TRAINING OF TRAINERS PROGRAMME ON CAPACITY DEVELOPMENT OF ETP OPERATORS

Promotion of Sustainability in the Textile and Garment Industry in Asia - FABRIC

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Day 5: Presentation 3

Membrane based treatment

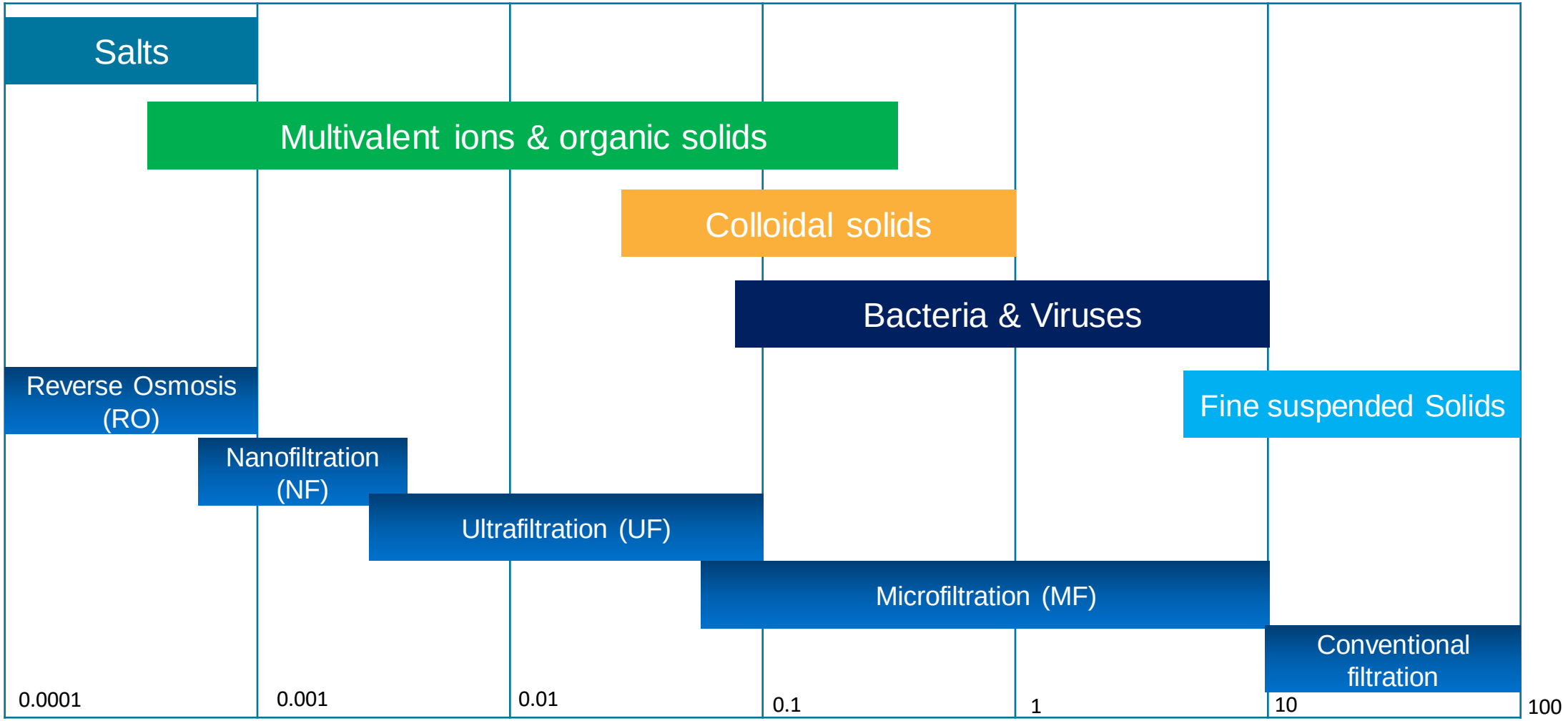
Contents

Membranes in wastewater treatment

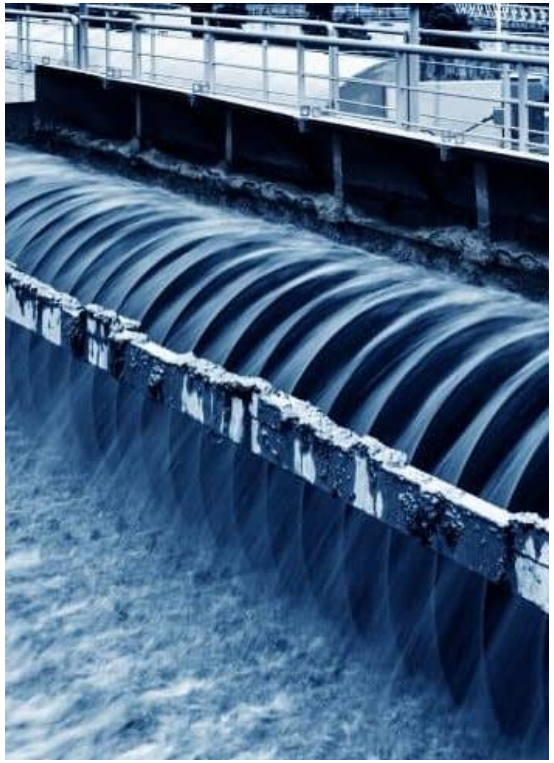
- Membranes are fine filters can filter out all suspended and colloidal solids, some times even dissolved solids.
- Starts with micron filters: remove most bacteria & viruses. MF with fine pore generally used in MBR systems.
- Ultrafilters remove all suspended & colloidal solids. Reduces the turbidity & silt in water. Used in effluent recovery units as pre-treatment to RO.
- Nano-filters can remove organics & tighter NF remove multi valent salts.
- RO membranes can remove salts too and allow only water to pass through. Most wastewater recycling systems & ZLD system uses RO membranes.

Membranes in wastewater treatment

Relative filtration sizes in micron



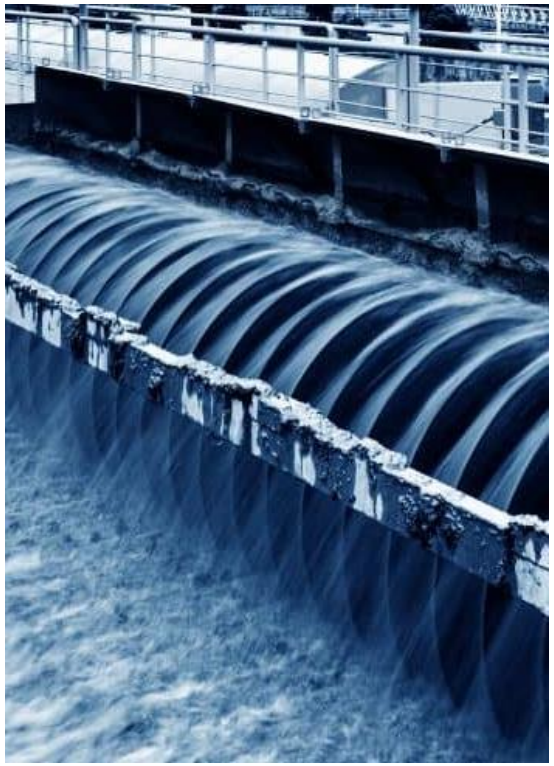
Membranes in wastewater treatment



Membrane configurations

- Four main types : plate & frame, tubular, spiral wound & hollow fibre.
- **Plate-and-frame** module is the simplest configuration, consisting of two end plates, the flat sheet membrane, and spacers.
- In **tubular modules**, the membrane is often on the inside of a tube, and the feed solution is pumped through the tube.
- Most popular configuration for nanofiltration or reverse osmosis membranes is **spiral wound**. Here membrane is wrapped around perforated permeate collection tube.
- **Hollow fiber modules** used for seawater desalination consist of bundles of hollow fibers in a pressure vessel .

Membranes in wastewater treatment



- In MBRs in textile sector, micro/ultrafilters are used for separation of bio-solids.
- Ultrafilter is a common pre-treatment for RO systems installed as a part of water recycling/ZLD systems installed in textile sector.
- Nano-filtration is used in some factories to segregate the salt solution from dye bath, enabling the salt re-use in dyeing.
- Reverse Osmosis is the main component in water recycling / ZLD in textile industries for removing the salts from the effluent.
- Some cases of ZLD, technologies such as high pressure RO (RO) or membrane distillation is used for concentrating the saline reject from main RO unit.
- Due to time limitation, we discuss MBR, nano filter & RO and ZLD.

