STUDY OF MEMBRANE BIOREACTOR TECHNOLOGY FOR TREATING MUNICIPAL WASTEWATER

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Abstract: A pilot-scale membrane bioreactor of capacity 100L/day was operated for a period of more than 6 months to determine the biokinetic coefficients of the MBR system under different hydraulic retention time (HRT) and Mixed liquor suspended Solids (MLSS) concentrations. The inlet and outlet from reactor were analyzed for determining parameters like pH, COD, BOD, along with TSS and MPN for outlet. On the basis of MLSS variation experiments were divided into 4 phases. In this paper two phases that is MLSS concentrations 6000-7000 mg/L and 7000- 8000 mg/L are discussed for biochemical parameters. The results showed a COD removal efficiency of 74.64 and 90.69% and BOD removal efficiency of 71.74 and 87.72 % for MLSS 6000-7000 mg/L and MLSS 7000-8000 mg/L respectively. The COD and BOD removal efficiency was found to increase with the increase in the MLSS concentration and HRT. pH, COD, BOD values for outlet water were found in prescribed discharge limits for STPs by Central Pollution Control Board (CPCB).

Keywords: MBR,HRT, MLSS, COD and BOD

Introduction:

It is said that current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus, wastewater/low quality water is rising as potential supply for demand management once essential treatment is done. (Kaur et al, 2012).

According to CPCB's report on status of STP's in India (updated on September 12, 2017), disposal of domestic sewage from cities and towns is the biggest source of pollution of water bodies in India . Class I cities and Class II towns generate an estimated 29129 MLD (Million Liters per Day) sewage (as per population in 2001 census). Against this, put in pollution treatment capability is only 6190 MLD. The utilization or use of waste water is a technique of supplementing available water supplies (Jain jyoti *et al*, 2013). Considering the need of waste management and treatment of municipal waste water for the same, the present study deals with treatment of municipal waste water i.e. waste water generated through domestic activities in residential areas or commercial complexes etc.

The increasing water scarcity of the world, along with increasing requirements for both municipal and industrial wastewater treatment quality, has created a need for promising wastewater treatment technologies. One of the new technologies that have gained attention is that of membrane bioreactor (MBR) technology, integrating conventional biotreatment and membrane filtration together (Melin *et al*, 2006, Nazim cicek,2002)

The MBR technology is known for providing benefits over conventional Activated Sludge Process (ASP) such as Higher-quality effluent and volumetric loading rates, shorter hydraulic retention times (HRT), longer solid retention times (SRT), less sludge production, and capability for nitrification/denitrification in long SRTs (Iorhemen *et al*, 2016, Brindle et al ,1996).

Over the last decade implementation/commissioning of MBRs for municipal wastewater treatment has increased dramatically. (Kraemer *et al*, 2012). This study also aimed to represent MBR technology as solution to meet stringent effluent discharge standard.

Materials and methods:

The pilot plant of capacity 100L/day was studied in the laboratory of Effwa Infra and Resarsch Pvt. Ltd., Thane, Maharashtra. The compact MBR pilot/demo plant was designed by ShenZhen KaiHong Membrane Environmental Technology co. Ltd China to meet demo and test purpose for various applications. The plant copy the real running of big MBR plant, but simpler than real. The plant has small foot print, and movable design.

