# Factors Affecting Filtration Characteristics in Submerged Membrane Bioreactor for Wastewater Treatment

**Dr V S SAPKAL[1]; D J GARKAL[2]; Dr R S SAPKAL[3]; P V SAPKAL[4]**

[1] Vice Chancellor, RTM Nagpur University, Nagpur
[2] Department of Chemical Engineering, Maharashtra Academy of Engineering, Alandi, Pune
[3] Department of Chemical Technology, Sant Gadge Baba Amravati University, Amravati
[4] Institute of Chemical Technology, Mumbai, Email - djgarkal@rediffmail.com

**Abstract**

*Membrane bioreactor (MBR) combines biological activated sludge process and membrane filtration. MBR has become more popular, abundant, and accepted in recent years for the treatment of many types of industrial wastewaters. MBR technology is also used in cases where demand on the quality of effluent exceeds the capability of conventional activated sludge process. A significant increase in MBR application is anticipated due to increase of water price and need for water reuse as well as more stringent regulations on the effluent quality. This paper presents MBR performance observed during the batch experiments conducted with real wastewater. The MBR is submerged membrane type with a 20 L working volume. The experiments were conducted for a short span of time of 210 min at different air flow rates at various levels of wastewater above the membrane module. The performance of wastewater treatment process has been improved from optimization of process parameters. This is due to degree of turbulence created with optimal air flow rate at optimized level of wastewater surface above membrane module. This also ensures the better performance of membrane bioreactor for longer duration, reducing the cost of operation.*

**Keywords:** Membrane bioreactor, Specific permeate production, Additional resistance

## Introduction

The membrane bioreactor (MBR) is a new technology for wastewater treatment. Compared to the conventional activated sludge process, it has many advantages such as a small footprint, high quality effluent, low sludge production rate, a highly retentive activated sludge concentration and easy management due to the combination of biological treatment with membrane separation (1). In recent years, the MBR process has been widely applied to treat various types of wastewater such as domestic wastewater, human excrement, and especially industrial wastewater (2, 3). As is well-known, the main factors affecting the performance of the MBR are membrane property, membrane module structure, operating condition and bioreactor parameter. When using certain membranes and membrane modules, the influence of operating conditions on membrane flux and MBR performance is important. Therefore, it is very significant to optimize operating conditions based on the effluent quality. Some researchers have carried out studies with regard to operating condition with different methods (4–6). Bai et al.(7) studied the influence of operating conditions on membrane filtration in recirculated membrane bioreactor, and proposed a model to predict the cake layer thickness and membrane flux. Gui et al. (8) investigated the effects of operating conditions, such as aeration intensity, membrane initial flux, pump-on time and pump-off time, on the membrane fouling, and obtained the parameter optimization. In addition, Wang Ying et al. (9) analysed and quantified the relationship with multivariate linear regression method between membrane filtration resistance, activated sludge concentration and organic concentrations in the supernatant. However, during these previous studies, the effects of operating conditions were either qualitatively or quantitatively analysed, without considering the interrelation between operating conditions. The influence of wastewater surface level above the membrane module has not been reported in the literature reviewed so far.

The purpose of this study is, therefore, to evaluate the effect of wastewater surface level above the membrane module in MBR on membrane filtration performance and effluent quality mainly based on COD removal.

**Materials And Methods**

**Experimental Setup**

The laboratory-scale submerged membrane bioreactor system was comprised of a 20-L aerated tank (SS 304) with two flat sheet membrane pouch (permionics make), as shown in Fig 1. The flat sheet membrane had a nominal pore size of 0.5 μm and surface area of each membrane pouch 0.06 $m^2$.

The temperature of wastewater in the membrane bioreactor is measured by digital thermometer (Santron make). Permeate suction pressure, for TMP calculation, was recorded using vacuum gauge mounted between the membrane bioreactor and the permeate pump. Permeate was withdrawn continuously through a diaphragm pump and permeate flow rate is recorded using a water flow rotameter. The permeate flow rate was also measured volumetrically in a measuring cylinder by collecting permeate over a known time period.

