Waughter

AKTION CONSULTANCY

Volume 1 : Edition 8 – Micro & Ultra Filtration (MF & UF), Moving Bed Biofilm Reactor (MBR) *Aug 31, 2021*

Dear Water Warriors,

The increase in popularity of Reverse Osmosis posed new Challenge in form of controlling SDI at the inlet of RO giving Rise to new solution up-stream of RO as MF/UF. MF though did the job was not very effective against Microbiology.

UF Provided excellent Control on Biofouling but thrown a new Challenge in form of use of HCl, NaOH and NaOCl during CEB. Use of Membrane further in microbiology (MBR) is to get rid of challenges of biomass water mixer settling.

This issue of '**Waughter**', we discuss the wonders of Membrane science for benefit of water.

Nidhi Jain
Editor Waughter

In this edition of water, while we cover membranes that provide an additional choice to process engineers in water treatment as well as wastewater, Highlights:

Q. Which are target Impurities in UF?

Q. Choice of Construction Vs Target Application?

Q. MBR: Is Monitoring Return MLSS Important?

Q. Why we generally prefer MBR Option?

Q. Operation & Automation of UF?

Q. What is Membrane Bioreactor?

We have not yet covered effluent treatment technologies in Waughter and thus only Membrane part of MBR is discussed here, not biology.

Q. Which are target Impurities in UF?

Ultra-Filtration (UF) aims at full or partial removal of impurities in comparison to NF & RO as shown below.

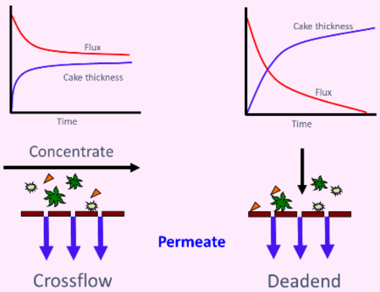
Parameter	Unit	Feed	UF	NF	RO
pH		7			~7
TSS	mg/l	35	1	0	0
Turbidity	NTU	104	1	0	0
Oil & Grease	mg/l	12	1	0	0
Colloids	SDI	>7	1	0	0
Color - Soluble	Pt Co	83	40	35	15
Color - Pigment	Pt Co	45	1	0	0
Fe	mg/l	6	1	0	0
Pb	mg/l	2	1	0	0
Zn	mg/l	1	1	0	0
Ca & Mg	mg/l	120		1	0
SO4, CO3	mg/l	125		1	0
Na, K	mg/l	170		170	0
Cl, NO3, HCO3	mg/l	310		310	0
SiO2	mg/l	22		11	0
CO2	mg/l	6	6	6	6
COD - Organics Soluble	mg/l	120	60	35	0
COD - Organics Particulate	mg/l	10	1	0	0
Pathogens - Bacteria, Virus	TBC / 1000 ml	10^5	1	0	0
Endotoxins - Bacteria Dead Body	EU/100 ml	200	1	0	0

0: means it will remove but Foul.
Gases: will not be removed by Any process
COD Removal: MWCO Dependent

Why one thinks of MF/UF?

If you look at below table, you observe that conventional coagulation filtration can remove TSS, Turbidity and SDI; the particles above >0.1µ, are still a concern for RO. Thus, UF produces best feed water quality to RO.

Item	Measurement method	Unit	Raw Water	Coagulation/ Sand Filtration	MF(USV) permeate
Turbidity	Turbidimeter 1720C(HACH)	NTU	2.352	0.390	0.035
Particle count (> 0.1µm)	Particle counter MILPA-1(MIKUNI)	No./ml	> 9,999	> 9,999	30-40
SDI	0.45 µm x 47mmΦ 15 minutes	—	> 6.67	4.8	1.7



MF/UF membrane are typically 0.1-0.01µm and are used as crossflow filtration for majority of the applications as the crossflow stream shall sweep membrane foulants.

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Thank you for making the ZeeWeed* MBR as India's most preferred choice for advanced decentralised sewage recycle

1000+ installations in India

(MBR starts at 5 KLD)

TOP 3 REASONS

why urbanization sector is adopting ZeeWeed MBR technology?

REUSE QUALITY

Best in class treated effluent quality ideal for reuse

RELIABILITY

> 10 years membrane life with robust & simple process

FOOTPRINT

Upto 50% less space than conventional technology

*may be registered in one or more countries.

