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Evaluation of impact of HRT in MBR for sewage treatment

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Abstract — **Water shortages and strict environmental provisions necessitates wastewater renovation using various wastewater treatment methods, among which application of Membrane BioReactors (MBR) are rapidly increasing due to their advantages such as high lading capacity and effluent quality. In this work, the effect of Hydraulic Retention Time(HRT) on the effluent quality is investigated in a 5 liter submerged MBR equipped with immersed PVDF hollow fibre membrane module. Acclimatization of bacteria for a period of one month was used for domestic wastewater. Results show that 90% and 87.52% COD removals were achieved initially for 12 hr and 8 hr HRT respectively. By lowering the HRT at 6 hr, COD removal efficiency achieved was 75% for MLSS concentration of 6000 mg/L. as per the literature review MBR can work sufficiently at shortest HRT of one hr.**

Keywords-Membrane BioReactor(MBR), Hydraulic Retention Time(HRT), Mixed Liquor Suspended Solids(MLSS), Chemical Oxygen Demand(COD)

I. INTRODUCTION

Membrane Bioreactor is being used extensively for its advantages such as ; High sludge concentration, high quality of effluent, long contact time between sludge and organic pollutants, and complete separation of HRT and SRT. Moreover, highly treated water in MBR is free from bacteria and it has the potential for industrial and municipal reuse. Although there are some shortcomings such as high cost and high energy consumption. But due to the high quality effluent it is widey used for reclamation purpose. In Europe, America and Japan, MBRs are being used to rebuild sewage treatment plants and to reclaim wastewater.

It is accepted that HRT is the key to further improve the capacity of MBR. At present when a MBR is used for domestic sewage treatment, the HRT is set to 1.5-7.5 hr in laboratory scale test. Until now, the lowest hrt 1.5 hr has been designed by Stefan and Watler to treat synthetic wastewater. They had achieved COD reduction upto 95%. However, little has been reported on the optimum HRT needed to meet reused water quality standards and determination of the shortest HRT possible. The purpose of this study is to investigate the shortest HRT needed in submerged MBR(SMBR) in order to run the plant optimally and to determine the impact of different HRTs on the effluent quality.

II. ADVANTAGES OF MBR OVER ASP

Domestic wastewater is usually treated by conventional activated sludge process(ASP), which involves the natural biodegradation of pollutants by hetetrophic bacteria in aerated bioreactors. Activated sludge can then be separated by using gravity settling. The treatment efficiency is usually limited by the difficulties in separating the suspended solids(SS). Nowadays effluent recycle and reuse are developing for irrigation, reclamation and agriculture., as well as for both direct and indirect potable uses. MBR has many advantages over ASP, and can be successfully used to treat the water to such an extend that it can be further reused for some beneficial purposes.

The advantages of MBR include :

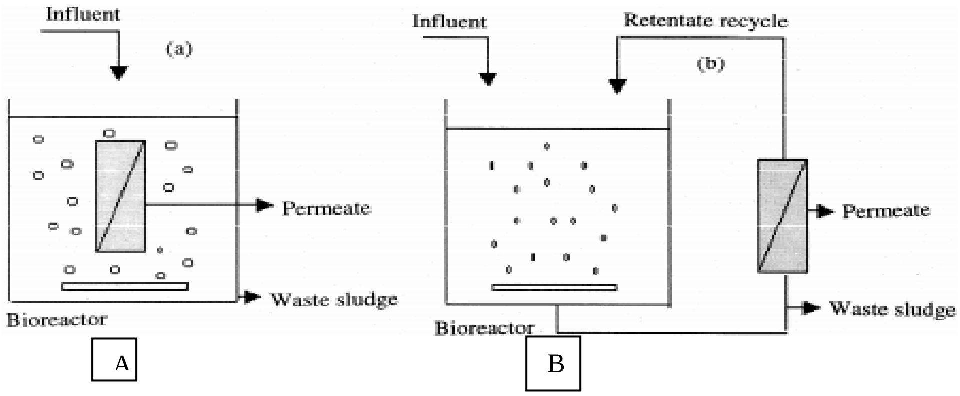
- Secondary clarifiers and tertiary filtration processes are eliminated, thereby reducing plant footprint. In certain instances, footprint can be further reduced because other process units such as digesters or UV disinfection can also be eliminated/minimised (dependent upon governing regulations).
- Ability to operate at high MLSS.
- Unlike secondary clarifiers, the quality of solids separation is not dependent on the mixed liquor suspended solids concentration or characteristics. Since elevated mixed liquor concentrations are possible, the aeration basin volume can be reduced, further reducing the plant footprint.
- No reliance upon achieving good sludge settleability, hence quite amenable to remote operation.
- Can be designed with long sludge age, hence low sludge production.