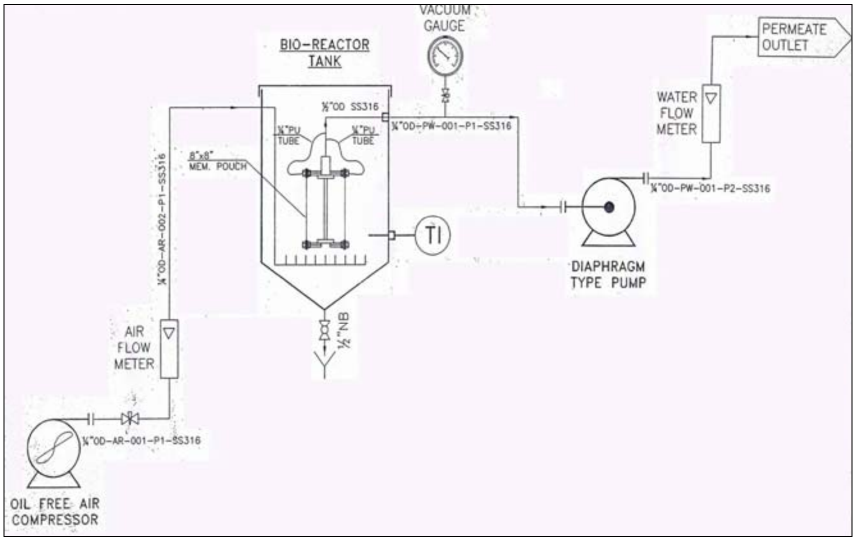



Fig 1 Experimental Setup

**Influent Characteristics**

The homogeneous and stable (mostly synthetic) feed solutions that are often used are not representative for the highly heterogeneous and dynamically alternating activated sludge suspensions as present in full-scale installations.

Influent used in the experiments is real industrial wastewater from the secondary sedimentation tank of CAS process. Table 1 presents the quality of this influent.

Table 1 Average characteristic of the MBR influent

| SN | Parameter | Value |
|---|---|---|
| 1 | pH | 6.3 |
| 2 | Temperature, $^0$C | 26.7 |
| 3 | COD, mg/l | 96.2 |
| 4 | DO, mg/l | 2.77 |
| 5 | MLSS, mg/l | 8094 |

Batch experiments were carried out at various operating conditions by varying air flow rates at different surface levels of wastewater in the membrane bioreactor. The fouling behavior was studied by measuring permeate flow and recording trans-membrane pressure. Chemical oxygen demand (COD) and dissolved oxygen (DO) were measured during the experiment to study the performance of the membrane bioreactor.

Different operating parameter values of the bioreactor maintained during the experimentation are shown in Table 2.

Table 2 Operating parameters of MBR

| Expt No | Air Flow Rate (LPM) | WW Surface Level (cm) |
|---|---|---|
| 1 | 0.5 | 7.5 |
| 2 | | 11.0 |
| 3 | | 14.5 |
| 4 | 1.0 | 7.5 |
| 5 | | 11.0 |
| 6 | | 14.5 |
| 7 | 1.5 | 7.5 |
| 8 | | 11.0 |
| 9 | | 14.5 |

**Analytical methods:**

COD and MLSS were determined according to Standard Methods (10). Dissolved oxygen and pH were measured by DO meter and pH meter respectively.

**RESULTS AND DISCUSSION**

In the constant TMP mode, the permeate flow rate decreases during membrane filtration as a result of membrane fouling. To understand fouling phenomenon, fouling resistance is calculated.

