Volume 2 : Edition 12 – Membrane Bio Reactor *Jan 01, 2023*

Dear Water Warriors,

Recycle needs required robust pre-treatment upstream of RO. The Clarifier (Secondary) after aeration tank always required operator's attention and at times a trouble point.

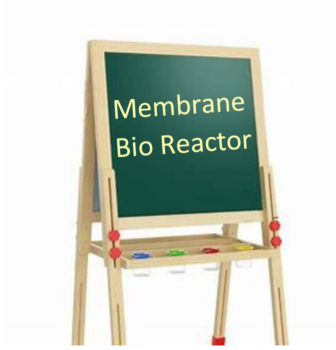
Membranes post Aeration for separation of biomass though challenging in terms of design, was sure of quality that need to be fed. And hence is becoming increasingly popular.

This issue of '**Waughter**', we dedicated the entire focus on MBR and accumulate our ideas on subject.

Nidhi Jain
Civil Engineer

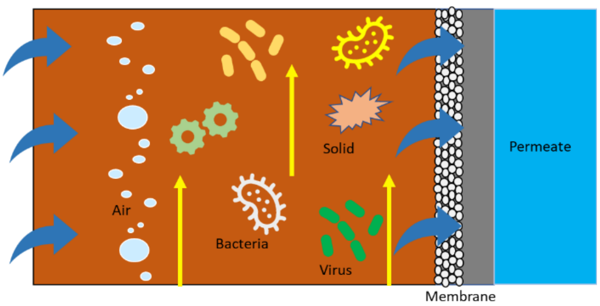
Effluent Treatment Plant, Sewage Treatment Plant, more commonly known as ETP/STP designed with MBR are a peace of mind. Highlights:

- History
- Fundamental MBR Design
- Choice of membrane – Construction & Material
- Operation
- Trouble Shooting
- MBBR-MBR Combo is wrong.



MBR: Need & Innovation?

The membrane bioreactor has become an important processing tool in the treatment of waste liquids and of suspensions of waste solids. "Necessity is the mother of invention" From the dawn of time to the present day, numerous examples demonstrate the truth of this proverb. The membrane bioreactor (MBR) has emerged as an efficient compact technology for municipal and industrial wastewater treatment.



MBR is, in fact, one of the most important innovations in wastewater treatment as it overcomes the drawbacks of the conventional ASP, including large space requirement for secondary clarifiers, liquid–solid separation issues, production of excess sludge, and limitations with removal of recalcitrant.

History?

The idea of combining sludge digestion with a very fine filter was first developed in the mid-1960s and MBR process was introduced in the late 1960s with the availability of commercial-scale ultrafiltration (UF) and microfiltration (MF) membranes.

As a system with flat plate membranes in a side stream loop. This development was made possible by the appearance on the market of commercial scale MF and UF membranes. In this form, the MBR served industrial markets that could afford a rather expensive system producing a low-value product.

The breakthrough, which allowed the MBR to grow much faster, was the development in Japan in 1989 of the submerged membrane. The resultant submerged (or immersed) membrane bioreactor used two orders of magnitude less energy than the side stream version. It was this version that then entered the European market in the mid-1990s.

Since 1990 the numbers of installed membrane bioreactors have grown almost exponentially.