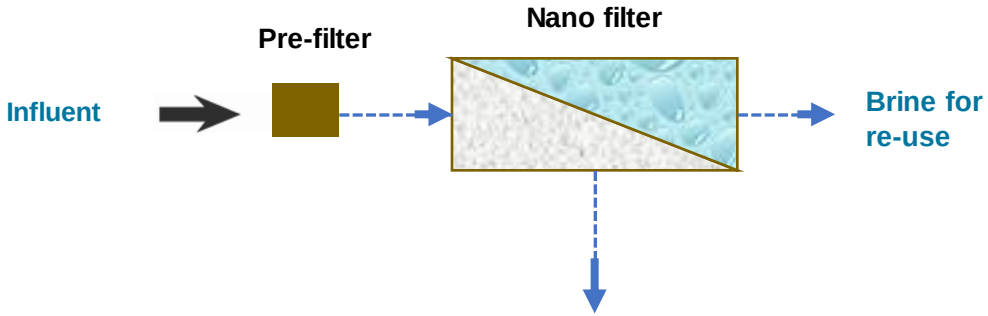
NANO FILTRATION FOR SALT RECOVERY

Nanofiltration

Nano filtration for salt recovery

- Concept: salt laden exhaust dye bath passed through a Nano membrane.
- This allows only salt pass through & remove organics, colour, other impurities.
- Exhaust dye bath with 4 to 7% salt concentration is pre-treated and passed through nanofiltration.
- Permeate will be clear salt solution and reject have all colour and multivalent ions etc.
- Based on molecular size of organics in exhaust dye bath, a nano-filter with 400-500 Daltons (about 0.0008 microns) pore size can give a decent recovery.

Nanofiltration



First, the exhaust dye bath is filtered through a pre-filter and then through a nano-filter. The permeate will be clear saline liquor which can be re-used in dyeing. The reject carrying all organic impurities, sulphates etc. are taken for reject handling in RO or evaporated to dryness. However, the recovered brine may not be good for all shades.

QUIZ

What are the advantages & disadvantages of Nano filtration?