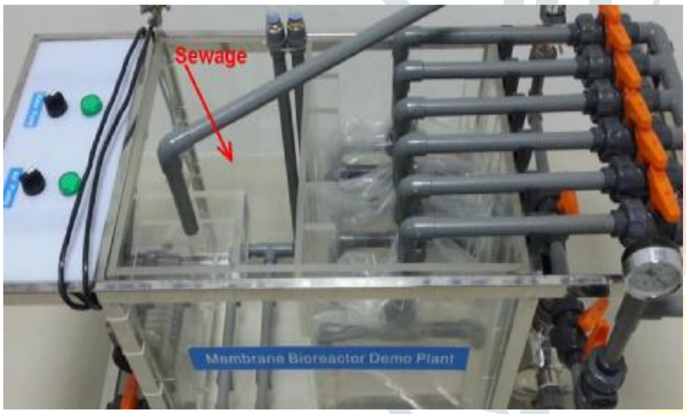


Fig 1. Membrane bioreactor demo plant

The dimensions of the reactor are 510 mm*370mm*420mm. MBR consists of two compartments, one Aeration tank in which sewage/ waste water shall be added which consist of a blower of capacity 85 L/min@ 0.04 MPa. and the other compartment is MBR part which consists of 6 nos. Hollow fiber membranes of area 0.2 m^2 and type reinforced PVDF material and as seen in fig 1.the aeration tank was supplied with additional blower at intermittent time intervals for additional supply of oxygen as aeration flow is also one of the main factors that affect the biochemical process of BOD and COD removals (Radjenovic et al, 2008).

The operation of pilot scale MBR unit is same as traditional active sludge treatment, the organics in raw wastewater is degraded by microorganisms in first compartment. Membrane play a role of separating water and sludge after biochemical process in the second compartment. The tank is equipped with water pump and Air Pump, once tank is filled Air pump is started. Water pump is provided to pump permeate flow from membranes. Once waste is added in first zone it is biologically degraded based on the principle of Activated Sludge process, after that filtration by means of membranes takes place providing clearer permeate. It is also called as membrane separation activated sludge treatment. Permeate collected from all the membranes is pumped and is transferred via permeate pipe.

Sufficient mixed liquor suspended solids were developed by adding continuously fresh synthetic wastewater. The cycle of wasting and feeding was continued till steady state condition was achieved. During this period, the pH was monitored throughout the study. The steady state condition is indicated by development of required MLSS. The MLSS was developed by addition of jaggery and synthetic sewage to aerated water in increasing concentration day by day. Synthetic sewage of concentration 500-600 ppm was prepared referring OECD guidelines for testing of chemicals simulation test as shown in table 1.

The raw sewage characteristics were referred from CPHEEO Manual on Sewerage and Sewerage treatment systems PART A Chapter 5. Table 2 represents concentration of various parameters for municipal waste water/sewerage.

The experimental protocol was designed to examine the effect of HRT and varying concentrations of MLSS in organic and nutrient removal. After the start-up period regular wasting and feeding were performed until steady state condition were reached. Daily 50 liter synthetic sewage was prepared in plastic drum and was mixed by using mechanical rotators. The loading was done using dosing pump, to vary the flow rate as per decided HRT for the particular set of experiment. The plant was run on semi-continuous mode.

Table 1. The concentration for preparing synthetic sewage of concentration 100 ppm was taken from OECD Guideline for The Testing of Chemicals Simulation Test - Aerobic Sewage Treatment:303 A: Activated Sludge [Organisation for Economic Co-operation and Development (OECD)]

Ingredient	mg/L
Peptone	160
Meat	110
Urea	30
K_2HPO_4	28
NaCl	7
CaCl2	4
MgSO4	2

The plant was run in following phases:

Phase I : MLSS 6000-7000 ; HRT 4 hrs, 6 hrs, 8 hrs and 10 hrs

Phase II : MLSS 7000-8000 ; HRT 4 hrs, 6 hrs, 8 hrs and 10 hrs

Table 2: Concentration of various parameters in the absence of drain or outfall

Illustration BOD = 27 *1000 (mg) / 135 X 0.8 (litres) = 250 mg/L

Parameter	Per capita contribution (g/c/d)	Water supply (L/C/d)	Sewage generation 80% of (3)	Concentration (mg/L)
(1)	(2)	(3)	(4)	(5)
BOD	27.0	135	108	250.0
COD	45.9	135	108	425.0
TSS	40.5	135	108	375.0
Total Nitrogen	5.4	135	108	50.0
Organic Nitrogen	1.4	135	108	12.5
Ammonia Nitrogen	3.5	135	108	32.5
Nitrate Nitrogen	0.5	135	108	5.0
Total Phosphorous	0.8	135	108	7.1
Ortho Phosphorous	0.5	135	108	5.0

Table 3. List of parameters analyzed along with adopted methods and instruments.