- Produces a MF/UF quality effluent suitable for reuse applications or as a high quality feed water source for Reverse Osmosis treatment. Indicative output quality of MF/UF systems include SS < 1mg/L, turbidity <0.2 NTU and up to 4 log removal of virus (depending on the membrane nominal pore size). In addition, MF/UF provides a barrier to certain chlorine resistant pathogens such as Cryptosporidium and Giardia.
- MBR facility produces reclaimed water consistently of high quality, regardless of variations in the quality of the wastewater reaching the facility.

III. PROCESS DESCRIPTION

MBR combines the ASP with a membrane separation process. The reactor is operated similar to the ASP but without the need of secondary clarifier and tertiary steps like sand filteration. Low pressure membrane filters either Micro Filteration (MF) or Ultra Filteration (UF) is used to separated the effluent from the activated sludge. The two MBR configurations involve either submerged membranes(fig A) or external circulation/side stream configuration(fig B).

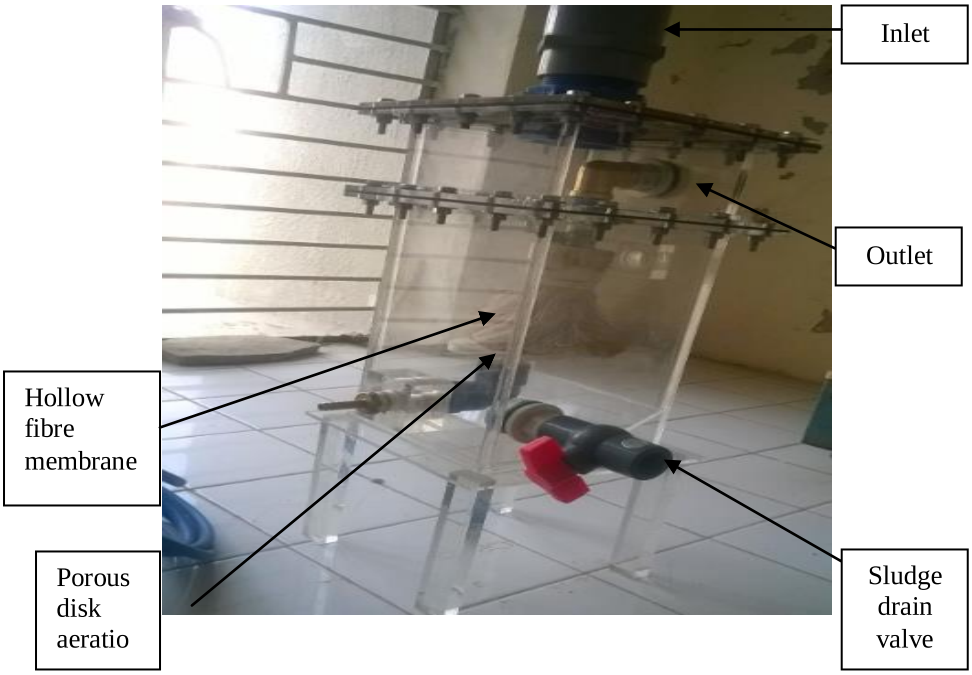
Submerged MBR is being used more due to the ease of the operation. After allowing the wastewater for the designed retention period in the reactor, the permeate is withdrawn from the membrane giving the high quality effluent.



