation system is considered as an alterative for wastewater treatment that would provides excellent water quality [3].

Membrane processes are normally categorized in order of decreasing pore size as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse Osmosis (RO). As a general rule, MF is suitable for the removal of suspended solids, including larger microorganisms like protozoa and bacteria. UF is required for the removal of viruses and organic macromolecules down to a size of around 20 nm. Smaller organics and multivalent ions may be removed by NF, while RO is even suitable for the removal of all dissolved species [4].

Membrane technology, specifically RO, can produce water which should meet even the most stringent guidelines. RO is a successful desalination method applied to seawater, brackish and industrial wastewater [5]. RO is the pressure driven membrane process that requires pressure to force clean water through the membrane, and thus

removes dissolved salts and harmful contaminants including bacteria, virus and chemicals with the reject steam [6].

Lesjean et al. [8] performed the study at Berlin wastewater treatment plant for biological phosphorus and nitrogen removal from municipal wastewater. The system consists of bioreactors having 2 m^3 of volume with hollow fiber membrane module directly immersed in the bioreactor. It was operated at the flow rate of 2.6 m^3/day at temperature between 16 -19 ^OC. The percentage removal efficiency of COD, ammonia nitrogen and phosphorus were 95.3, 98.8 and 98.6 respectively. Innocenti et al. [9] performed the MBR experiment at Fusina, Italy to study the effect of sludge age on nutrient removal from the municipal wastewater. The system consists of bioreactors having 0.4 m^3 volume with ultra filtration hollow fiber membrane module directly immersed in the bioreactor. It was operated at hydraulic retention time of 4 h (for Anoxic/anaerobic phase 1.5 h and for aerobic phase 2.5 h). The percentage removal efficiency of COD, ammonia nitrogen and phosphorus were 93.56, 97.80 and 75 respectively. Rosenberger et al. [10] conducted the study at Germany federal environmental agency in Berlin to study the performance of MBR. The system consists of bioreactors having 3.9 m^3 of volume with hollow fiber micro filtration membrane module directly immersed in the bioreactor. It was operated at flow rate of 6 m^3/day temperature 10-20 ^OC. The percentage removal efficiency of COD, ammonia nitrogen and phosphorus were 95, 95 and 85 respectively. Ahn et al. [7] studied the enhanced biological phosphorus and nitrogen removal from municipal wastewater using a sequencing anoxic/anaerobic membrane bioreactor with aerobic process at Korea Institute of Science and Technology. The system consists of bioreactors having 0.01 m^3 of volume with flat sheet micro filtration membrane module directly immersed in the bioreactor. It was operated at the flow rate of 0.03 m^3/day. The percentage removal efficiency of COD, ammonia nitrogen and phosphorus were 96, 60 and 93 respectively. Yoon et al. [11] conducted the study at South Korea municipal wastewater treatment. The system consists of bioreactor having 16.06 m^3 of volume with hydrophilic polyethylene hollow fiber membrane module directly immersed in the bioreactor. It was operated at flow rate of 57.6 m^3/day and hydraulic retention time 6 h at temperature 10-28^OC. The percentage removal efficiency of COD, ammonia nitrogen and phosphorus were 96.3, 91.9 and 72.9 respectively. This study focused on removal of COD, nitrogen and phosphorous contents from the Municipal wastewater using pre and post denitrification MBR system.

2. Material and methods

The membrane bioreactor consists of bioreactor (volume 9 L) with reverse osmosis (RO) system placed outside the bioreactor. Bioreactor divides into three zones anaerobic, anoxic and aerobic. Spiral wound polyamide RO membrane module, 0.001 µm pore size and 0.075 m^2 of filtration area used in this study. MBR system is introduced to treat Municipal wastewater collected from the staff colonies at Mahavir Chemical Pvt. Ltd., Nagpur, India. The schematic diagram of the experimental unit is shown in fig. 1. The experiments conducted using pre and post denitrification set up with batch process condition. During the operation feed goes from feed tank to pump from where pressurized feed comes to inlet header. From inlet header it goes to bioreactor and RO module. Feed comes to the outlet header from RO module by pump . The pure collected in permeate tank and rejected water collected in retentate tank .High pressure cut off is provided for safety purpose. If pressure exceeds beyond certain limit it stops the motor automatically. The operating parameters for the systems are given in table 1.The inlet flow rate was kept between 10-14 l/hr for the pressure applied between the feed and permeate was varying accordingly. The wastewater collected on weekly basis for 12 months from March, 2006 to Feb, 2007.During this period the temperature of