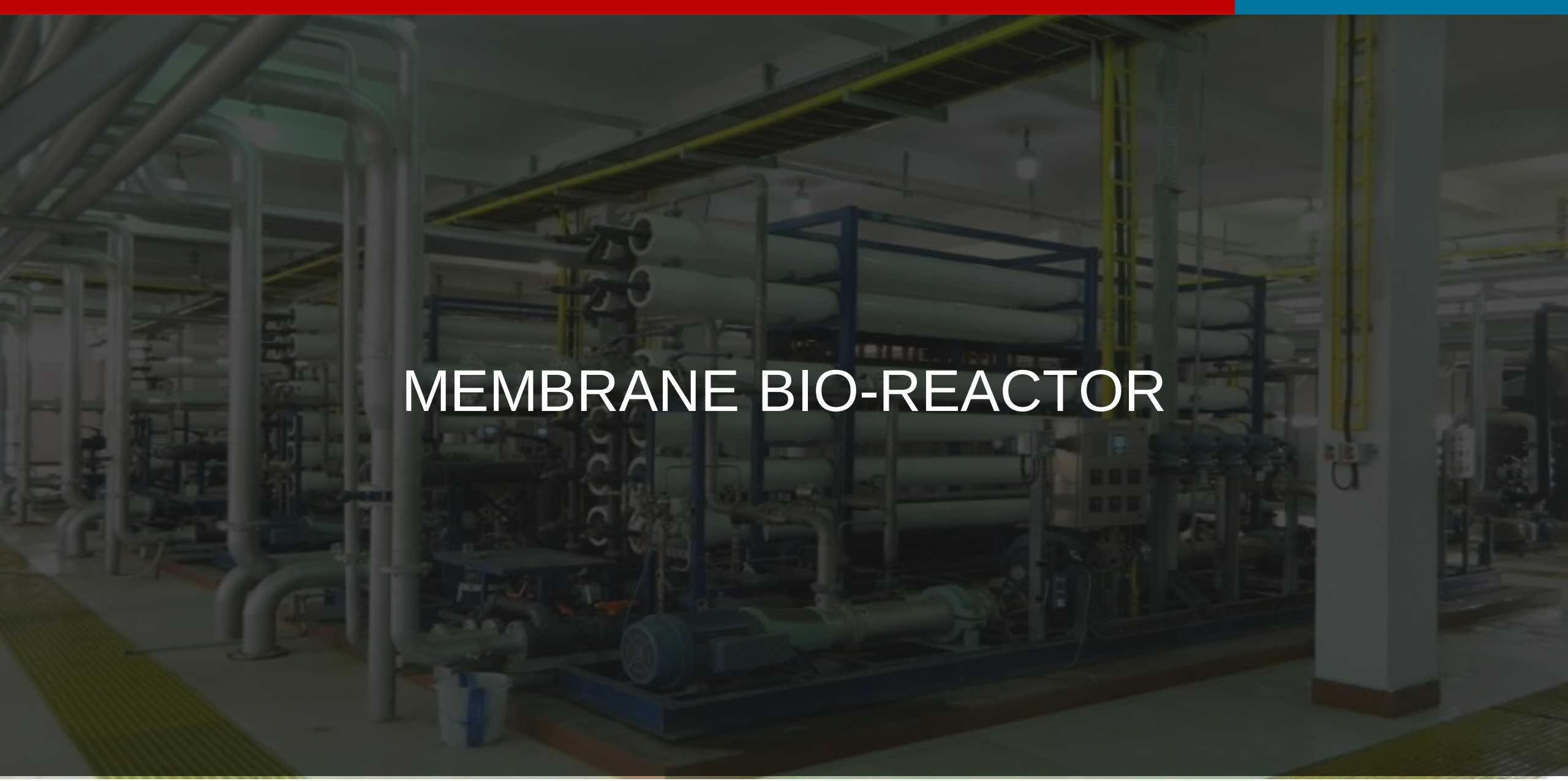
Nanofiltration

Salt recovery through Nano filtration - Myths & Facts

- Nano filtration allows only mono/divalent ions and water to pass through, retains hydrolized dyes and multivalent salts.
- Theoretically it is possible to recover all salts through the membrane, in practice recovery is affected by a variety of factors.
- Pore size of the nano membranes is crucial
- Too large a pore size (say >500 daltons) ensure good recovery, above 70% of salt liquor, but allows passage of some smaller organic molecules too.

Nanofiltration

- Passage of organics makes recovered salt solution coloured and potentially unsafe for re-use
- On the other hand, too narrow pore sizes (say <300 daltons) ensure recovery of clear salt liquor, safe for re-use
- but then recovery rate could be very low, say less than 35% of salt.
- The matter is further complicated by the presence of reacted salts, i.e., salts produced due to inter-reaction of acid and alkali used in the textile processing.



MEMBRANE BIO-REACTOR

QUIZ

What is membrane bio-reactor, how is it different from conventional treatment?

Membrane bio-reactor

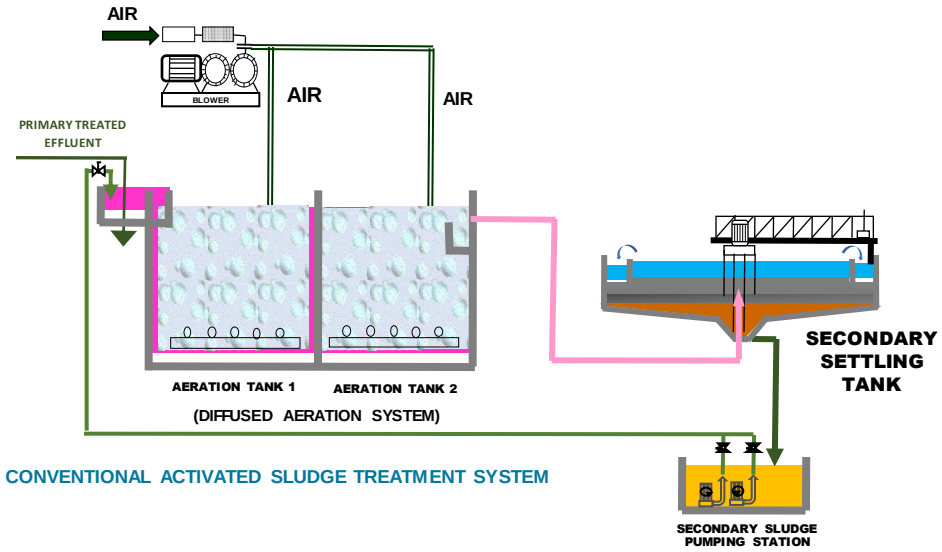
- MBR is basically activated sludge treatment, except instead of a secondary settling tank to separate bio-solids, a micro or ultra filtration is used.
- No limitation due to settling characteristics of MLSS. So, much higher MLSS in aeration tank. Hence size of aeration and area needed for ETP comes down.
- MBR concept developed in the late 1960's, but was not popular due to high power consumption till end of 80's. Then submerged MBR was developed.

Membrane bio-reactor

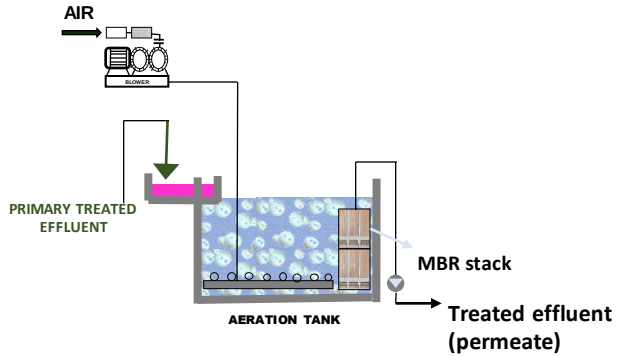
- Submerged MBR use less power. But frequent membranes fouling an issue.
- The external MBR, generally called side stream MBR, continued to be the preferred MBR system for small plants.
- Generally MBR is preferred over conventional system where the space availability is a concern and recycle options are considered for future.