PURE WATER

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Choice of Construction Vs Target Application?

Tubular or Multibore Module

Is used when higher particle size in feed or high viscosity needs higher shear force. Flux is usually low.

Capillary Module

Common choice for water & Waughter, flux 40-80 l/m2.h, usually cross flow but can be used as dead end for clean water.

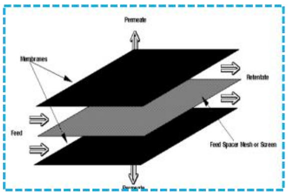
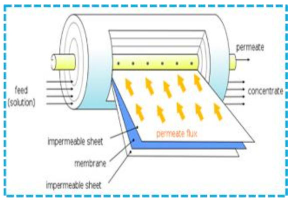


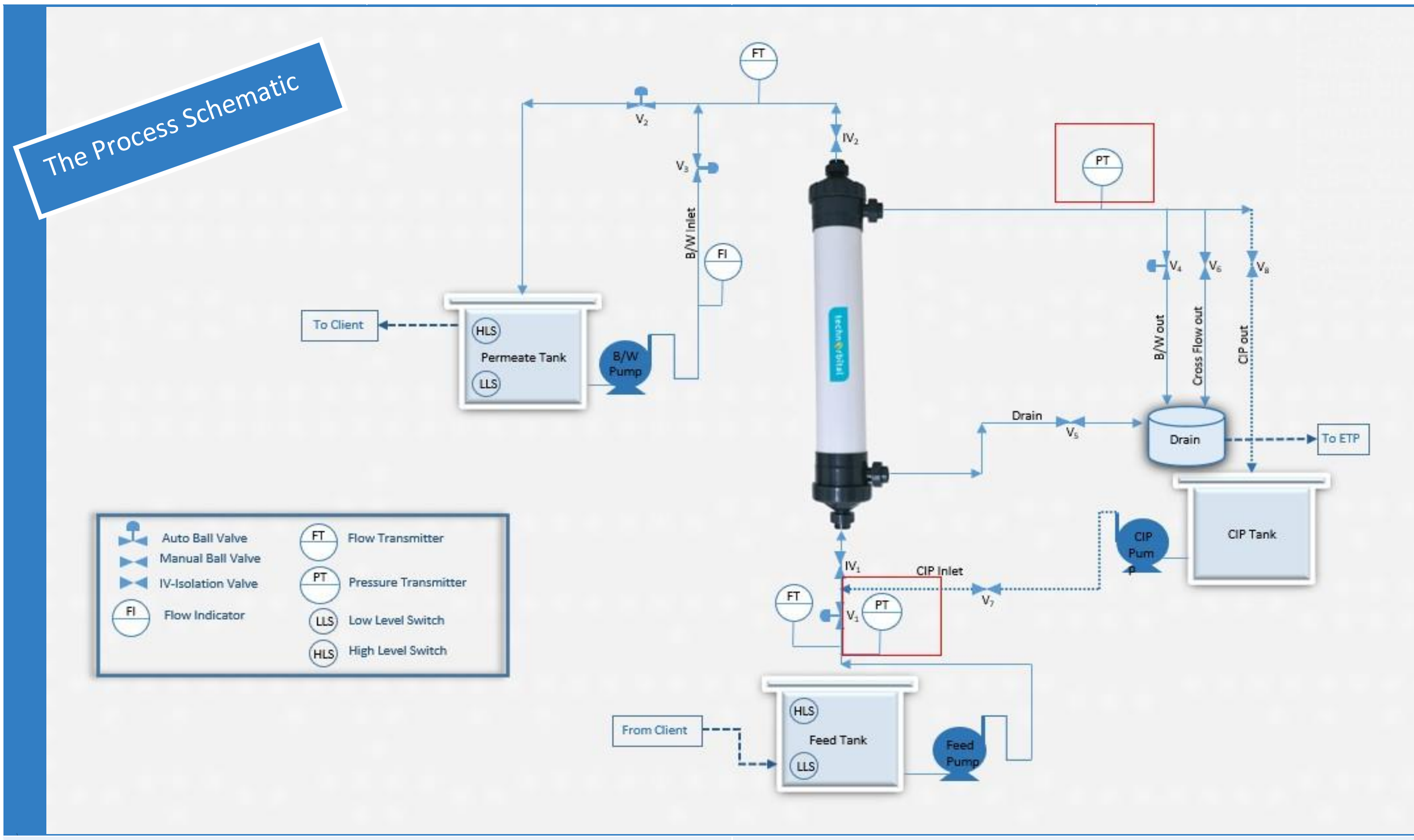
Plate And Frame Module

The beauty here is you can open frame and wash membrane. Thus, only recommend for unique application. e.g., when high O&G, Fat.