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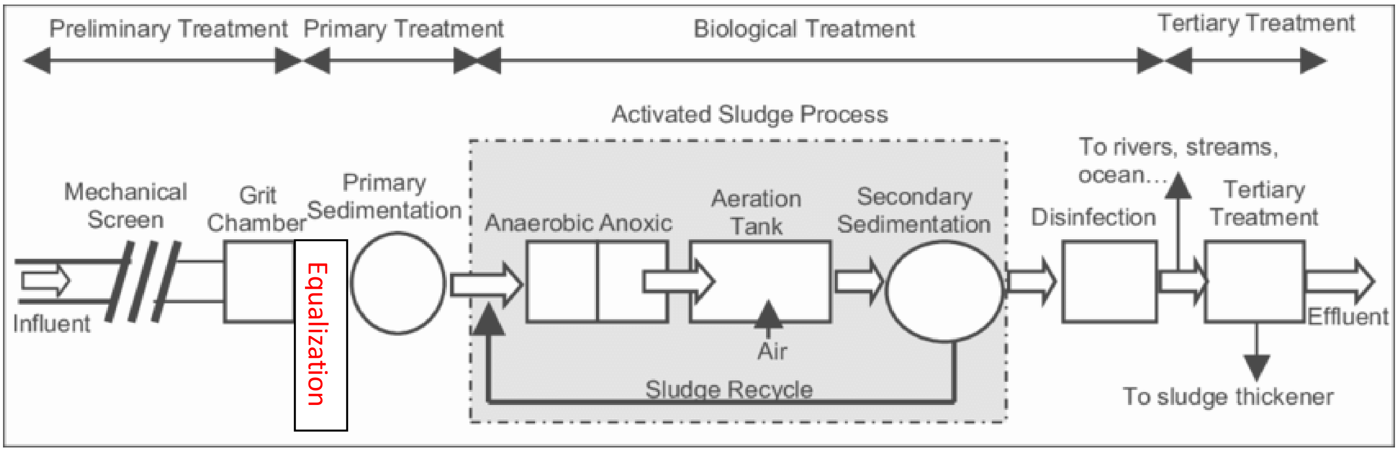
Fundamental MBR Idea is to replace Secondary & Tertiary Treatment?

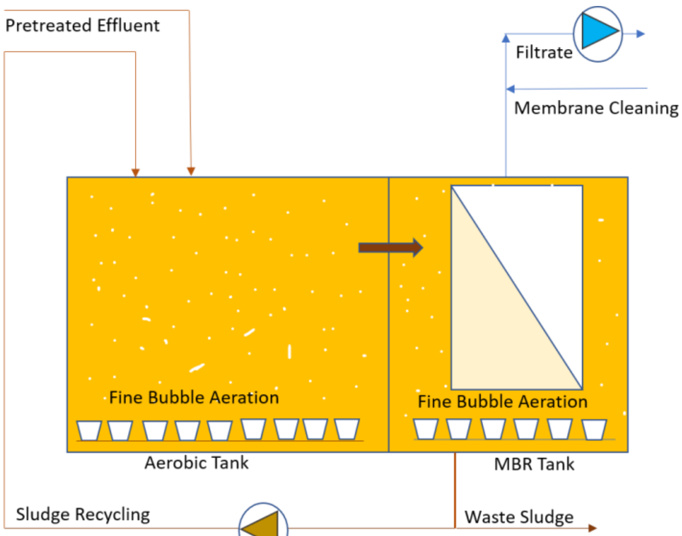


1 The waste water treatment Plant remains the same up-to Aeration Tank shown above, albeit designed for high MLSS.

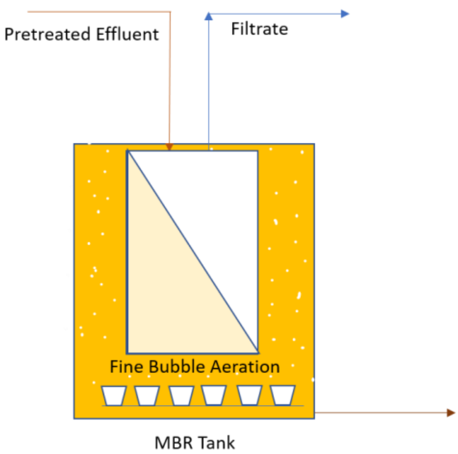
2 The Secondary clarifier is completely abandoned and instead water biomass mixer is taken into a Membrane Tank.

3 The membranes submerged in the membrane tank are connected at the suction of a pump (like Suction strainer).

4 The Pump operating thus sucks X clean water and leaves the biomass in membrane tank. To avoid concentration of biomass 3-5X recirculation is required.



Side Stream



Submerged

Membranes in Same Tank?