wastewater varies between 25 and 35^{O}C and variation in pH value was between 7.2 and 7.6.Conventional analysis of sample collected from feed, retentate and permeate include pH, Temperature, COD, BOD, TN, NH_4, NO_3, TP, PO_4 and TSS. They were carried out according to the Indian standard methods [20]. Frequent cleaning has been done once a day (before starting with new sample) for the better performance of membrane using the solution of sodium Metabisulfate, Trisodium Phosphate and Sodium Lauryl Sulphate.

3. Results and discussion

The average value of percentage removal efficiency by MBR system for removing BOD, COD, TN, NH_4, NO_3, TP, PO_4 and TSS from municipal wastewater for the period of 12 month is presented in Table 3.

It is found that the average COD removal efficiency of MBR system was 96.00 % for pre denitrification and 97 % for post denitrification. Similarly BOD removal efficiency of MBR system found to be 98 % for pre denitrification and 99 % for pre denitrification. For nitrogen content such as TN and NH_4 average percentage removal efficiency found to be 89.00 and 93.00 respectively for pre denitrification and 90.00 and 94.00 for post denitrification in the MBR system. For phosphorus content such as TP and PO_4, average percentage removal efficiency found to be 85.00 and 93.00 respectively for pre denitrification and 87.00 and 94.00 for post denitrification in the MBR system. Table 3, table 5 and table 7 shows that solids content in the wastewater was complete removed by both the pre denitrification and post denitrification MBR system. The percentage removal efficiency found to be almost 100 % for TSS. The values of effluent concentration meet the Indian drinking water as well as reuse water standards for all the parameters. The results show that post denitrification is better than pre denitrification.

Table 4 and 5 give the results with respect to different values of SRT. It is found that the average COD removal efficiency of MBR system was increase from 95.00 to 97.00 % with increase in SRT from 10 days to 30 days for pre denitrification and increase from 96.00 to 97.50 % with increase in SRT from 10 days to 30 days for post denitrification. Similarly the average BOD removal efficiency of MBR system was increase from 96.00 to 98.50 % with increase in SRT for pre denitrification and increase from 98.00 to 99.00 % with increase in SRT for post denitrification. For nitrogen content such as TN average percentage removal efficiency found to be increase from 87.00 to 90.00 % for pre denitrification process and increase from 89.00 to 91.00 % for post denitrification process with increase in SRT .Similarly for NH_4, average percentage removal efficiency found to be increase from 91.00 to 94.00 % for pre denitrification process and increase from 92.00 to 94.80 % for post denitrification process with increase in SRT. For phosphorus content such as TP average percentage removal efficiency found to be increase from 83.00 to 86.00 % for pre denitrification process and increase from 86.00 to 87.90 % for post denitrification process with increase in SRT .Similarly for PO_4, average percentage removal efficiency found to be increase from 90.00 to 93.70 % for pre denitrification process and increase from 92.00 to 95.50 % for post denitrification process with increase in SRT.