Spiral Wound Module

As you know the feed here is as stringent as in RO, the only known application for such type is colloidal silica removal post Demineralization.



MF/UF process is a batch process. We need Feed Tank, Product Tank. Since batch could be just 30 or 60 min, UF is always 100% Auto operation.

The crossflow stream has contaminants and thus cannot be looped back to Feed Tank. The backwash water should be pure permeate, and post backwash it shall be discarded.

In UF applications, if Chemical Enhanced Backwash (CEB) is considered; the Acid, Alkali laden waste shall be managed accordingly.

Adequate Instrumentation for automation hence a pre-requisite for success of a UF Operation. Irrespective of supplier of UF, the one shown above is bare minimum.

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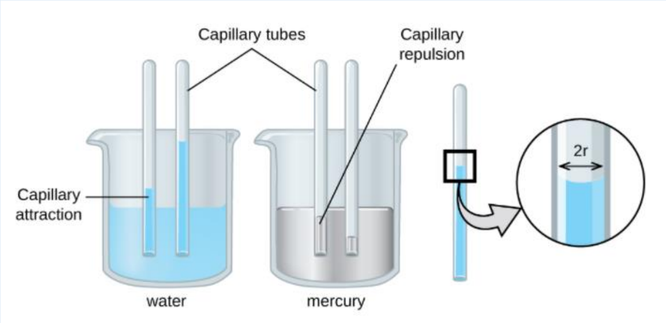
Material– Hydrophilicity & Strength

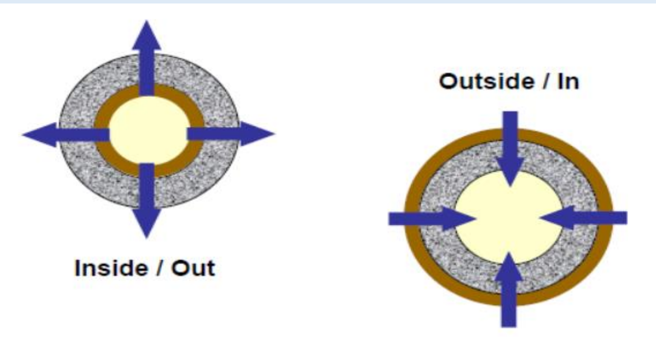
Hydrophilic means water loving. The membrane which is hydrophilic would have more contact with water on its surface. Lesser the degree of contact of water on the membrane surface, higher the hydrophilicity. So, the membrane which is hydrophilic can easily be washed by water for removing impurities.



The figure above explains Surface tension, the love and repel relation of a fluid H_2O or Hg and glass. Similar relation in context of H_2O and different material like PES, PAN, PVDF, CPA, etc.

Membrane Material	Possitives	Care Needed
Polyethersulfone (PES)	Good thermal & chemical stability	Less hydrophilicity leads to fouling
PVDF	High mechanical strength & abrasive resistant	Less membrane wettability/Hydrophobic → leads to fouling
PAN	High hydrophilicity, chemical stability against chlorine, NaOCl, & NaOH	Low chemical resistance and strength

Membrane manufacturer issue process guide like in-out filtration or Out-in Filtration for Feed, considering strength & hydrophilicity. Be aware during backwash the direction is reversed.

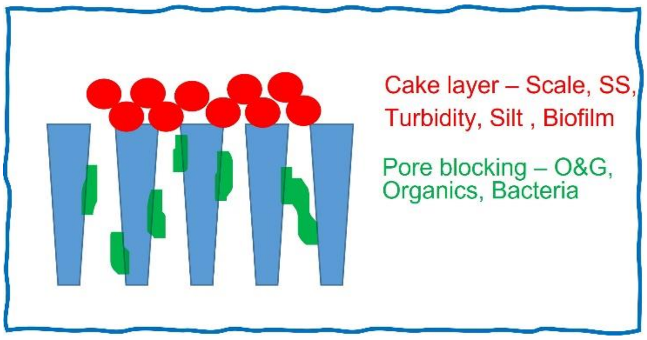


Be carefull to understand from manufacturer about his views and engineering ideas on use of their product for an application.