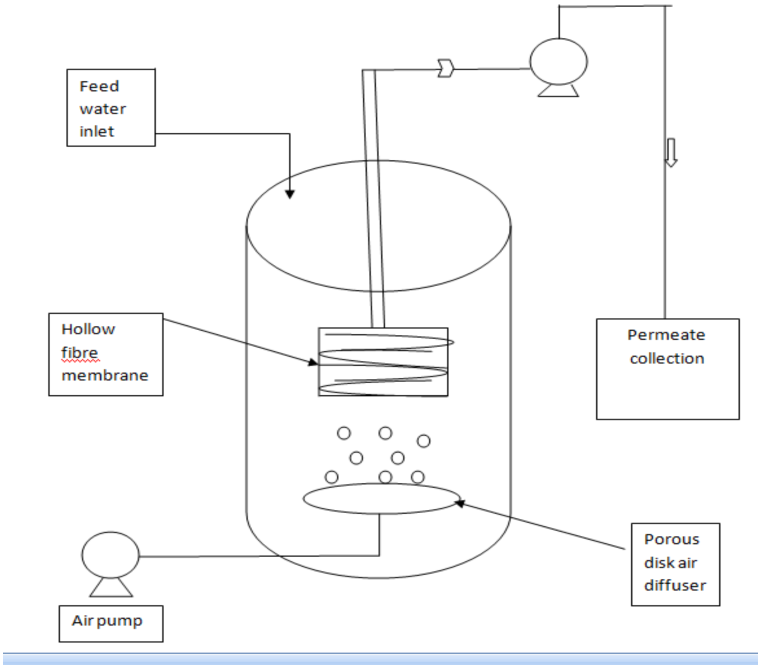
IV. EXPERIMENTAL SET UP OF THE MODEL

4.1 Model Description

The model consisted of a biological reactor of 5 L volume in which a submerged hollow fibre membrane was installed. The complete plant lay out is represented in fig 1. The influent waste water was taken from the municipal waste water treatment plant, Ahmedabad, which operates with conventional activated sludge technology. The wastewater enters the pilot plant and gets treated with the biomass developed in the bioreactor for the designed HRT .Continuous aeration is provided with the porous disk situated beneath the membrane which serves two purposes : provides aeration and reduces fouling on the membrane surface. After getting treated for the designed period, the permeate was extracted by imposing negative pressure on the outlet probe using pedestrial pump



[fig: Lab scale model]



[fig 1 : schematic of the experimental set up]

4.2 Model specifications

The specification of the designed model is as below:

Volume of the reactor	5 L
MOC of the plant	Acrylic
Membrane module	Hollow fibre (HF)
Membrane material	Polyvinylidene difluoride (PVDF)
Pore size of the membrane	0.1 µ

Table no :1 Specifications of the model

4.3 Important membrane material properties

- High porosity
- Narrow pore distribution
- High polymer strength: elongation, high burst and
- collapse pressure
- Good polymer flexibility
- Permanent hydrophilic character
- Wide range of pH stability
- Good chlorine tolerance
- Low cost

4.4 Comparison between different membrane materials.

Material	**Abbreviation**	**Advantages**	**Disadvantages**
Polypropylene	PP	• Low material cost • High pH tolerance	• No chlorine tolerance • Expensive cleaning chemicals required • Brittle
Polysulfone	PSF	• High mechanical strength • Easy to form structure	• Low chemical durability • High cost of raw materials
Cellulose acetate	CA	• Hydrophilic • Low cost	• Biologically active • Low acid/base durability • Low chemical durability
Polyvinylidene difluoride	PVDF	• High chemical durability • Narrow pore size distribution • Simple cleaning chemicals • High chlorine tolerance	• Cannot sustain pH>10 • Not easy to form structure.
Ceramic membranes		• They foul less rapidly • Longer life span	• Economically not viable due to high cost

III PLANT START UP

3.1 Bacterial seeding and acclimatization

First of all, clean water testing was done to check the leakages. The start up phase of the bioreactor is a crucial step. In order to reach to the high MLSS concentration, the plant needs to be started with the addition of the bacterial seeding. From a practical point of view, quickly enhancing the pollutant treatment performance is the main purpose of the startup.

- Bacterial seeding is often used to jumpstart the biological system. Usually there are two approaches involved.
  - Dry seeding (using bacterial culture in powder form)
  - Wet seeding (sludge obtained from the existing treatment plant)

Firstly biomass seeding consisted of the dry powder was used to start up the plant. The bioreactor was filled with the solution of potable Glucose water as glucose is easily biodegradable. The aim is to run the plant on domestic waste water which generally consists of COD ranging from 400-600 ppm. Thus the glucose water solution was prepared such that it imparts COD of 400 ppm. The proportion of glucose was calculated as below

