Effluent Treatment using Microbial Bio Reactor

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Abstract— Continuous discharge of effluent from industries into fresh water bodies has led to fresh water crisis. This creates an urgent need for the treatment of effluents. The membrane bioreactor technology is one such method which become more popular, abundant and are accepted in recent years for the treatment of many types of wastewater where the conventional activated sludge process cannot cope with either composition of waste water or fluctuations of waste water flow rate. The membrane bioreactor combines biological-activated sludge process and membrane filtration. Effluent degradation takes place with the help of biological microorganisms and generated biomass is separated through submerged membrane.

Key words: Effluent Treatment, Microbial Bio Reactor

I. Introduction

Membrane bioreactor (MBR) technology, which combines biological-activated sludge process and membrane filtration has become more popular, abundant, and accepted in recent years for the treatment of many types of wastewaters. Along with better understanding of emerging contaminants in wastewater, their biodegradability, and with their inclusion in new regulations, MBR may become a necessary upgrade of existing technology in order to fulfil the legal requirements in wastewater treatment plants (WWTPs).

A. Bioreactor

A reactor in which substrate is converted into product by the action of biocatalyst. This process can be aerobic or anaerobic. Bioreactors are used in Brewing industries, food industries, production of pharmaceuticals, sewage water treatment, industrial effluent treatment, etc. Size of bioreactor depends upon the purpose of use .Some examples of bioreactor with varying sizes are: Shake flask - (100-1000ml). Laboratory Scale – (1-50litre). Pilot Scale – (0.3-10 m^3).Plant scale- (2-520 m^3).

B. Parameters Defining Bioreactors

1) Type and form of biocatalyst:

- Free cells in submerged culture.
- Bound / immobilised cell/ enzyme.

2) Configuration:

- Tank (height: diameter <3m).
- Column (height: diameter>3m)

3) Hydrodynamics:

Perfect mixing, Partial mixing, No mixing.

4) Mode of operation:

Batch , Continuous, Fed-batch

C. Strategies for choosing a Bioreactor

- Microorganism species.
- Growth and oxygen requirement.
- Shear and Rheology Effect.
- Cleaning and Sterility.
- Foam

D. Industrial effluents

Industrial effluents are materials generally discarded from industrial operation or derived from manufacturing process. These are characterised by turbidity, conductivity, total hardness, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solid (TSS).These industrial discharge may also contain toxic substances such as heavy metals, pesticides, PCBs, dioxins, Poly-Aromatic Hydrocarbon (PAHs), Petrochemicals, Phenolic compounds, and microorganisms

E. Membrane

A membrane is simply two dimensional material used to separate components of fluids usually on the basis of their relative size or electrical charge. The normal pore size of Flat Sheet membrane is 0.03 to 1.3 microns, using micro or ultra-filtration to block bacteria and other solids in the water allowing for superior effluent quality.

F. Membrane Configurations for MBR

The configurations of MBR are based on either planar or cylindrical geometry. There are five principal membrane configurations currently employed in practice:

- Hollow fibre (HF)
- Spiral-wound
- Plate-and-frame (i.e., flat sheet (FS))
- Pleated filter cartridge
- Tubular.

II. Methodology

A. Process Description

Waste water collected from the wastewater collection system, initially flow through the coarse screen to remove large solid and then the wastewater combine with return flow from the sludge reduction system is fed to the Grit removal chamber to eliminate grit. Next, the waste water passes through flow equalization and primary sedimentation tank sequentially, which, however, are optional depending on the site's particular condition .The objective e of a flow equalisation tank is to generate stable flow downstream, while a primary sedimentation tank remove settle able and floating solid.

B. Pre-treatments

1) Screening:

Screening is a physical process meant for selective removal of undesired substances on the basis of their relative sizes. In MBR screening is done with the help of coarse screen and Fine screen.

2) Grit Removal:

Permanent grit removal facilities meeting the requirements of code &standards should be provided for sewer systems and industrial effluent system receiving substantial amount of grit

3) Primary Clarification:
Primary clarification must be considered for all plants. Proposals that do not include primary clarification should justify why primary clarifiers are not practical due to facility size constraints or limited benefit in comparison to the cost of handling primary solids.
4) Biological degradation & Filtration:
Biological treatment is normally aerobic, though some anaerobic MBR installations exist. Biological nutrient removal (BNR) is normally achieved by a combination of these aerobic within anoxic and anaerobic (An) conditions in the process tank conditions, recirculating the mixed liquor (or sludge) through the different tanks.
5) Filtration:
Filtration is done through the selective membrane module. The biomass coming out from the aeration tank is fed to the membranes, and the existence of Trans membrane Pressure (TMP) between membrane and aeration tank facilitates pressurised filtration through the membrane.
6) Aeration Tank:
It utilises aerobic process. Aerobic processes require dissolved oxygen to convert organic carbon to carbon dioxide and ammonia to nitrate (nitrification). These both represent biochemical oxidative ‘aerobic’ processes. The dissolved oxygen is provided through the aerators.