Operation of UF Plant…1

Once the inside or outside surface start filtration, suspended matter present in it will start accumulating. Cross flow configuration where 5-10% of waster is rejected out helps in reducing accumulation.

Backwashing of membrane is carried out by using the permeate water in the reverse flow and the debris deposited on the surface of the fibre is dislodged.



Fouling in UF leads to either cake formation because of deposition of matter or pore blocking. Both of these phenomena results into increase in TMP when the UF is operated at constant permeate flux.

Transmembrane Pressure (TMP) is the pressure gradient of the membrane, that is the average pressure of the feed minus the product pressure.

TMP Clean = Avg Applied Pressure – Product Pr
= [(Feed Pr + Reject Pr)/2] – Product Pr

Role of Chemical Enhance Backwash (CEB)

The Chemical is added with permeate to help in CUTTING the deposits. Hydrophilicity thus is of paramount importance in membrane selection as Water and Chemical must reach all pores to CUT.

The logic to keep membrane Hydrophobic is good as it prevents fouling. But what if they foul? Hydrophobic membranes are difficult to clean.

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Automation & Control Philosophy…2

Rule 1

Instrumentation helps in process control & automation and can never be more then expectation of process design engineer. Let's understand our operation.

At time = 0, Plant goes in service by an operator and what operator would like to know?

What	How	Log (Yes / No)
Feed Flow	Manual	Yes
Feed Pressure	Manual	Yes
Cross Flow	Manual	Yes
Product Flow	Manual	Yes
Reject Pressure	Manual	Yes
Product Pressure	Manual	Yes

At time = 25 min, what will happen, off-course some deposition on membrane will result in

What	How	Observation	Change
Feed Flow	Manual	Yes	↓
Feed Pressure	Manual	Yes	↑
Cross Flow	Manual	Yes	→
Product Flow	Manual	Yes	↓
Reject Pressure	Manual	Yes	↑
Product Pressure	Manual	Yes	→

Would you like to sit near plant and regulate it for 48 time a day * 7 days a week? NO

Rule 2

UF Plant is always Auto Operation wrt to Service Cycle Filtration, Backwash & CEB (if needed)

Rule 3

Membrane shall not Foul, we should have Auto Cure or At-least Stoppage of Plant in case of failure to our operational Idea.

1. Increase in TMP beyond the limiting no < 1.5 kg/Cm^2 (Low Cost - DPT or Individual PTs)
2. Increase in Feed Pressure > 3.0 kg/Cm^2 (Lowest Cost - Pr Switch)
3. Drop in Permeate Production? (High Cost – Flow Transmitters – recommend for large Plants, connected with VFD to regulate Feed flow, and allow to increase permeate production till allowed by PT readings)

Pre-treatment for the UF System

Selection of any membrane techniques depends on the inlet parameters of the feed. If the feed has suspended solids or colloidal solids, then the influent is passed through a pressure sand filter.

Anything that is needed to ensure Feed Limiting conditions are within limit for

- TSS
- Turbidity
- Temperature
- COD
- Oil & Grease
- Free Residual Chlorine
- pH

Additionally, for In-to-Out membrane, we have limit on particle Size to enter in UF fiber. One must put a Basket Strainer of Micron rating i.e., = Inner pore día in mm ÷ 8, i.e., if pore dia is 2 mm or 2000 micron, the basket strainer micron rating shall be 2000 ÷ 8 = 125 micron. Any larger particle entering the UF fiber (Inside) is not recommended.

For Out to In Filtration Basket Strainer of 200 micron is good. One can go for a strainer of a smaller size also but that leads to frequent chocking of strainer itself.