Membrane bio-reactor

Conventional activated sludge system Vs MBR



CONVENTIONAL ACTIVATED SLUDGE TREATMENT SYSTEM

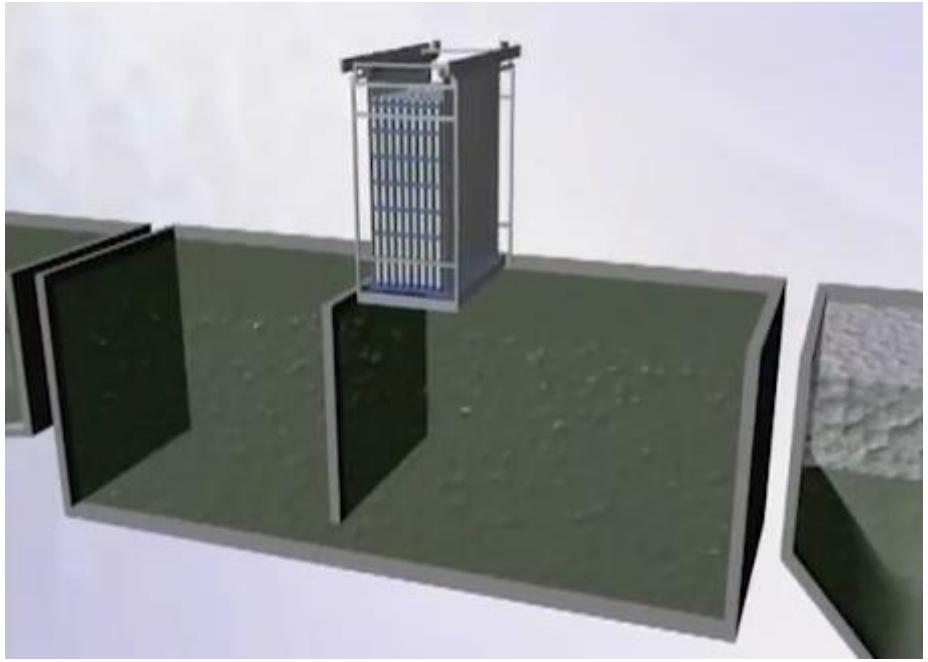


MEMBRANE BIO-REACTOR (MBR)

In conventional activated sludge treatment system, we have aeration tank with aeration, followed by secondary clarifier and sludge return. In MBR ,the clear effluent is sucked out through an ultrafiltration.

Membrane bio-reactor

Placement of submerged membranes



- MBR uses membranes to separate MLSS.
- The ultrafilter filters out clean water.
- Thus, a separate secondary clarifier is avoided.
- Also MLSS is higher.
- Hence the installation becomes much smaller.

(Image courtesy: Koch)

Membrane bio-reactor

Placement of submerged membranes

- MBR has basically two components: aeration tank and set of micro/ultra filter.
- In side stream MBR, aeration tank contents is pumped into an external MBR mounted on a skid.
- The filtered clear effluent is discharged.
- Retained MLSS solution is sent back to aeration tank.
- A modification of side-stream MBR is called air-lift - scouring by air for additional backwash.

Membrane bio-reactor

- In submerged MBR, ultrafilters are stacked in cassettes which is installed in aeration tank
- The filtrate is sucked out using vacuum/ pressure pump.
- This leaves back the concentrated MLSS in the aeration tank.
- Airflow is calculated with dual purpose of
  - ✓(a) aerating the aeration tank and
  - ✓(b) continuously scour & clean membrane surface.

Membrane bio-reactor

Operating conditions of MBR

- MLSS levels in MBR would be much higher than conventional activated sludge system. The typical range is 10000-15000 mg/l.
- Submerged MBR can also be in two ways:
- where the membrane cassettes are installed directly in the aeration tank and
- aeration tank is constructed in two compartments and membrane stack is installed in one of the compartment.
- Submerged MBR normally consumes power @ 0.5 kWh/m3 of effluent treated Vs side stream @ 2-4 kWh/m3 depending on the type of effluent.

Membrane bio-reactor

Placement of submerged membranes

- In MBR, submerged membrane cartridge can be placed in the same aeration tank or in a separate compartment

(Courtesy Koch)

Membrane bio-reactor

Operating conditions of MBR

- Because the solids are filtered & retained in the aeration tank, sludge retention time in an MBR is high.
- Typical SRT is 30-50 days. Higher SRT is possible, but increases fouling.
- Fouling of membrane by MLSS particles, colloids etc is the major concern of MBR.
- Once fouling increases, the flow drops. Once membrane is cleaned, the flow rate (often called flux) through the membrane increases.