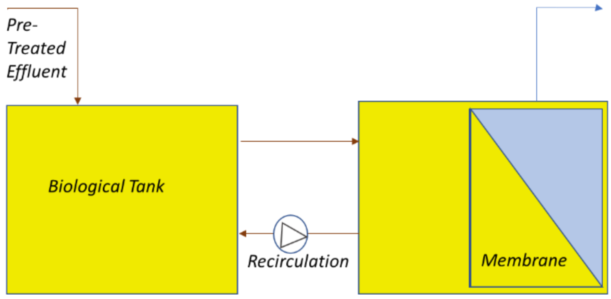
For smaller size plants ~ 30 m3/day it is a good idea to submerge the membranes in aeration tank itself and save on capex and air. But be aware since 3-5X recirculation is not available, membrane air-scouring is very critical to avoid membrane fouling.

Need of Anoxic Tank?

It's always advisable to have an anoxic tank upstream of Aeration tank. Higher MLSS in Aeration means low sludge wastage and high sludge age. Autotrophic activities will generate NO3 that need to de-nitrified in anoxic condition for better membrane life and to avoid slime deposit on membranes.

Working Principle of Membrane Bio-Reactor?

Membrane Bioreactors works on the principle of combining conventional biological treatment like activated sludge processes with membrane filtration to provide an advanced level of organic and suspended solids removal.



In the MBR process, membranes act as a solid-liquid separation device, keeping the biomass within the bioreactor before discharging the treated effluent to nature. Since the biomass rejected on membrane surface need to return to Aeration Tank, we have 2 options:

Pump to Design: Feed 3-5X water to MBR Reactor and suck 1X permeate, the rest returns from MBR tank to Aeration Tank.

Pump from Design: Draw 3-4X water from MBR reactor and feed to aeration tank. The over flow of aeration tank would now feed the Membrane Reactor.

MBR: Component & Design?

MBR consists of basic design with membrane bundle, module row and technical module.

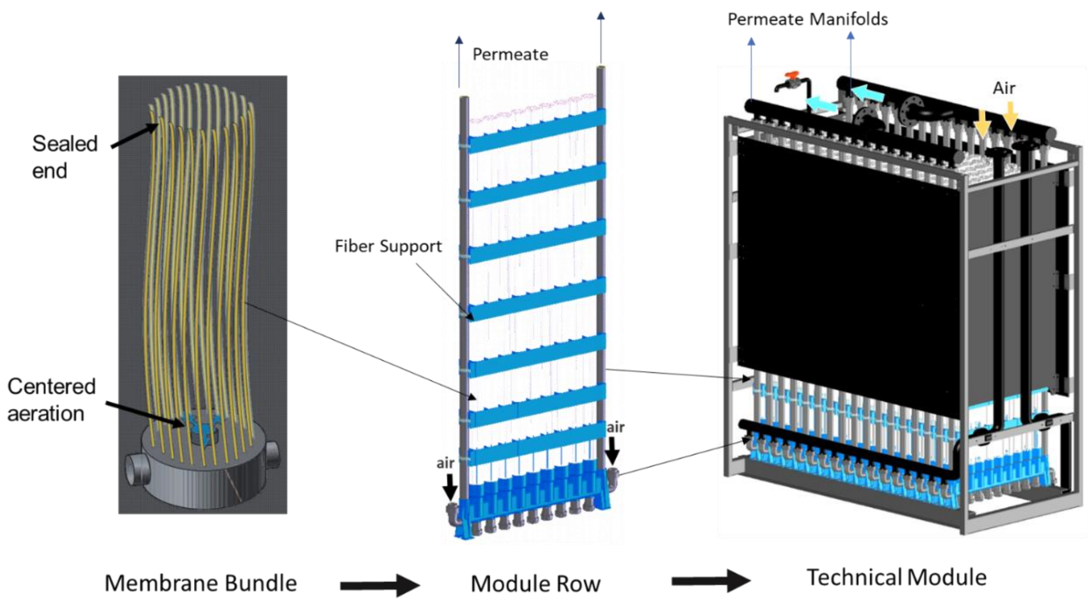
1. Membrane module consists of fibres attached in a bundle having sealed end. Bacteria or germ gets filtered via these membranes and permeate passes.