Table 6 and 7 give the results with respect to different values of HRT. It is found that the average COD removal efficiency of MBR system was increase from 94.80 to 95.10 % with increase in HRT from 5 hours to 7 hours for pre denitrification and increase from 95.90 to 96.00 % with increase in HRT from 5 hours to 7 hours for post denitrification. Similarly the average BOD removal efficiency of MBR system was increase from 95.70 to 96.20 % with increase in HRT for pre denitrification and increase from 997.20 to 98.10 % with increase in HRT for post denitrification. For nitrogen content such as TN average percentage removal efficiency found to be increase from 86.80 to 87.20 % for pre

denitrification process and increase from 87.90 to 90.00 % for post denitrification process with increase in HRT .Similarly for NH_4, average percentage removal efficiency found to be increase from 90.50 to 91.00 % for pre denitrification process and increase from 91.00 to 93.00 % for post denitrification process with increase in HRT. For phosphorus content such as TP average percentage removal efficiency found to be increase from 82.80 to 83.20 % for pre denitrification process and increase from 85.60 to 86.50 % for post denitrification process with increase in HRT .Similarly for PO_4, average percentage removal efficiency found to be increase from 88.70 to 90.10 % for pre denitrification process and increase from 91.50 to 92.50 % for post denitrification process with increase in HRT.

Finally, it is also observed that, the contribution of RO system in removing pollutants is found to be 12 – 15 % and that of bioreactor it is 80 – 85 %.

4. Conclusions

The laboratory studies for performance of pre and post denitrification MBR system for municipal industry wastewater shows that post denitrification system is much better than pre denitrification system. The average removal efficiency of COD and BOD were found to be 96.00 % and 98 % respectively for pre denitrification and 97.00 % and 99 % respectively for post denitrification. The suspended and dissolved solids were found to be removed almost completely for both the pre and post denitrification MBR system. It is found that for post denitrification MBR system TN, and NH_4 removal found to be 89.00 % and 93.00 % respectively and for post denitrification MBR system it were 90.00 % and 94.00 % respectively. It is also found that TP and PO_4 removal found to be 85.00 % and 93.00 % respectively for pre denitrification system and are 87.00 %and 94.00 % respectively for post denitrification system. The experimental results also observed to follow the Indian drinking water standards for both the pre and post denitrification MBR system.

Similarly, it is also found that the percentage removal efficiency improved with increase in SRT and HRT. The contribution of RO system in removing pollutants is found to be 12 – 15 % and that of bioreactor it is 80 – 85 %.

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Table 1: RO Membrane Specifications Used In the Experiments

Characteristics	Reverse Osmosis
Membrane Configuration	Spiral wound
Membrane material	Polyamide
Filtration Principle	Cross flow
Membrane Surface area ,m^2	0.075
Maximum operating Feed flow rate (m^3/day)	21.6
Maximum operating Pressure (KPA)	200
Maximum operating temperature ^OC	45
Maximum feed turbidity, NTU	1
Maximum feed SDI	4
Allowable pH range	2-11

Table 2 Characteristics of wastewater (March, 2006 - February, 2007)

Parameters	Mar-May, 2006	Jun-Aug, 2006	Sept-Nov, 2006	Dec,2006-Feb,2007
Temperature ^OC	30 – 35	28-31	25-29	25-27
pH	7.5-7.7	7.1-7.4	7-7.2	7-7.1
COD (mg/l)	290	290.75	290	289
BOD (mg/l)	206	207	206	205.5
TN (mg/l)	42	43	44	43
NH_4 (mg/l)	21	22	21	20.8
NO_3 (mg/l)	0-0.1	0	0	0
TP (mg/l)	4.8	5	5	5.2
PO_4 (mg/l)	1.3	1.2	1.25	1.32
TSS (mg/l)	245	244	246	245

Table3: Results of pre and post denitrification system

Para-meters	**Influent**	**Pre-Denitrification** Removal Efficiency	**Post-Denitrification** Removal Efficiency
COD	290	96.00	97.00
BOD	206	98.00	99.00
TN	43	89.00	90.00
NH_4	21	93.00	94.00
NO_3	0	-	-
TP	5	85.00	87.00
PO_4	1.3	93.00	94.00
TSS	245	100.00	100.00

Table 4 : Results of pre and post denitrification system with different SRT in terms of Concentration (HRT = 6 hours)