Membrane bio-reactor

Operating conditions of MBR

- There are two operating modes for MBR.
- One is by keeping the pumping pressure constant with varying permeate flow.
- Second is by keeping the permeate flow constant by varying the pressure. Clearly, the second mode is better.
- MBR performance is better at higher temperature (say, upto 450C).
- Lower temperature also increases the operating pressure due to higher viscosity.

Membrane bio-reactor

Fouling control techniques for MBR

- Membrane backwashing: permeate water is pumped back to the membrane
- Intermittent operation of submerged membranes: Air backwashing through continued aeration, stopping filtration.
- Better membranes: Use of advanced anti-fouling membrane materials for the UF.
- Chemical cleaning involving:
  - (a) chemically enhanced backwash (daily),
  - (b) Maintenance cleaning with high chemical (weekly)
  - (c) Intensive chemical cleaning (once or twice a year).

Membrane bio-reactor

Advantages of MBR

- Advantages of MBR
- Better removal of BOD/COD and pathogens compared to conventional ASP.
- Better degradation of complex organics/FOGs due to the higher SRT possible.
- With no suspended solids, treated effluent will be very clear & less turbid.
- Lesser pre-treatment when effluent recovery is considered.
- Much less area compared to conventional ASP.

Membrane bio-reactor

Disadvantages of MBRs

- Higher capital cost for a good system.
- Higher O & M cost due to additional power and membrane cleaning/replacement.
- System is more sensitive and complex in operation.
- Membrane replacement add to the list of consumables.
- Improper solids control in inlet may **increase the problem of membrane clogging.**

REVERSE OSMOSIS FOR EFFLEUNT DESALINATION

Reverse Osmosis

- Reverse Osmosis is the finest of all membranes.
- It has the pore size so small that even the salt molecules are filtered out and only water is allowed to pass through.
- RO operates under very high pressure. Pressure depends on inlet salt concentration
- Unlike MF or UF, RO units are not backwashed and cleaned only using chemicals.

QUIZ

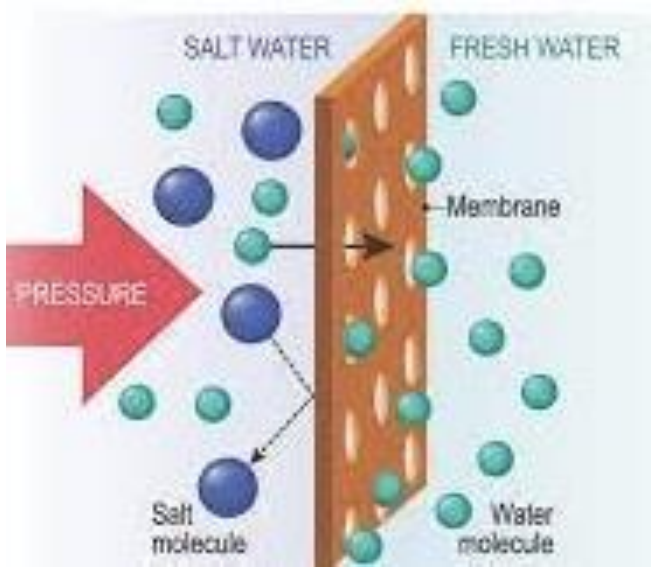
How does Reverse Osmosis work?

Reverse Osmosis

- Osmosis is a process when saline water is separated from fresh water by a membrane which allow passage of only water, fresh water moves to the saline water.
- This is due to a pressure exerted by salt water called ‘osmotic pressure’.
- If it is reversed, i.e., if we apply pressure on salt side to overcome osmotic pressure, water from saline side passes to fresh water side. This is called Reverse Osmosis.