Sr No.	Parameter	Method [Ref. Standard Methods for the examination of water and wastewater 21st edition (2005)]	Instruments used [Make: Spectralabs]
1.	pH	pH meter	MULTIPARA (Model MP-8)
2.	BOD	BOD 5210 C Winkler's method	Make :Spectralabs
3.	COD	COD 5220 B Open reflux method	Model – COD 2015M
4.	MLSS	Weighing method	Analytical Balance Model: PA214
5.	DO	DO meter	MULTIPARA(Model MP-8)

After attaining steady state, inlet and outlet samples that is permeate/effluent from reactor were analyzed. Inlet and effluent were checked mainly for pH, BOD, COD, (APHA 2005).

The activated sludge was examined often for pH and DO as both of the parameters play crucial role in proper running of reactor. pH was neutralized using alkali or acid as per requirement, as during the course of MLSS development pH used to decline. DO was maintained in the range of 0.5-1.5 mg/L using aeration. The aeration tank was run with additional blower for intermittent cycles of excessive aeration and normal aeration designed in the reactor. MLSS and SVI for sludge were determined on daily basis. The parameters analyzed, methods and instruments used are summarized in table 3.

Results and discussion:

Phase I: MLSS 6000-7000

During Phase I, MLSS was maintained in the range of 6000-7000 mg/L varying HRT's i.e. 4 hrs, 6 hrs, 8 hrs and 10 hrs and also varying SRT's. For each set of HRT 5 experimental runs were carried out. During this phase pH, MLSS, SVI, COD, BOD were determined.

pH

pH was kept in the range of 6.5-7.5 at the start of each set of experiment, during initial phase i.e. in the developing stage pH used to decline if food source is less, pH was set in the neutral range using sodium hydroxide (NaOH). During the run of experiments at phase I pH was observed in the expected range of 6.5-8.5 with occasional addition of alkali. Table 4 shows that mean pH was 7.25 and it was in the range of 6.27-8.46 during experimental run.

MLSS:

As per table 4, mean MLSS was found to be 6626.2 mg/L and range was 5834-7122 mg/L. On the basis of waste sludge flow from the reactor SRT's were calculated.

COD:

Figure 2 represents COD profile at Phase I MLSS 6000-7000 mg/L, COD at inlet was found in the range of 455-733 mg/L where as it is in the range of 94-237 mg/L at outlet. Table 4 shows statistical analysis for COD at inlet, at Outlet and reduction efficiency of COD. COD reduction efficiency was found in the range of 60.49 - 84.77 % with mean efficiency of 64.74 %. Figure 3 shows that the reduction efficiency was found to be increasing with increase in HRT. Highest reduction was observed at HRT of 10 hrs, but there is no huge difference in efficiency at HRT 8 hrs and HRT 10 hrs. Hence HRT 8 hrs can be considered ideal for higher reduction at phase I.

BOD:

Table 4 represents statistical analysis for BOD. Figure 4 represents BOD profile at Phase I MLSS 6000-7000 mg/L, BOD at inlet was found in the range of 227-373 mg/L where as it is in the range of 38-113 mg/L at outlet. BOD reduction efficiency was found in the range of 65.64-87.25 % with mean efficiency of 75.11%. Figure 5 shows BOD reduction efficiency at different HRT's. The reduction efficiency was found to be increasing with increase in HRT. Highest reduction was observed at HRT of 10 hrs, Hence HRT 10 hrs can be considered ideal for higher reduction at MLSS 6000-7000 mg/L.