2. Module Row consists of bunch of membrane modules arranged in series with help of fibre support and there is provision of air in both ends of fibre support. Permeate gets extracted from top of permeate manifolds.

3. Finally technical module consists of all basic arrangements including membrane module, fibre support, module element along with air supply.

4. Accessories include:

- Membrane Degasification system
- Permeate Extraction Pump
- Membrane Backwash Pump (In HF Module)
- CIP system
- Membrane Module lifting arrangement
- & Off-course the most important – membrane aeration equipment. (Approval must from membrane module supplier)



Choice of Membrane?

Membranes can be classified on the basis of types of material and construction. Based on the membrane material, membranes can be classified into:

1. Ceramic membranes
2. Polymeric membranes
3. Composite membranes

Ceramic membranes

It exhibits good filtration performance due to their high chemical resistance, integrity, inert nature, and ease of cleaning leading to low operating costs. Ceramic membranes are also highly hydrophilic which makes them more fouling resistant.

However, their high cost of fabrication and fragile nature make them economically unfeasible for use in MBR applications.

Polymeric membranes

These are the most common membrane types available. Polymeric membranes have good physical and chemical resistance but are mostly hydrophobic. Due to their hydrophobic nature, polymeric membranes tend to foul easily, but they tend to be widely used now due to the ease of fabrication of the pore sizes.

Composite membranes

They are membranes produced from two or more materials to combine the strengths of the constituent materials in the final product. Typically, one material constitutes the active surface and another forms the support layer.

In composite membrane applications, hydrophobic membranes are coated with hydrophilic polymer to overcome the fouling shortcoming.

The comparison of various membranes is presented in below table. The tubular membrane is more compactible as compared to other but due to high maintenance it gets avoided.

Module	High pressure Operation	Membrane Replacement	Aseembly or Disassembly	Hold Up Volume	Ease Of Cleaning	Ease Of Operation
Hollow Fiber	No	Yes	Difficult	Low	Moderate	Good
Plate Frame	No	Yes	Easy	Moderate	Moderate	Moderate
Tubular Membrane	Yes	Sometime	Easy	High	Very Good	Good

The majority MBRs are Flat Sheet or Hollow Fibre with PVDF material.

Membrane Construction Choice?

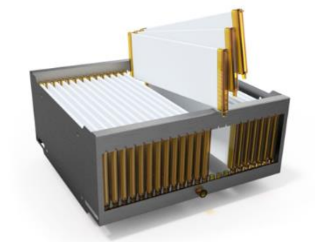
Based on construction membranes are classified as:

Tubular Ceramic/Organic Membrane

Tubular membranes are membranes that bring the porosity expected for microfiltration/ultrafiltration (MF/UF) separation along with the added features of a durable material with high chemical, temperature, and pressure tolerance.

These membranes offer lifecycles up to 20 years or more but due to high cost they are often neglected.

Flat Sheet Membrane



Flat Sheet Membranes are types of Bioreactor membrane that have Sheet type configuration and are mainly rectangular in shape.

The liquid flows through even gaps in the membrane arrangement and it is sucked from all odd gaps to allow liquid to pass through the membrane surface. Continuous aeration is required for flat sheet membrane.

Hollow Fiber Membrane

Hollow Fiber Membrane are the most common type of membrane used now- a days.

These are nearly always vertically oriented with the aerators either integrated with the membrane module or fitted to the frame. The fibers are usually provided with some slack, to allow them to move laterally in the flow of air bubbles which also air lift the sludge through the fiber bundle. Cyclic aeration allows to reduce air consumption but increases operational cumbersome.