Operation, CIP & Maintenance and Membrane Storage

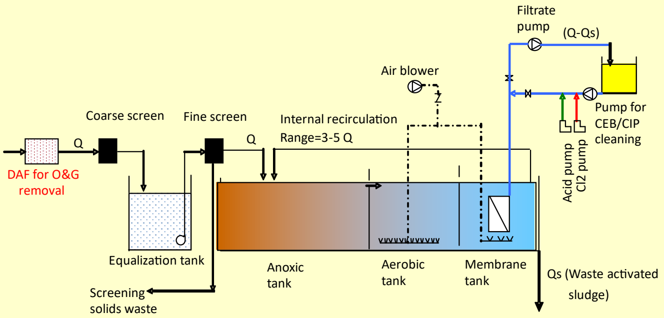
UF System Operation Logic

Step Description / UF System Start Mode	Sr. No.	Time	Flow Rate	UF Feed Pump (P1)	UF Backwash Pump (P2)	CIP Pump (P3)	Feed in Valve (V1)	Permeate Out Valve (V2)	Backwash In Valve (V3)	Backwash Out Valve (V4)	Drain Valve (V5)	Cross Flow Out Valve (V6)	CIP In Valve (V7)	CIP Out Valve (V8)	Feed Isolation Valve (IV1)	Permeate Isolation Valve (IV2)
Filtration Cycle																
Filtration Service	1	29 min	—	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	ON
Backwash	2	1 min	—	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON
Draining	3	NA	—	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON
Attention !	If TMP after backwash is still higher than the limit of 1.5 kg/cm2, perform the backwash cycle 2 times - 5 times subject to avaibility of permeate in permeate tank.															
Membrane Performance Restoration																
Draining	1	NA	—	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON
Clean In Place	2	30 min	—	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON
Soaking	3	60 min	NA	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
Draining	4	NA	—	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON
Backwash	5	1 min	—	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON
Flushing	6	1 min	—	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	ON
Filtration Service	7	29 min	—	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	ON
Attention !	1) The BW out valve V4 shall be manually activated to open during flushing. 2) Soaking time will varry and can be extent to 24 hrs. depending on the degree of fouling. Consult Technorbital for longer soak. 3) The CIP steps described above are for a single alkali or acid chemical solution. 4) If an acid and alkali cleaning are required, the CIP steps would be repeated for each chemical solution															

The above chart provides necessary guidelines to design engineer to develop their projects.

What is Membrane Bioreactor?

MBR is a combination of suspended growth biological treatment like activated sludge process followed by membrane filtration technique for separating out the biomass. This technology can replace the secondary clarifier and sand filter in a typical activated sludge process.



In MBR, membrane is submerged either in the same or in different vessel where biodegradation place. Mixed liquor i.e., influent, and recirculated biomass is entered into the reactor vessel where secondary treatment like bCOD reduction, nitrification, and phosphorus removal takes place.

Aeration is provided in the vessel for biological growth of bacteria through diffusers. Bacteria cleans the water by degrading the pollutant.

In the next stage, membrane allows the water to pass through the water whereas the impurities and bio film gets deposited on the outer surface of the membrane.

The reject stream consisting of concentrated bio-solids, is returned to the bioreactor.

Excess bio-solids are purged out from the bioreactor.

Why air is supplied in MBR?

MBRs need a shear force over the membrane surface in order to avoid membrane fouling from the wastewater contents and is critical in maintaining a desired permeate flux.

When an air/ liquid stream flows parallel to the membrane surface it creates a shear force which helps limiting the degree of fouling. This makes it difficult for the activated sludge to stick at the surface, thereby ensuring the stability of the filtration process.

What care should be taken for long-life of MBR:

Good screening of larger solids before the membranes to protect the membranes from physical damage.

Feeding rate should not be excessive i.e., it should not push the system to its design limits. Such high rates increase the matter to be forced into the membrane and eventually cause membrane deterioration.

Regular use of cleaning chemicals. Most cleaning solution used are bleach (sodium) or citric acid. Membrane cleaning intervals depends on the membrane used from the manufacturer.

Why we generally prefer MBR Option?

Quality with easy operation and control as MBR is 100% automatic. No operational intervention in separation.

- MBR is compact and efficient: Could work in the sludge concentration of 8000-18000mg/l.
- Relatively smaller footprint. Also, while expansion of capacity with conventional treatment plant can make installing another large clarifier, in an MBR plant you can simply add more membranes to existing basins expanding capacity without expanding footprint.
- Stable & excellent produced water quality. Suspended solids and some micro-organisms such as e-coli, cryptosporidium, etc., all can be removed by the MBR membrane.