Statistical analysis

Table 4: Descriptive statistics for pH, MLSS, HRT, COD & BOD at MLSS 6000-7000 mg/L

Parameters	pH	MLSS (mg/L)	HRT (hrs)	COD inlet (mg/L)	COD outlet (mg/L)	Efficiency (%)	BOD inlet (mg/L)	BOD outlet (mg/L)	Efficiency (%)
Mean	7.25	6626.2	7	605.65	151.55	74.64	301.4	74.355	75.10826
Median	7.29	6688.5	7	601	139.5	76.28	297	74.5	75.41183
Mode	7.34	#N/A	4	622	154	#N/A	298	59	#N/A
Range	2.19	1288	6	278	143	24.28	146	75	21.60956
Minimum	6.27	5834	4	455	94	60.49	227	38	65.63877
Maximum	8.46	7122	10	733	237	84.77	373	113	87.24832
Count	20	20	20	20	20	20	20	20	20

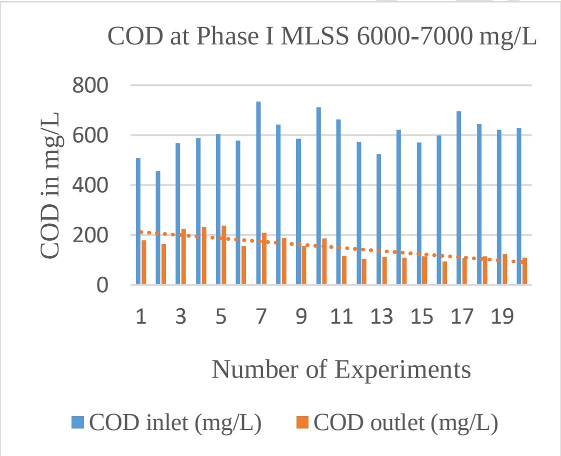


Fig 2 COD at Phase I MLSS 6000-7000mg/L

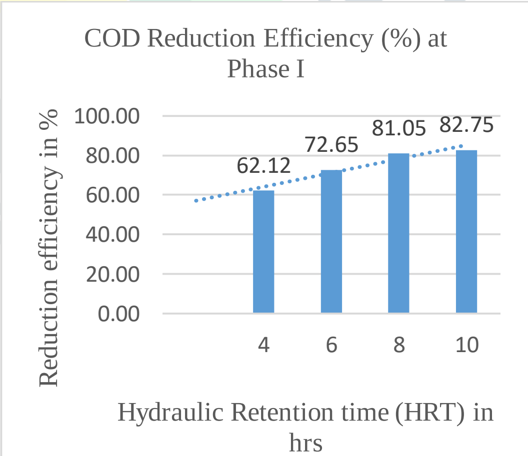


Fig 3 COD reduction efficiency at Phase I

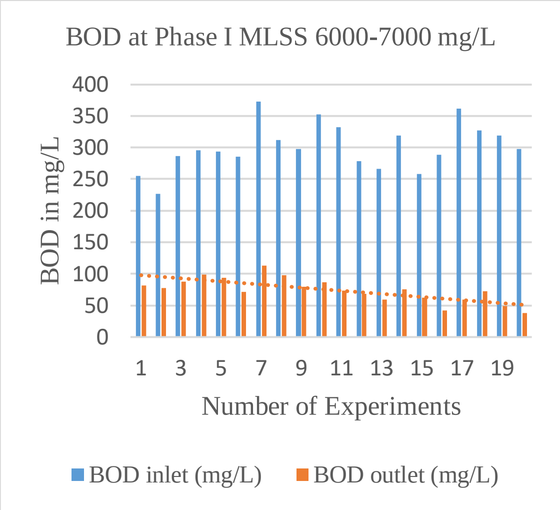


Fig 4 BOD at Phase I MLSS 6000-7000 mg/L

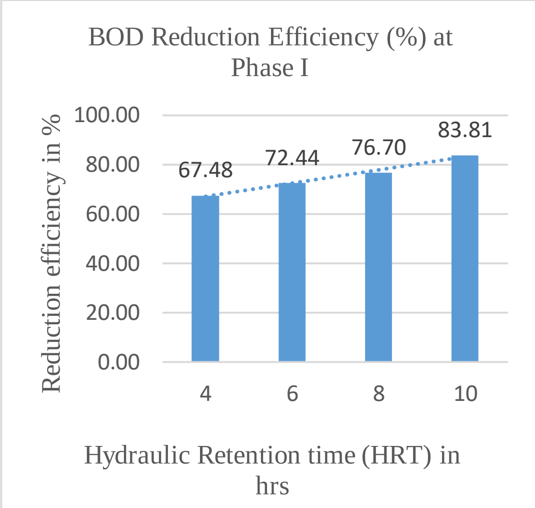


Fig 5 BOD reduction efficiency at Phase I

Phase II: MLSS 7000-8000

During Phase II, MLSS was in the range of 7000-8000 mg/L with varying HRT's i.e. 4 hrs, 6 hrs, 8 hrs and 10 hrs and also varying SRT's. For each set of HRT 5 experimental runs were carried out. During this phase pH, MLSS, SVI, COD, BOD were determined.

pH

pH was kept in the range of 6.5-7.5 at the start of each set of experiment, during initial phase i.e. in the developing stage pH used to decline if food source is less, pH was set in the neutral range using sodium hydroxide (NaOH). During the run of experiments at phase II pH was observed in the expected range of 6.5-8.5 with occasional addition of alkali. Table 5 shows that mean pH was 7.24 and it was in the range of 6.38-8.15.

MLSS:

As per table 5, mean MLSS was found to be 7893.2 mg/L and range was 7239-8246 mg/L. On the basis of waste sludge flow from the reactor SRT's were calculated.

Statistical analysis