Membrane fouling resistance was analysed by Darcy's law as shown below:

$$R_t = R_m + R_f = \frac{TMP}{\mu J} \qquad \ldots\ldots (1)$$

where $R_t$ is the total membrane fouling resistance ($m^{-1}$), $R_f$ is the fouling resistance due to pore blocking and cake formation ($m^{-1}$), $R_m$ is the intrinsic membrane resistance ($m^{-1}$), TMP is the trans-membrane pressure (kPa), μ is the permeate viscosity (kg $m^{-1}$ $s^{-1}$) and J is the permeate flux (LMH). $R_m$ was determined by distilled water filtration while $R_t$ by the TMP value.

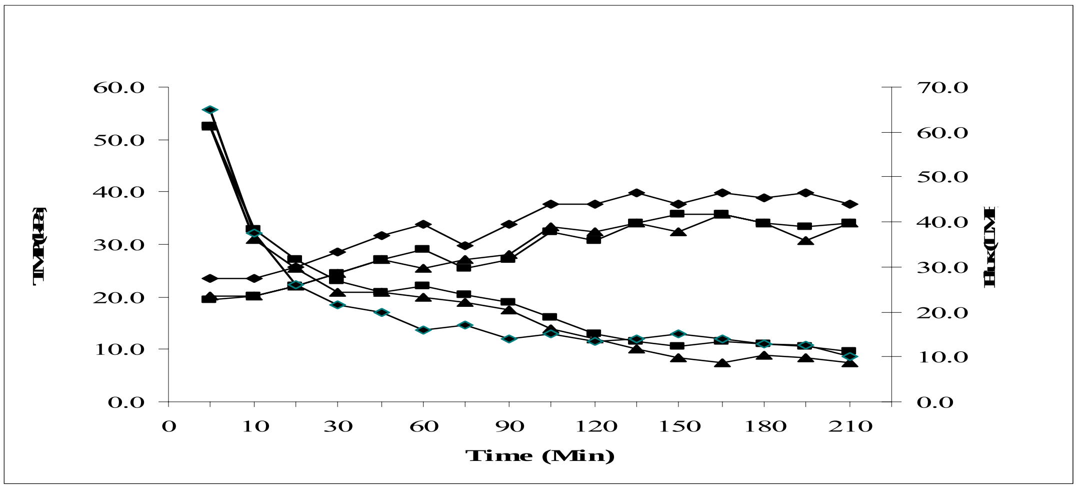
Total cake resistance or fouling resistance can be expressed as a function of the specific permeates production $V$ ($L/m^2$) with three constants that are related to the activated sludge characteristics: (i) the concentration of substances accumulating in the cake layer, $c_i$ (g/L), (ii) the specific cake resistance caused by the substances at a reference total cake resistance, $\alpha_R$ (m/kg) and (iii) the compressibility coefficient of the accumulated substances, $s$ (-). The coefficients, $\alpha_{R,} c_i$ and $s$ can be determined from the experimental data obtained. A closer analysis indicates that in the relevant range of filtration resistance the compression of the cake layer plays a minor role; the total filtration resistance is predominantly determined by coefficient ($\alpha_R$ $c_i$).

$$\Delta R = (\alpha_R\, c_i\, V)^{1/(1-S)} = (\alpha_R\, c_i)^{1/(1-S)}\, (V)^{1/(1-S)} \quad \ldots\ldots (2)$$