Some other advantages that MBR offers over conventional treatments methods are:

- Waughter of high quality
- Can be operated at high MLSS
- High chlorine tolerance
- High mechanical strength
- Simple operation, low chemical consumption
- Independent control of HRT and SRT

Membrane Fouling

Membrane fouling is the "talk of the town". Numerous logics are given for given in diagram below:

Factors Effecting Membrane Fouling in MBR		
Operating Conditions	Membrane Characteristics	Feed & Biomass Characteristics
Operating Mode	Type of Material	MLSS
Rate of Aeration	Water Affinity	Sludge Apparent Viscocity
SRT	Surface Roughness	EPS
HRT	Surface Charge	Floc Size
F/M Ratio	Pore Size	Alkalinity & pH
OLR	etc.	Salinity
COD/N Ratio		etc.
Temerature		
etc.		
As collected from many authentic documents		

The degree of fouling in a MBR could be determined by 3 basic fouling factors:

- *Feed and biomass properties (the nature of the feed and biomass present)*
- *Membrane properties*
- *Operating conditions (hydrodynamic environment experienced by the membrane)*

The above is not true and is just the blame game. As a designer, please understand the limits of your design as hereunder:

a. No Solvent in feed as that may result in damaging either membrane or glue line, potting material, or in extreme cases may react with ABS housings.

b. No hair or lint or textile fibres. Hair may cut the fibre and textile fines will result in Ragging (a type of clogging) that is irreversible.

c. No sharp object that can chock fibre neck or apply a force, plastic wires, threads etc.

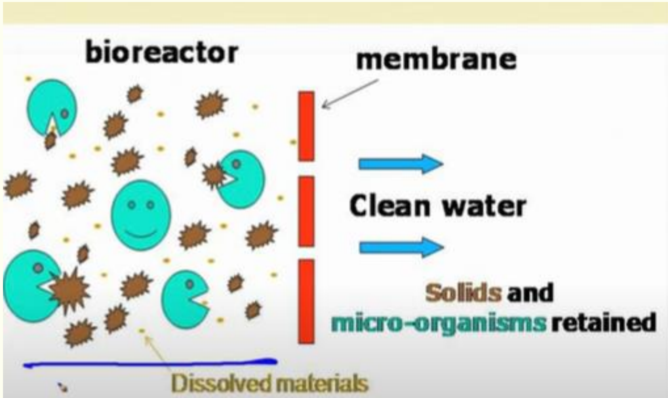
d. No excessive oil & Grease. Limit of 48 deg C temperature.

Microbiology of ASP is neither altered nor supposed to be controlled by MBR expert and thus "Feed & Biomass characteristics", can not be responsible for Fouling. MBR Expert is supposed to plan his operation cycle to avoid fouling.

MBR Design for No Fouling

So, what's the secret in design of MBR.

MBR design has nothing to with biology design. That's simple ASP Extended Aeration with only one difference that the MLSS now can be higher as you do not have typical settling issues. Famous SVI goes out of picture.



See above, nothing passes membrane.

A realization, that now you deal with a Continuous process ASP, where feed is always coming in 24 * 7, and a membrane process that is batch (Cyclic) typically 96 cycles a day if not more?

Air can only add to shear, you still have the responsibility of "Rejected MLSS" to return to the Aeration Tank. This means Q_R of 3-5 times Q, depending upon maximum MLSS planned need to be seriously understood. While you can design either:

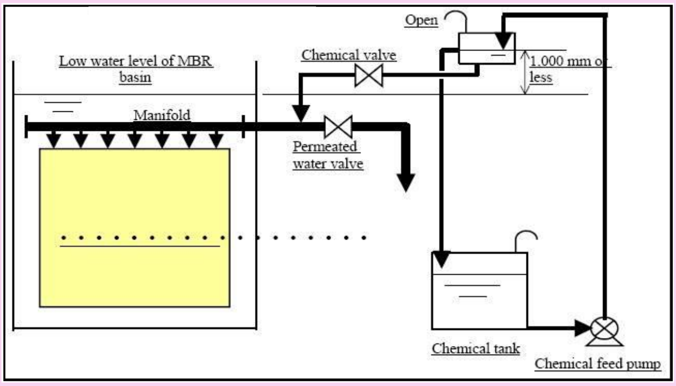
A. Pump to MBR Tank and Return to Anoxic, Aeration Tank
B. Or Pump from MBR tank to Anoxic, Aeration Tank

This is something like Beta Factor or concentration Polarization referred in RO. The 5Q flow comes to Membrane, 1Q becomes permeate and the rest 4Q sweeps the membrane foulants. This is must !! if not serious fouling issues.