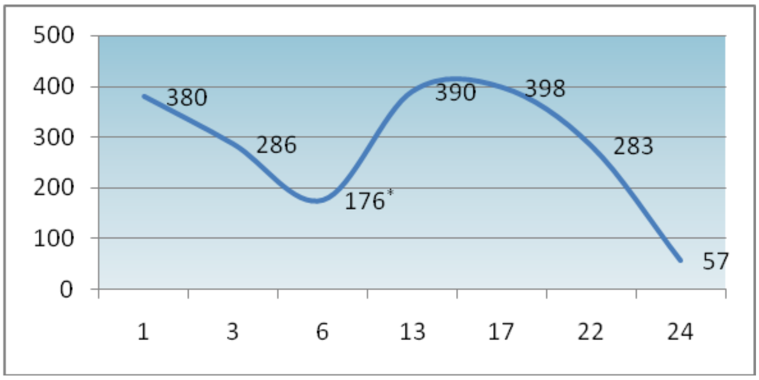
- Theoretical oxygen demand of glucose…

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$$

Molecular weight of Glucose = 180 g/mol

Molecular weight of Oxygen = 16 g/mol

Therefore, 192 g O_2 is required to degrade 180 g of $C_6H_{12}O_6$ Thus, 1.07 g of oxygen is required to degrade 1 g of glucose. So a solution of 400 ppm COD can be prepared by adding 0.374 g glucose in 1 liter water. The calculated proportion of glucose was added to the potable water and the tank was filled with this water with the seeding of dry bacteria of 2ppm Tthe color of the waste water was slight yellow due to the dry powder. The MLSS concentration after 3 days of the seeding reached 3000 mg/L which gradually increased with the time. And the color of the reactor was turning to brown slowly indicating the biomass growth. It took almost a month for the acclimatization and the bacterial growth. The COD reduction was observed gradually indicating the biomass growth. after the completion of the acclimatization the wastewater was introduced.



[Graph-1 : COD of permeate v/s days spent after the reactor start up]

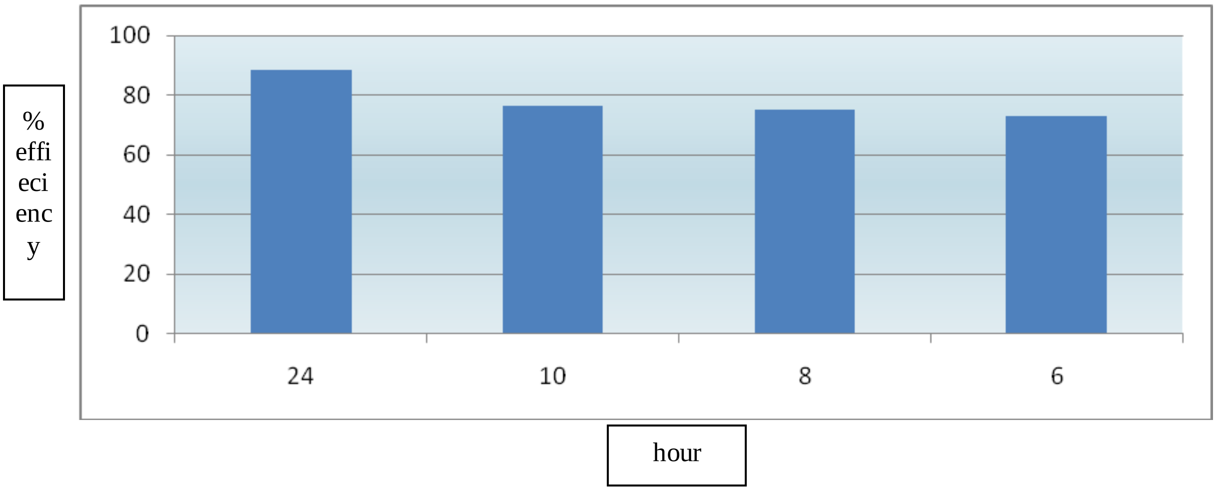
[* occurrence of dead biomass resulted in no further COD reduction]

3.2 Feed wastewater characteristics

Parameter	Unit	Value
pH	-	7
COD	mg/L	457

BOD	mg/L	200
TSS	mg/L	288
Ammoniacal nitrogen	mg/L	30

3.3 Variation in COD observed



3.4 Characteristics of Permeate

Parameter	Effluent concentration	% Removal
COD	57 mg/L	87.52
BOD	21mg/L	89.5
TSS	15 mg/L	94.79
pH	Near neutral	Near neutral
Ammoniacal nitrogen	30 mg/L	48

IV CONCLUSION

The membrane bio reactor was operated at different HRTs i.e. 24 hr, 10 hr, 8 hr, 6 hr at MLSS concentration being 5000 ± 500 mg/L for the treatment of domestic wastewater. A satisfactory effluent quality was obtained and COD removal efficiency was higher than 70% under all the HRTs. The MBR was able to retain almost all the particles and had negligible TSS in the outlet during each run. The MLSS concentration can further be increased and can reach upto 8000-12000mg/L giving even more satisfactory results at shorter HRTs than 6 hr. It can be concluded that MBR is capable of producing excellent quality permeate, suitable for various reuse applications and shorter HRTs can also result into lower footprint therefore reducing the capital cost. Hence, MBR can be strongly recommended for the treatment and reuse/recycling of municipal wastewater .

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