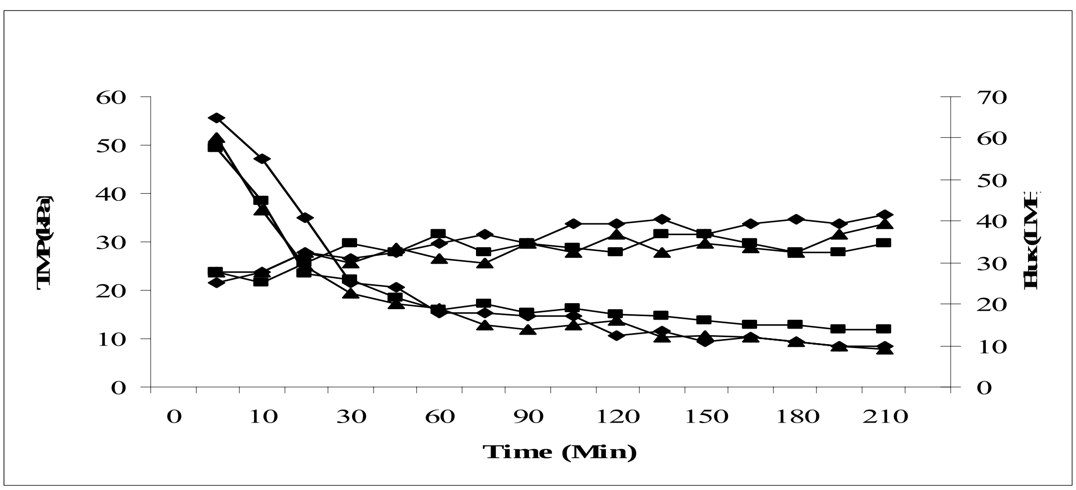
In this work to characterize the filterability of the sludge and to compare different experiments on the basis of a single value, the parameter $\Delta R_{25}$ is used. It is the additional resistance ($m^{-1}$) after filtration of 25 $L/m^2$ of a sludge sample.

**Flux and TMP profiles**

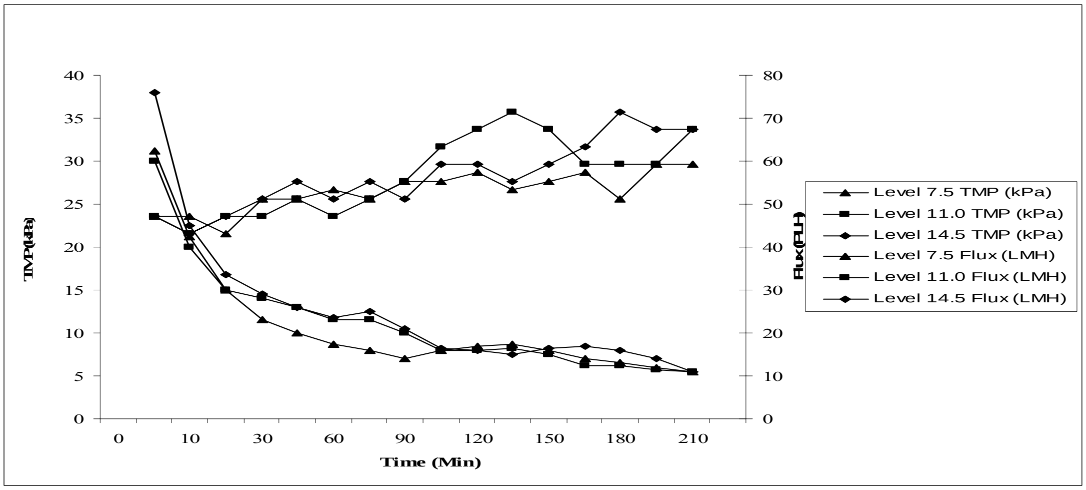
Submerged membrane bioreactor was operated at three different levels of wastewater above membrane module, 7.5 cm, 11.0 cm and 14.5 cm. The variation in trans-membrane pressure (TMP) and permeate flux over the test duration is presented in Fig 2.




(i) Air Flow, 0.5 LPM




(ii) Air Flow, 1.0 LPM




(iii) Air Flow, 1.5 LPM

Fig 2 TMP and Flux for different air flow rates at various surface levels

During the experimental run, exponential decay in the permeate flow is observed. The flux decreased rapidly in the beginning and then it was almost linear decrease. At higher air flow of 1.5 LPM, the flux was having less variations the flux. From 100 min onward, for all three cases, the flux is of almost same value. Trans-membrane pressure is increased steadily, but more fluctuations observed when MBR was operated at air flow rate of 1.5 LPM.