Is Degasification in MBR is must, why?

Henry's law is one of the gas laws and was formulated by the British chemist, William Henry, in 1803. It states that: At a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid. According to this the gases present in MBR Tank shall escape to permeate header rather than atmosphere as the pressure in permeate header is < 1 atm.

So MBR permeate header needs degasification that can be achieved by two methods:



Removal of entrapped air during gravity assisted back flush (something like priming of pump):

In this design water volume twice the volume of permeate extraction network is injected by gravity into the system to remove all the gases. Assuming that all pipes in permeate extraction network have a total volume of 300 l , we shall inject 600 l of permeate by gravity by opening an auto valve.

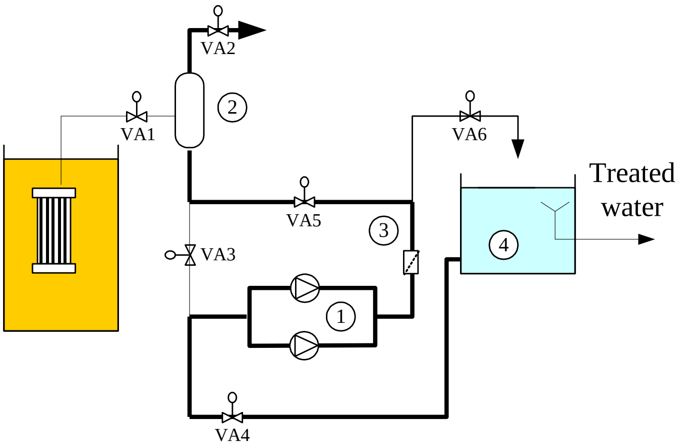
For this to function extracted permeate or any other clean water shall first fill a Priming tank. The overflow of priming tank shall be placed at a level that shall allow 600 l of water filling and rest shall return to Final permeate storage tank.

The Priming tank shall be located so as to maintain a level difference of 1 m (Overflow nozzle) and Top liquid level in membrane tank.

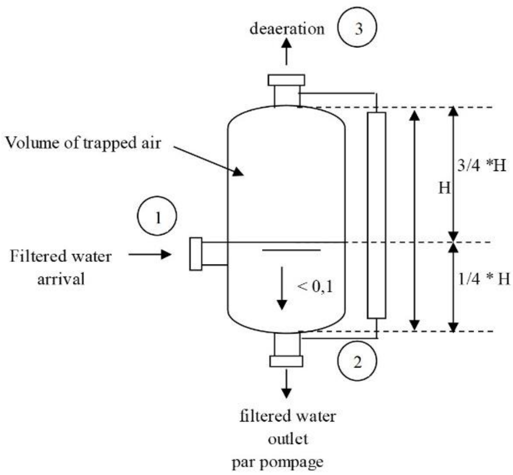
The back flush operation shall be auto by opening of a valve.

Dedicated degasification tank and automation

In this process, the gases are stored in a vessel (see pic below) and are automatically released by opening air release valve.



Valve VA2 need to be operated for degasification. It shall not be Solenoid-type as it may lead to suction of air during filtration phase.



We need an Air release vessel. Flow velocity during the filtration < 0.1 m/s this determines the dia of the vessel. Height above the filtrate header shall be 3/4 of overall H. Air volume to be set free is 0.5 litres per 100 l of filtrate. A Visualization tube need to be provided to understand the level inside the vessel, in addition to a level switch.

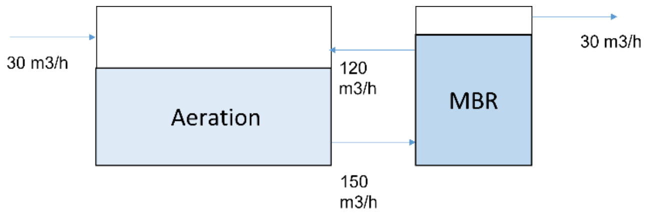
MBR Reactor Design

What's there in a tank? Just know module L x W x H and immerse MBR Module in a tank, right.