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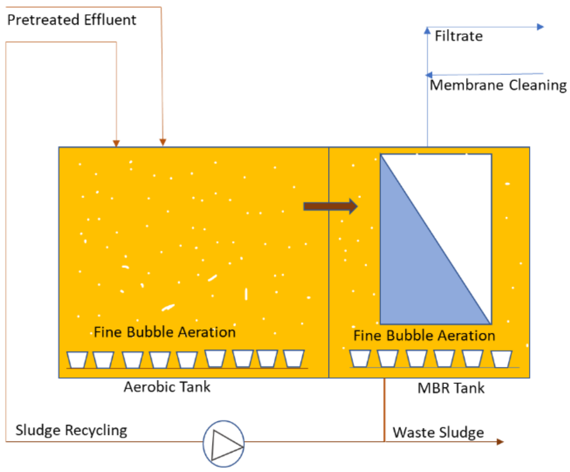
MBR: Process & Operation?

There are two possible membrane configurations for MBR processes. Membranes can be installed either inside (submerged) or outside (side stream) the reactors. The most used process configuration is submerged side stream configuration.

Submerged Side stream Configuration

In Submerged Side Stream Configuration process MBR is within the bioreactor and operated under vacuum since it is more cost effective at higher wastewater flowrates. It is currently the dominant MBR System.

Hollow Fibre membranes are generally applied in submerged configurations.



MBR Operation is based on three Sequence

1. Filtration phase generally referred as treatment phase. It usually takes 10-12 min.

2. Then Backwashing (Hollow Fibre) or relaxation (Flat Sheet) cycle takes place for maximum 60-180 sec.

3. Degasification is also required by under pressure filtration. It's time duration lies between 10-20 sec.

One major feature of MBR process is its high treatment stability and robustness under varying operating conditions.

Operating Conditions?

1. MBR System can operate at longer SRT (Sludge Retention Time).

2. MBR HRT (Hydraulic Retention Time) are much lower than CAS (Conventional Activated Sludge).

3. MBR's in side stream configuration is usually operated at high MLSS.

4. High MLSS concentration in MBR Processes may require a high-capacity aeration system to ensure adequate oxygenation in aeration tank.

5. Membranes are operated across a wide range of permeate fluxes and TMP depending on module type and configuration, membrane material, and solid content of the feed. Always design as per guidance of membrane supplier.

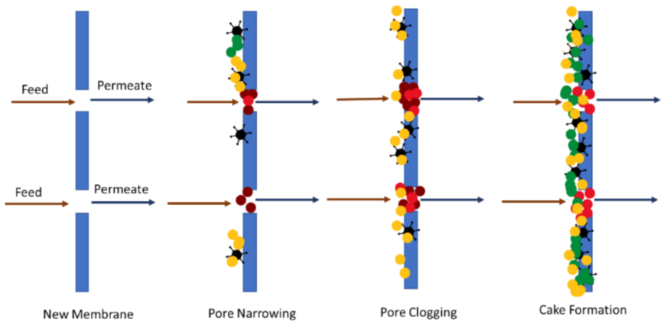
6. Operating at extended SRTs and possibly lower F/M ratio, may require a closure monitoring of biology. While MBR means "Easy Operation", it's not "Fit & Forget."

7. MBR must be Automated and minimum instrumentation recommended is given below:

Vertical	Equipment
Electrical	MCC & Control Panel
Electrical	VFD
Instrument	Flow meter
Instrument	Flow Transmitter
Instrument	Pressure Transmitter
Instrument	Air flow meter
Instrument	DO meter with analog output
Instrument	DO meter
Instrument	Pressure Gauge
Instrument	Pressure Switch
Instrument	Level Switch
Instrument	Level Gauge

Trouble?

Membrane fouling remains a major drawback of MBR, as it significantly reduces membrane performance and membrane lifespan, leading to an increase in maintenance and operating costs.