Table 5: Descriptive statistics for pH, MLSS, HRT, COD & BOD at MLSS 7000-8000 mg/L

Parameters	pH	MLSS (mg/L)	HRT (hrs)	COD inlet (mg/L)	COD outlet (mg/L)	Efficiency (%)	BOD inlet (mg/L)	BOD outlet (mg/L)	Efficiency (%)
Mean	7.244	7893.2	7	608.7	54.9	90.69	273.2	24.05	91.16
Median	7.335	7984.5	7	621	45	92.67	265.5	21	91.87
Mode	#N/A	#N/A	4	621	35	#N/A	#N/A	21	#N/A
Standard Deviation	0.497	271.55	2.294	75.012	24.378	4.859	30.30	9.179	3.390
Range	1.77	1007	6	228	73	16.74	111	31	10.75
Minimum	6.38	7239	4	473	29	78.93	235	12	84.62
Maximum	8.15	8246	10	701	102	95.66	346	43	95.37
Count	20	20	20	20	20	20	20	20	20

COD:

Figure 6 represents COD profile at Phase II MLSS 7000-8000 mg/L, COD at inlet was found in the range of 473-701 mg/L where as it is in the range of 29-102 mg/L at outlet. Table 5 shows COD at inlet, at Outlet and reduction efficiency of COD. COD reduction efficiency was found in the range of 78.93- 95.66% with mean efficiency of 90.69 %. Figure 7 shows that the reduction efficiency was found to be increasing with increase in HRT. Highest reduction was observed at HRT of 10 hrs, but there is no huge difference in efficiency at HRT 8 hrs and HRT 10 hrs. Hence HRT 8 hrs can be considered ideal for higher reduction at phase II also.

BOD:

Table 5 shows statistical analysis for BOD at inlet, at Outlet and reduction efficiency of BOD. Figure 8 represents BOD profile at Phase II MLSS 7000-8000 mg/L, BOD at inlet was found in the range of 235-346 mg/L where as it is in the range of 12-43 mg/L at outlet. BOD reduction efficiency was found in the range of 84.62 - 95.37 % with mean efficiency of 91.16%. Figure 9 shows BOD reduction efficiency at different HRT's. The reduction efficiency was found to be increasing with increase in HRT. Highest reduction was observed at HRT of 10 hrs, Hence HRT 10 hrs can be considered ideal for higher reduction at MLSS 7000-8000 mg/L.