C. Mode of Operation

1) Side Stream MBR
2) Submerged MBR

Membrane separation is carried out either by pressure-driven filtration in side-stream MBRs or with vacuum-driven membranes immersed directly into the bioreactor.

The basic principle is that the feed water passes over the membrane surface and the product is called permeate, whereas the rejected constituents form concentrate or retentate.
Mass balance of the solute in the process can be presented by the equation:

$$Q_f\, C_f = Q_p C_p + Q_c C_c$$

Q_f – feed flow rate,
C_f – solute concentration in feed flow,
Q_p – permeate flow rate,
C_p – solute concentration in permeate,
Q_c – solute concentration in concentrate;
C_c – solute concentration in concentrate;
Membrane rejection of solutes can be calculated according to the following equation:

$$R = (C_f - C_p) \backslash C_f$$

Where,
C_f represents concentration of solute in feed flow and, Cp represents solute concentration in permeate.
The fraction of feed flow converted to permeate is called yield, recovery or water recovery (S).
Water recovery of the membrane process is given with the equation:

$$Y = Q_p / Q_f$$

, Where, QP is the permeate flow and QF is the feed flow.
According to recognized mechanisms, the fouling on the membrane occurs as:

1) Complete blocking caused by occlusion of pores by the particles with no particle superimposition.
2) Intermediate blocking caused by occlusion of pores by particles with particle superimposition.
3) Standard blocking where particles smaller than the membrane pore size deposit onto the pore walls thus reducing the pore size.
4) Cake filtration where particles larger than the membrane pore size deposit onto the membrane surface.

$$R_t = R_m + R_c + R_f$$

Where, R_m is the membrane resistance,
R_c is the cake resistance,
R_f is the fouling resistance, and
R_t is total filtration resistance.

D. Methods to Control Fouling

To control the fouling that inevitably occurs in MBR operation, several key parameters can be modified. The most important strategies are concentration polarization suppression, optimization of physical and chemical cleaning protocols, pre-treatment of feed wastewater, and mixed-liquor modification. Fouling related to concentration polarization can be reduced either by promoting turbulence or by reducing flux. As mentioned above, both MBR configurations need shear over the membrane surface to prevent this type of fouling

E. Design Consideration

1) Tank (Reactor) Design:
Capacities and Loadings

1) The design sludge retention time (SRT) should be at least 10 days but no more than 25 days. An SRT outside this range may be acceptable if supported by a pilot study.
2) The design hydraulic retention time (HRT) should be between 6 hours and 15 hours.
3) Organic loadings for reactors not required to provide biological nutrient removal should be in accordance with Section.

F. Mixing and Aeration Equipment

1) Mechanical mixing independent of aeration should be provided for all plants designed to provide biological phosphorus removal or de-nitrification.
2) Provisions should be included to lift equipment for removal, installation, maintenance, and repair.
3) In the case where a crane may be needed to lift equipment, access for the crane shall be considered.

G. Membrane Design

1) MBR processes should be based on maximum design flow rate criteria at the coldest expected wastewater temperature. Maximum day or peak hour flows at the expected coldest wastewater temperature will dictate the membrane surface area required.
2) Membranes need to be mechanically robust, chemically resistant to high chlorine concentrations used in cleaning, and non-bio-degradable.
3) Membranes should be made from the following materials

Polyethersulfone (PES);
Polyvinylidene fluoride (PVDF);
Polypropylene (PP);
Polyethylene (PE);

4) The nominal pore size used in a MBR for microfiltration membranes should be at least 0.10 um but not more than 0.4 um.
5) The nominal pore size used in a MBR for ultrafiltration should be at least 0.02 um but not more than 0.10 um.
6) The MBRs should be designed for an average daily net flux rate of not more than 15 gallons per day per square foot of membrane area (gfd). A peak daily net flux rate equal to or less than 1.5 times the average daily net flux rate.