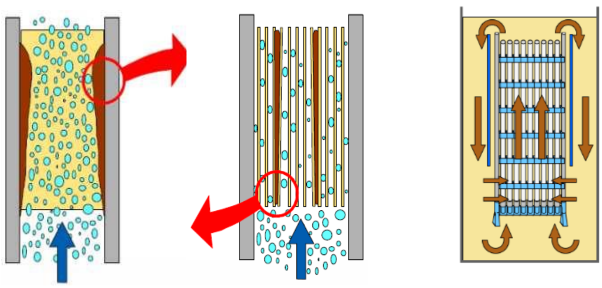
Membrane Fouling in MBR

Fouling in MBRs occurs in different forms, namely, pore narrowing, pore clogging and cake formation. Pore clogging refers to the blocking of membrane micro pores by foulants.

Pore clogging depends, to a large extent, on the size of the particle and the membrane pore size. The attachment of the materials in the pores is aided by sticky substances in the solution.

Cake formation, on the other hand, results from the continuous accumulation of bacteria clusters, biopolymers, and inorganic matter, which form a layer (bio cake) on the membrane. The cake layer increases membrane filtration resistance.

In operational terms, membrane fouling decreases the permeate flux when the MBR is operated at constant transmembrane pressure (TMP), and results in the increase of TMP when the MBR is operated at constant permeate flux.



To troubleshoot or control membrane fouling the operators need to observe.

Membrane Aeration

It is done to prevent sludge from sticking to fibres or plates. Please record the video of early commissioning days and keep it safe. Compare periodically (turbulence) the bubbling on top. Visual inspection can give lot of information on aeration effectiveness.

Backwash

It is a process of injection of treated water in a reverse way especially in hollow fibre membrane to prevent fouling. Maintain flow and check instrument accuracy as well as level changes in MBR reactor. (Applicable for Pump from design)

Relaxation

In this filtration is stopped for short time especially for flat sheet. During this face aeration is kept on. One can also consider a gravity assisted (Not Pump) backwash of flat sheet membranes at a very low flowrate.

Chemical Clean of Membranes

Maintenance cleaning is preferred once in a week while recovery cleaning is suggested 2-3 times in a year.

Some membranes manufacturer recommends NaOCl injection during backwash at-least once a day.

Depending upon the LSI of water in membrane reactor, even citric acid can be injected once a day.

The other noted troubles from various sites are:

1. Cavitation of Permeate Extraction Pump
2. Air lock and need of priming or ejector for degasification
3. Overuse/underuse of certain section of modules (reflects in Differential pressure of flux)
4. Fe deposit on membranes (If excess Fe carryover from Primary clarifier $FeCl_3$ dosing.
5. Floating plastics in MBR Tank – Check screens functioning.

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Oversell the MBR:

In recent times "Aktion Team" has seen a few sites where customers have either installed Moving Bed Biofilm Reactor + Membranes or are planning to do so in near future.

To our readers thus we once again clarify the 2 different growth types:

A. Suspended growth – as in ASP

B. Fixed film – as in MBBR

The above two are not just the name but related to type of biomass. While activated sludge biomass (MLSS) is quite granular, often hydrophobic and presents a very clear separation of water from bio-mass (remember SVI), the biofilm sloughed off the MBBR carrier are fluffy low density and often easy to float.

Further, majority of good MBBR are not designed with RAS recirculation – a must for Membrane filtration in MBR. If one thinks that we can do the recirculation, the way we do in simple MBR process with conventional aeration tank, it would create a flux imbalance in MBBR reactor. The L X W ratio of MBBR reactor and velocity of water across Elevation is an important design criterion. Disturbing the same can lead to no performance of biology.

Thus, MBR after MBBR reactor is a wrong design and actually would lead to sever biofouling issue, something we don't want on membrane supplier.

The right technology after MBBR is actually floatation, thanks to the lower sp. gravity of biofilm and also its tendency to keep releasing gases even when the biomass is sloughed.

To summarize:

- MBBR is not Aeration Tank + Plastic Media.
- In MBR membrane is not just about Filtration and good treated water quality.

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Nidhi Jain • 1st
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Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead.

Our next edition focuses on: **"Membrane Bio Reactor – Process, Design & Operation"**

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