Unfortunately, it's not that simple. MBR is part of a ETP process where, we have

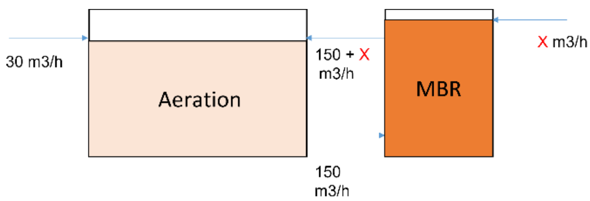
- a Continuous Process (Primary, Anoxic, Aeration)
- a Batch Process (Filtration, Backwash, Filtration cycle – 15 min)

Imagine if we have 30 m^3/h (Q) and design for MLSS 9000 mg/l in AT and decide for Q_R to be 5 times, we mush push 150 m^3/h water + MLSS to MBR tank.



A. In normal operation MBR level is higher then that of Aeration

During backwash, since we do not have any permeate extraction and the Reactor volumes Anoxic, Aerobic and MBR Tank are fixed level changes during this time. This is further complicated by X m^3/h of Backwash water that is needed for 1 min.



B. During Backwash extra flow to return to Aeration Tank and the level increases

Therefore, for MBR and Aeration Tank design together, the tank hydraulics, pipe size and flange for return water line, velocity in that pipe, Angle of inclination (straight or Inclined) need to be designed for both filtration as well as backwash application.

Rise in level, volume must be considered for DO meter installation, Air blower designs and level transmitters, VFD for blower etc.

Is Monitoring Return MLSS Important?

On the same chart if we apply mass balance the MLSS return from MBR tank to Aeration Tank shall be 11250 mg/l, means at membrane surface, where we are "Sucking", permeate, we are suddenly increasing the concentration of MLSS by 25%.

While Air, provides the shear to ensure membrane is continuously kept clean, the reactor design wrt flow must ensure its upwards plug flow reactor to keep sending all the MLSS back to Aeration Tank.

Entry & Exit Design.

One must avoid short circuiting of flow entering MBR basin and design properly at entry and exit.

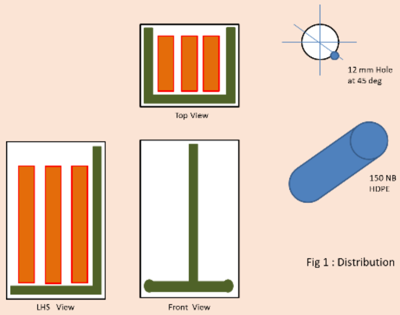


Fig 1 : Distribution

The above picture details the best way of distributing the incoming feed to reactor for a uniform homogenous flow through the entire cross section of the MBR, any mismatch shall result in deposits of SS which will have a cascading effect.

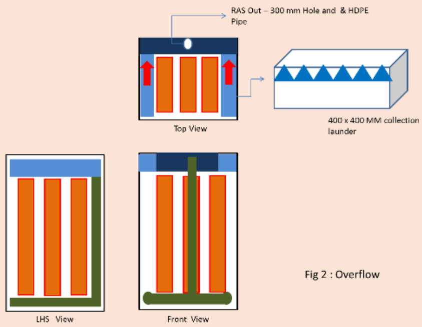


Fig 2 : Overflow

Fig 2 above details how the return MLSS shall be collected on top of the MBR basin. This can be avoided if we have clear 60% (Of larger dimension of tank cross section) free space and a simple one wall escape can be considered.

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The Eight Edition of water is now reaching almost 4500 people, while we started with just 632.

Waughter V1 E1: The Chemistry of Water

Waughter V1 E2: The Chemistry of Water

Waughter V1 E3: The Water Microbiology

Waughter V1 E4: The Industrial Water Treatment

Waughter V1 E5: Pre - Treatment Technology, Process and Design Tools

Waughter V1 E6: Ion Exchange, Resin, Softening, DM Plant & CPU, and Regeneration

Waughter V1 E7: Desalting - RO & Fouling with special Pre - Treatment






Here is the glimpse of previous editions. Please feel free to ask for an edition that you might have missed.

जल जीवन जननी !!

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: The Chemicals & additives in Water management for internal conditioning.

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