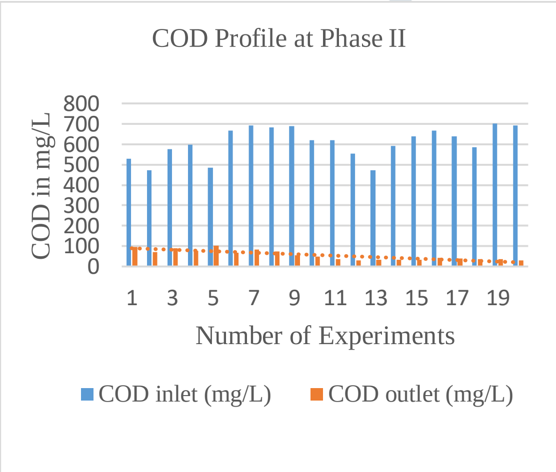


Fig 6 COD at Phase II MLSS 7000-8000 mg/L

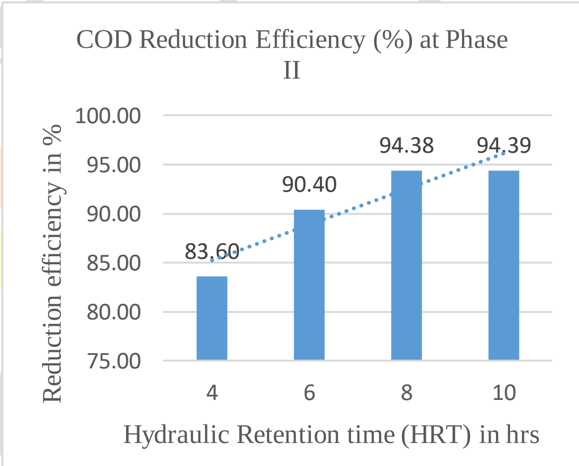


Fig 7 COD reduction efficiency at Phase II

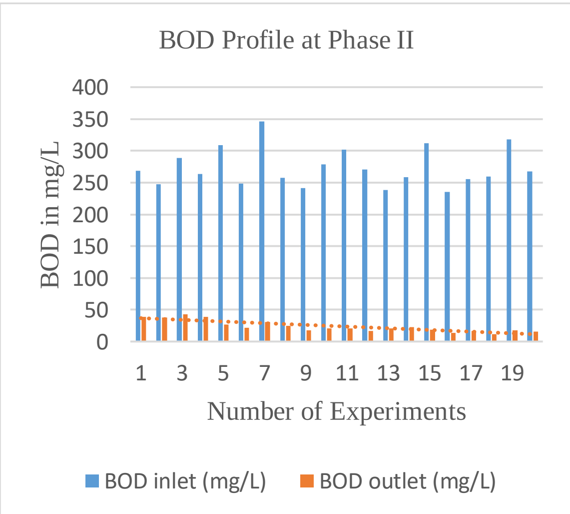


Fig 8 BOD at Phase II MLSS 7000-8000 mg/L

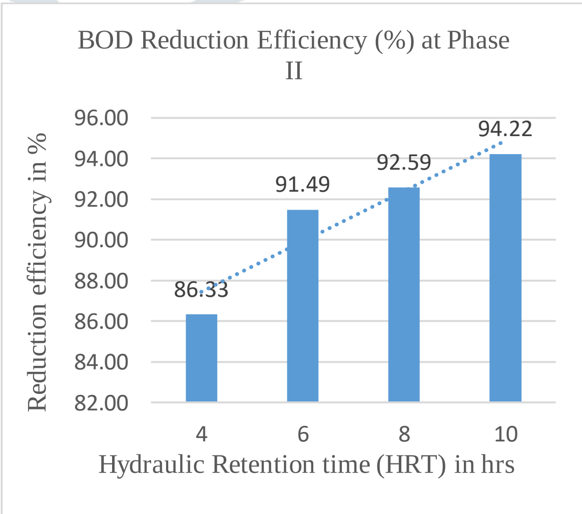


Fig 9 BOD reduction at Phase II

Figure 10 gives comparative account of removal efficiency at Phase I and II for COD and BOD, which shows COD & BOD reduction is greater in phase II as compared to phase I indicating effect of higher MLSS which can be maintained in MBR process.

