Keywords: submerged Ceramic Membrane Bioreactor; transmembrane pressure; fouling; permeate flux.

1. Introduction
For wastewater treatment, membrane bioreactors have been examined for BOD removal for removal of BOD and Nitrogen and anaerobic process for methane production. Membrane bioreactor (MBR) is a biological system which combines activated sludge process and membrane technology into an integrated system. MBR systems have gained many advantages over the conventional processes with better effluent quality, higher organic loading, small footprint occupation and decreased sludge production. However, the principle limitation of MBR lies in membrane fouling which is mainly associated with the deposition of a filter cake or fouling layer onto the membrane surface, thus limiting the permeate flux. Membrane fouling leads to the frequent cleaning of membranes and/or the replacement of membranes, due to which the operating costs are increased. As a result, it has become essential to study all the parameters involved in the design and operation of MBR which have an influence on membrane fouling. Such factors may include pore size, membrane surface structure, pore openings and various operating conditions such as sludge retention time (SRT) and transmembrane pressure (TMP).
2. Objectives
The main objectives of this project are i) to fabricate a fully functional submerged tubular ceramic membrane bioreactor system using vacuum microfiltration technique. The importance of the system is in the secondary treatment of industrial, domestic and municipal wastewater. ii) To study variation of permeate flux and Transmembrane pressure (TMP) with time. iii) To graphically evaluate influent and effluent parameters in order to determine the differences in water quality of the two streams. The main parameters in consideration are Chemical Oxygen Demand (COD), Turbidity, Dissolved Oxygen (DO). iv) To identify the type of fouling taking place in the membranes by fitting the filtration data into Standard Pore Blocking (SBM) and Complete Pore Plugging (CPBM) mathematical models. v) To achieve regeneration of membranes by chemical cleaning in order to restore the permeate flux.

3. Methodology
Batch operation of a pilot scale microfiltration submerged ceramic membrane bioreactor system was carried out in this study. Schematic process flow diagram of pilot setup with a picture of the system in operation is shown in Fig. 1.

![Process flow diagram of a pilot submerged ceramic MBR setup](image)

Figure 1 Process flow diagram of a pilot submerged ceramic MBR setup

An acrylic tank having a volume of 36 liters was used as a membrane bioreactor. Four tubular ceramic membranes were used for microfiltration of wastewater. Activated sludge was used in the same tank, for providing a biological environment in an integrated system making use of both conventional activated sludge process, along with membrane separation technology.
Mechanical stirrer was used to provide homogeneous mixing of the wastewater and activated sludge. Aeration was provided by means of diffusers, provided at the bottom of the bioreactor for providing aeration for survival of microorganisms in the reactor and also for maintaining the optimum amount of DO in water. Vacuum pump was used in the system due to which the waste water entered the ceramic membranes because of suction. Any solids whose size exceeded the pore size of the membranes were retained onto the membrane surface. Pressure across the membranes (TMP) was monitored using a vacuum gauge and once the threshold value of TMP was reached, the membranes had to be taken out for chemical cleaning. Pilot scale studies were performed by treating 21-25 litres of waste water for a period of 25-35 days. After each trial, membrane flux was calculated in order to determine the critical flux at which the membranes would stop filtering water and would require chemical cleaning. Feed and effluent water were analyzed and compared in terms of parameters such as turbidity, COD and DO. Studies on membrane fouling, membrane flux and membrane cleaning were conducted during the operation of bioreactor.

4. Results and Discussions

Some major conclusions that can be drawn from this study are i) Pilot scale setup of a submerged ceramic membrane bioreactor for microfiltration of synthetic fermentation feed has been fabricated. ii) Vacuum filtration has been used instead of pressurized filtration. iii) Aeration was found to be helpful in reducing the membrane fouling by partially scouring the membrane surface, which resulted in the removal of biomass and organic matter from the membrane surface iv) Treatment performance of MBR in terms of parameters like COD, DO and turbidity have been investigated and significant removal of COD and turbidity was reported v) The influent fed to the MBR for treatment was black in colour with a high turbidity and a very foul smell, whereas the effluent was a colourless, clear and odourless liquid vi) Increase in DO content in effluent was also observed vii) A gradual decrease in permeate flux was observed as the fouling of membrane surface due to suspended solids and organic matter increased with time viii) TMP was found to increase with duration of operation of MBR ix) Chemical cleaning of the membranes was done after the critical permeate flux value was reached. After cleaning, drastic increase in permeate flux was observed due to regeneration of the membrane surface. x) The filtration data was found to fit CPBM mathematical model more accurately as compared to SBM model which suggests that fouling due to complete plugging of membrane pores is taking place xi) According to General Standards for Discharge of Environmental Pollutants Part-A: Effluents set by Central Pollution Control Board, the effluent
(as per its COD, temperature, DO and turbidity values) is fit to be discharged as inland surface water and into marine coastal areas.

5. **Scope for future work**

There exists a lot of scope for future work in this project as all the parameters of study have not been investigated by us. Detailed studies on fouling of membranes can be done and data obtained can be fitted into various existing mathematical models such as the Activated Sludge Model (ASM), membrane fouling model and the interface model. Effect of activated sludge concentration, particle size and concentration, intermittent aeration, viscosity, aeration intensity can be further studied in this project. Membrane pore sizes and membrane surface properties, which have previously been found to affect membrane fouling, may be studied in detail in order to determine MBR performance in water treatment.

Further investigation of water quality in terms of Mixed Liquor Suspended Solids (MLSS), Total Nitrogen (TN), Total Phosphorus (TP), Dissolved Organic Carbon (DOC), Biological Oxygen Demand (BOD) can be conducted to determine the efficiency of the ceramic membranes. Concentration of heavy metals like Lead(Pb), Arsenic(As), Cadmium(Cd), Copper(Cu), Iron(Fe) in influent and effluent can be measured to check whether these membranes are effective in removing heavy metals.

Study of the growth and activities of microorganisms present in the sludge which consume organic matter and reduce the COD/BOD of wastewater may also be done for determining the optimum population of these organisms at which the highest reduction in COD/BOD of water occurs.