H. Biological Performance of Membrane Bioreactor

1) Microbiological Aspects:

In the biochemical stage of wastewater treatment, organic carbon and nutrients are removed from wastewater by microbes. These microbes live and grow enmeshed in EPS that bind them into discrete micro-colonies forming three-dimensional aggregated microbial structures called flocs. The ability of microorganisms to form flocs is vital for the activated sludge treatment of wastewater. The floc structure enables not only the adsorption of soluble substrates but also the adsorption of the colloidal matter and macromolecules additionally found in waste waters.

2) Nitrification/ Denitrification and Phosphorus Removal:

Nitrogen can be removed from wastewater by reducing nitrate to nitrogen gas (N_2) in the process of anoxic de-nitrification. Because of the low growth rate and poor cell yield of nitrifying bacteria, nitrification is generally a rate-limiting step in biological nitrogen removal performance.

Phosphorus removal will be significantly improved in an MBR by a physical retention of PAOs, whose\ size is typically larger than 0.5 μm. Since an MF membrane (0.2 μm) will act as a physical barrier to retain the PAOs in the reactor, sufficient biomass is provided for the EBPR mechanism to take place

I. Bacteria and Virus Removal

The removal of enteric viruses requires specific attention, given their low infective dose, long-term survival in the environment, and low removal efficiency in the conventional wastewater treatment.

III. Result

The high percentage removal of suspended solids by the MBR indicates that the membrane was in a good condition. MBR suspended solids removal effectiveness as a result of the fact that separation of bio-solids by membranes is independent of the bio solid flocculation and solid reduction in permeate water depends on the pore size and the integrity of the membrane. Only a small fraction of no biodegradable substances passed through the membrane. Similar results were reported by Jianguo (2004) .The effluent COD consists of principally aquatic humic substances, which are naturally occurring compounds. They are hard to biodegrade aerobically and they are responsible for the yellowish colour of treated wastewater effluent. These matters may consist of humin, and fulvic acids. In the present study, the MBR achieved a high removal of Al, Pb, and Cu (81%, 94%, and 91%, respectively) which indicates that these matters are mostly in particulate form while other metals exist in both particulate and soluble forms in wastewater. Hence, the soluble parts can pass through the membrane and their concentrations in the effluent are relatively significant. Therefore, removal efficiency for Fe, Ni, and Cr (53%, 59%, and 49%, respectively) is less than that of Al, Pb, and Cu. As some studies have reported, the fluctuation in heavy metal removal efficiencies in MBR pilot is attributed to some factors, such as metal competition, changes in pH and MLSS concentrations, and fluctuations in influent metal concentrations Results from permeate analysis in this study demonstrate that almost complete removal of coliforms can be achieved by using MBR. This was expected since the size of coliform bacteria is larger than the membrane pore size.

IV. Conclusion

The application of MBR technology is rapidly expanding, with new installation occuring every year. MBR technology is highly suited for the reclamation of wastewater due to the ability to produce drinking water quality effluent. The effluent produced can be reused within industrial processes or discharged to surface waters without degrading streams and rivers.

Heavy metals present at very low concentrations are toxic for the environment and the aquatic life as well as human health. Therefore, state-of-the-art technologies are used for removal of these pollutants from the environment. As the application of MBR technology for water and wastewater treatment is rapidly expanding every year, the following conclusions drawn from the present study:

1) MBR treatment with biomass concentration (MLSS) 2000 mg/L provided an excellent treatment for industrial wastewater treatment effluent.
2) The removal of SS reached 99.99% resulting in a MBR permeates with SS levels below 1 mg/L. This demonstrated excellent solids separation is reachable through the UF membrane.
3) MBR showed a good reduction of inorganic and biodegradable matter. The average COD removal was 75% resulting in an effluent with COD ranging between 41 and 51 mg/L.
4) MBR showed very high removal of total coliform. The MBR effluent with such a high quality can be reused within processes industries such as refineries, petrochemical plants and cleaning, recreational water supplies, or discharged to surface waters.

Acknowledgment

I would like to take this opportunity to acknowledge the guidance and support given by my esteemed and worthy guide, Mr.Ashutosh Mishra (HOD, Department of Chemical Engineering of Dr.AITH). His influence, leniency, vital suggestions, keen interest, inspiring guidance and approachability have in many ways assisted in my progress to the completion of this project.

I would also like to thank all the faculty members of Chemical department who has directly or indirectly co-operated and encouraged during the course of study.

Finally, I would like to thank my family & friends for their constant love and support and for providing me with the opportunity and the encouragement to pursue my goals.

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