Reverse Osmosis

Reverse Osmosis porcess

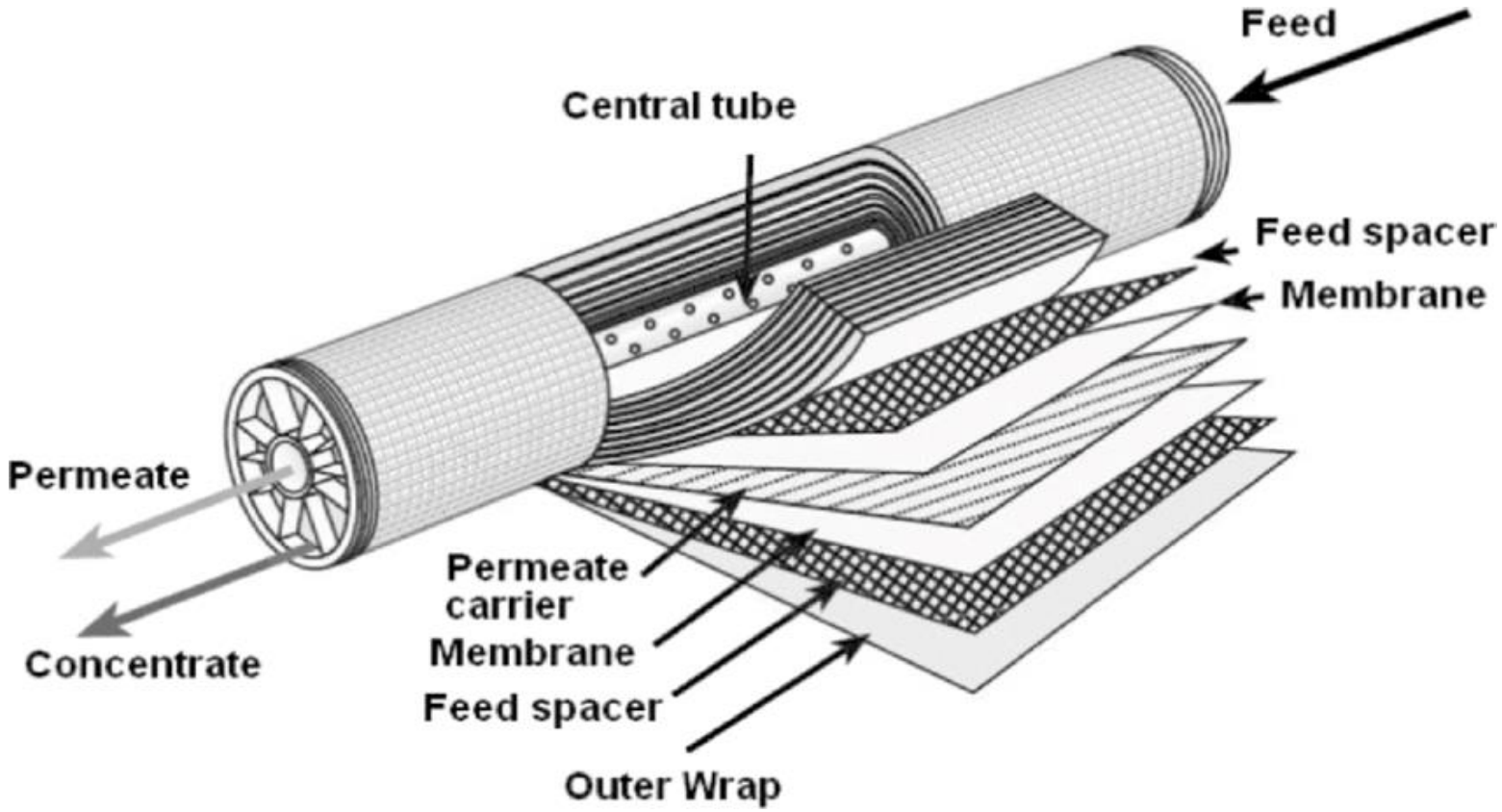


Reverse Osmosis

- RO system generally consist of pre-treatment, high pressure pump, RO membranes.
- Earlier version of RO membranes made of cellulose acetate. Now, polyamide layer laid over a poly sulfone layer, mounted on a polyester base.
- RO membrane made by modified polymerization process, leaves openings of molecular size.
- RO membrane comes in different configuration depends on how the membranes are arranged in a vessel.
- The most common configuration is spiral wound. For wastewater applications, disc & tube or tubular configurations too are used.