**Permeate Quality**

The percentage removals of COD for various operating conditions are presented in Fig 3.

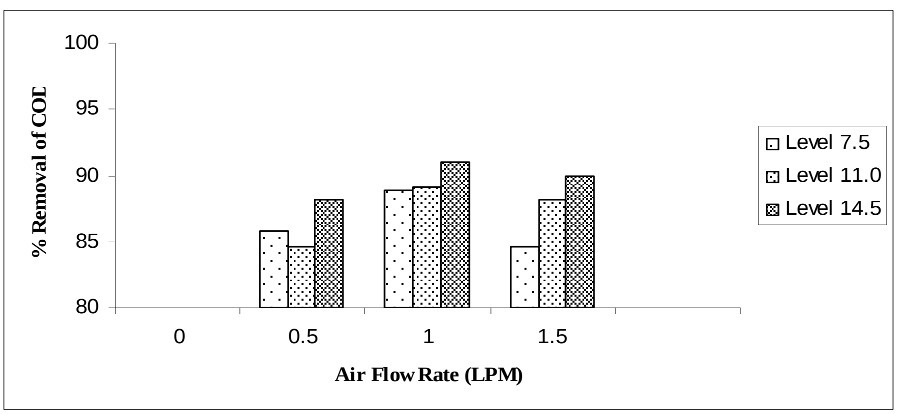



Fig 3 Percentage removal of COD

The graphs in the figure indicate that MBR performance is improved when operated at higher levels. Lowest percentage removal obtained when operated at low level. % Removal of COD increased at higher levels. When MBR operated at air flow rates of 0.5 and 1.5 LPM, variation % removal of COD is ranging from 84.60 to 89.91. Less variation in % removal, from 88.88 to 90.96 is observed when operated at air flow of 1.0 LPM. In all cases the % removal of COD is more than 84 %. To reduce the aeration cost and for satisfactory performance MBR can be operated at air flow of 1.0 LPM with 11.0 cm surface level above membrane module. Fig 4 shows the values of $\Delta R_{25,}$ the additional resistance ($m^{-1}$) after filtration of 25 L/$m^2$ of the wastewater.

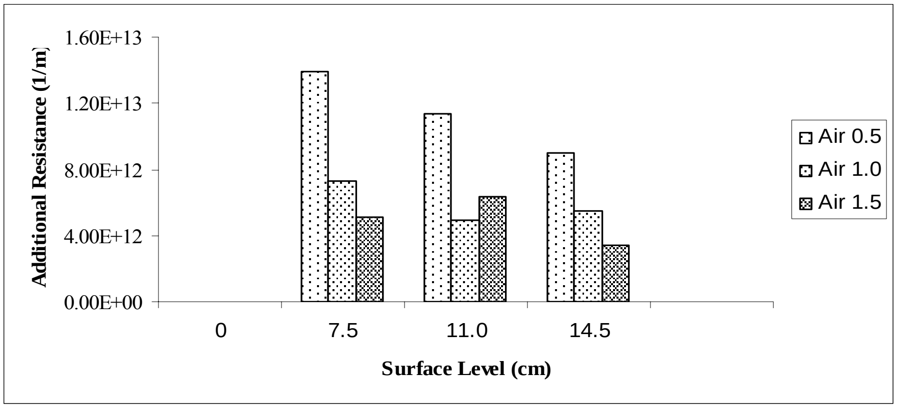



Fig 4 $\Delta R_{25}$, additional resistance at various surface levels

It is evident from the results that increase in the surface level, decreases the additional resistance and hence increase in the filterability of the wastewater. The decrease in the resistance is 18.5 % and 20.4 % when surface level increased from 7.5 to 11.0 to 14.5 cm respectively.

$\Delta R_{25}$ decreased substantially by 47.44 % when air flow rate increased from 0.5 to 1.0 LPM. Further increase in the air flow rate to 1.5 LPM reduces the resistance by 13.76 %, indicating that further increase in the aeration has no marginal effect on fouling layer removal.