Para-meters	**Influent**	**Pre-Denitrification** (g/m^3)			**Post-Denitrification** (g/m^3)		
		SRT (days)					
		10	**20**	**30**	**10**	**20**	**30**
COD	290	14.50	11.60	8.70	11.60	8.70	7.25
BOD	206	8.24	4.12	3.09	4.12	2.06	2.06
TN	43	5.59	4.73	4.30	4.73	4.30	3.87
NH_4	21	1.89	1.47	1.26	1.68	1.26	1.09
NO_3	0	13.00	14.00	17.00	15.00	16.00	18.00
TP	5	0.85	0.75	0.70	0.70	0.65	0.65
PO_4	1.3	0.13	0.091	0.082	0.10	0.078	0.059
TSS	245	bdl	bdl	bdl	bdl	bdl	bdl

Bdl- Below detection limit

Table 5: Results of pre and post denitrification system with different SRT in terms of Removal Efficiency

Para-meters	**Influent**	**Pre-Denitrification** Removal Efficiency			**Post-Denitrification** Removal Efficiency		
		SRT (days)					
		10	**20**	**30**	**10**	**20**	**30**
COD	290	95	96	97	96	97	97.5
BOD	206	96	98	98.5	98	99	99
TN	43	87	89	90	89	90	91
NH_4	21.00	91	93	94	92	94	94.8
NO_3	0.00	-	-	-	-	-	-
TP	5.00	83	85	86	86	87	87.9
PO_4	1.30	90	93	93.7	92	94	95.5
TSS	245	100	100	100	100	100	100

Table 6: Results of pre and post denitrification system with different HRT in terms of Concentration

Para-meters	**Inf-luen t**	**Pre-Denitrification** (g/m^3)			**Post-Denitrification** (g/m^3)		
		HRT (hours)					
		5	**6**	**7**	**5**	**6**	**7**
COD	290	15.08	14.5	14.21	11.89	11.6	11.6
BOD	206	8.86	8.24	7.83	5.77	4.12	3.9
TN	43	5.68	5.59	5.5	5.2	4.73	4.3
NH_4	21	1.99	1.89	1.89	1.89	1.68	1.47
NO_3	0	10	13	14	12	14	15
TP	5	0.86	0.85	0.84	0.72	0.7	0.68
PO_4	1.3	0.15	0.13	0.12	0.11	0.1	0.98
TSS	290	bdl	bdl	bdl	bdl	bdl	bdl

Table 7 : Results of pre and post denitrification system with different HRT in terms of Removal Efficiency

Para-meters	**Influent**	**Pre-Denitrification** Removal Efficiency			**Post-Denitrification** Removal Efficiency		
		HRT (hours)					
		5	**6**	**7**	**5**	**6**	**7**
COD	290	94.8	95	95.1	95.9	96	96
BOD	206	95.7	96	96.2	97.2	98	98.1
TN	43	86.8	87	87.2	87.9	89	90
NH_4	21	90.5	91	91	91	92	93
NO_3	0	-	-	-	-	-	-
TP	5	82.8	83	83.2	85.6	86	86.5
PO_4	1.3	88.7	90	90.1	91.5	92	92.5
TSS	245	100	100	100	100	100	100

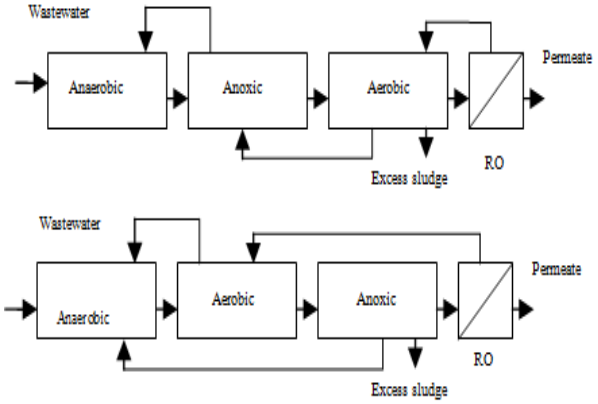

Figure 1: Schematic of pre –nitrification and post nitrification biological phosphorus removal MBR plant