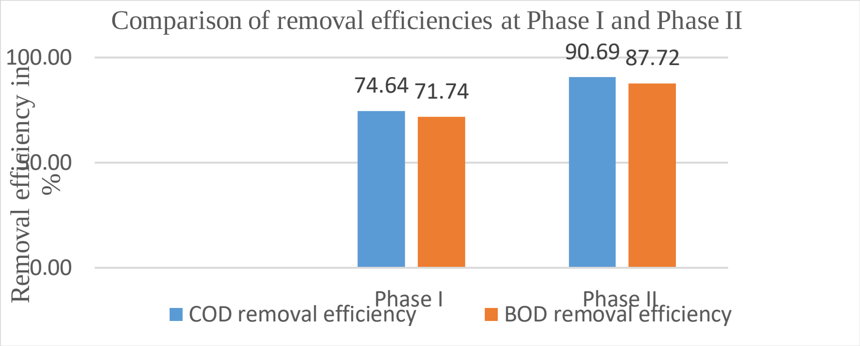


Fig 10 Comparison of COD and BOD removal efficiency at Phase I and Phase II

Conclusion:

This study evaluated the removal efficiency of MBR for municipal wastewater to meet stringent discharge standards given by pollution control boards. The following conclusions can be drawn:

1. The organic matter removal in terms of reduction in COD and BOD upto 90.69 % and 87.72 % respectively was observed. The reduction efficiency was found to increase with increase in MLSS and HRT. HRT of 8 hrs can be considered ideal for achieving higher reduction. The COD removal mechanism may include other substrate-removal strategies like sorption, accumulation and storage. As per Radjenovic et al, 2008, there are several factors that may contribute to the lower organic carbon content of MBR effluents as compared to CAS processes, like longer retention times, smaller floc sizes, and aeration flow.
2. Figure 11 represents inlet and outlet from Pilot scale MBR during phase I and II which shows clear and transparent outlet of MBR. The very low and uniform TSS concentration in the MBR effluent could exclude the necessity of filtration in order to reach more stringent wastewater discharge standards (Lerner et al, 2007).

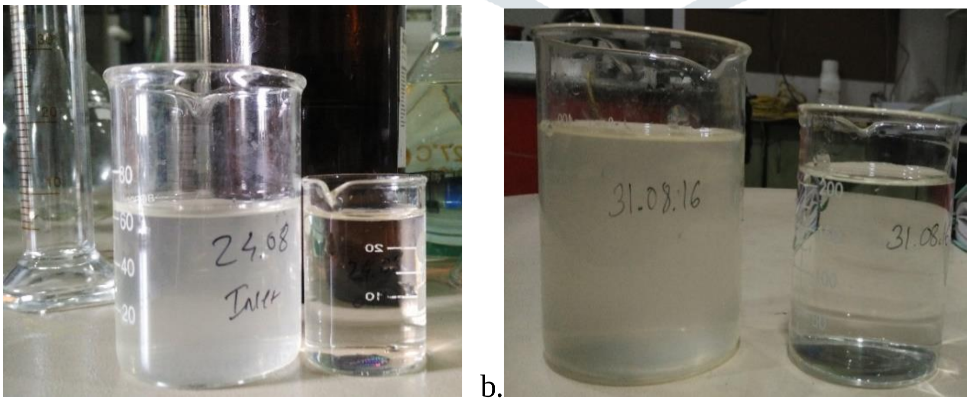
a.  b.

Fig 11 a & b Inlet and Outlet from MBR pilot plant during experimental run of phase I and II

3. Thus it can be included that higher reduction in COD and BOD can be achieved through MBR, thus effect of further increase in MLSS on effluent discharge parameters should be studied to determine ideal conditions for organic removal.

Acknowledgement:

Authors would like to express their gratitude to Effwa Infra & Research Pvt. Ltd for funding of membrane bioreactor pilot plant and chemicals for experiments in laboratory. Authors are also thankful to Vidya Prasarak Mandal for providing support.

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