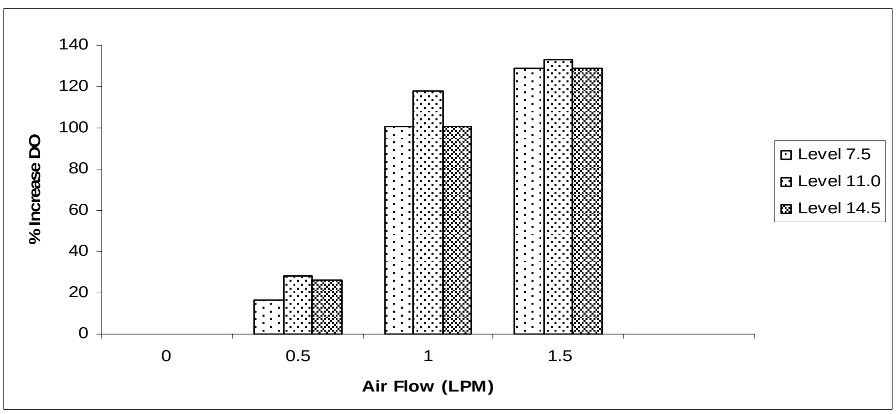



Fig 5 Percentage increase in DO

Increase in the aeration increases the dissolved oxygen content in the effluent as indicated in Fig 5. The percentage increase in DO is much higher when operated at air flow rate of 1.0 and 1.5 LPM than the operation at 0.5 LPM.

Aeration can represent up to 50 % of the MBR operating cost and therefore optimum air flow rate and MBR configuration must be determined. The biological suspension state and behaviour have a major influence on fouling propensity and thus on membrane fouling.

## Conclusion

The performance of wastewater treatment process has been improved from optimization of process parameters leading to abatement of fouling on membrane surface. This is due to degree of turbulence created with optimal air flow rate at optimized level of wastewater surface above membrane module. This also ensures the better performance of membrane bioreactor for longer duration, reducing the cost of operation.

## References

1. (1) C. Visvanathan, R.B. Aim and K. Parameshwaran, Membrane separation bioreactors for wastewater treatment, Crit. Rev. Environ. Sci. Technol., 30 (2000) 1–48.
2. B. Jefferson, A.L. Laine and S.J. Judd, Membrane bioreactors and their role in astewater reuse, Water Sci. Tech., 41 (2000) 197–204.
3. T. Melin, B. Jefferson and D. Bixio, Membrane bioreactor technology for wastewater treatment and reuse, Desalination, 187 (2006) 271–282.
4. R. Liu, X. Huang, Y.F. Sun and Y. Qian, Hydrodynamic effect on sludge accumulation over membrane surfaces in a submerged membrane bioreactor, Process Biochem., 39 (2003) 157–163.
5. X.Y. Li and X.M. Wang, Modelling of membrane fouling in a submerged membrane bioreactor, J. Membr. Sci., 278 (2006) 151–161.
6. E. Germain, T. Stephenson and P. Pearce, Biomass characteristics and membrane aeration: toward a better understanding of membrane fouling in submerged membrane bioreactors (MBRs), Biotechnol. Bioeng., 90 (2005) 316–322.
7. R. Bai and H.F. Leow, Microfiltration of activated sludge wastewater: the effect of system operation parameters, Sep. Purif. Technol., 29 (2002) 189–198.
8. P. Gui and X. Huang, Effect of operating parameters on sludge accumulation on membrane surfaces in a submerged membrane bioreactor, Desalination, 151 (2002) 185–194.
9. Y. Wang, X. Huang and Q.P. Yuan, Influence factors on membrane fouling in a submerged MBR for treatment of high strength organic wastewater, Membr. Sci. Technol., 24 (2004) 1–5.
10. Standard Methods for the Examination of Water and Wastewater, 20th ed., American Public Health Association, 1998.