Reverse Osmosis

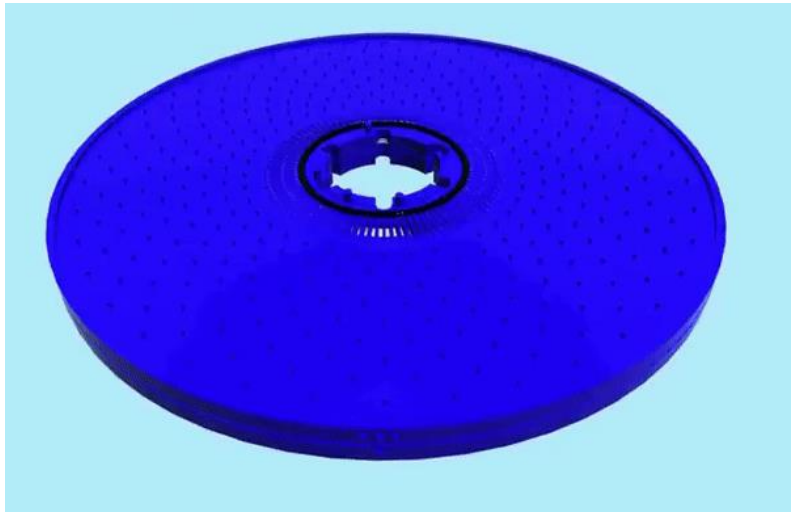
Spiral wound RO configuration



Reverse Osmosis

Disc & Tube RO configuration

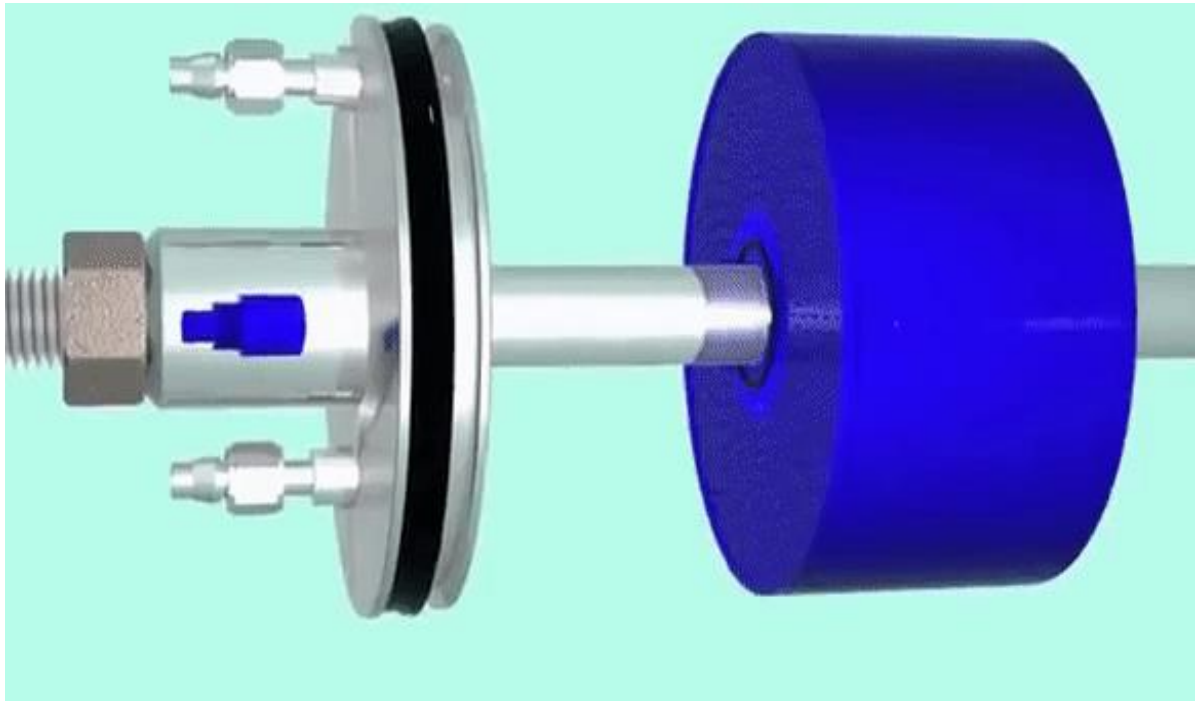
In order to have a DT membrane stack, first RO membranes are cut in hexagonal shape and then it is placed on a disk. The process is repeated to form a cassette.



Reverse Osmosis

Spiral wound RO configuration

To have a DT membrane module, several cassettes are packed together.



Reverse Osmosis

Application of RO system

- RO systems for effluent need extensive pre-treatment.
- If hardness is high, softening is needed (zeolite softener/lime soda softener) to prevent fouling/scaling.
- The term fouling refers to blocking of membrane pore by organic or inorganic solids.
- Effluent with high BOD/COD, or silica/clay/iron etc. fouls membranes.
- Dosing of antiscalants at RO inlet to control scaling due to calcium carbonate/sulfate.

Reverse Osmosis

Application of RO system

- RO inlet is kept at slightly acidic side to reduce scaling potential.
- Periodically, membrane cleaning by cleaning-in-process (CIP) is done.
- Special CIP chemicals with acid/alkali cleaning is used for this process.
- Over a period of time, RO recovery rate (flux rate) comes down due to scaling.
- When cleaning not improve recovery, membranes are replaced (2-4 years).

QUIZ

What is ZLD, does any body really achieve it?

ZERO LIQUID DISCHARGE SYSTEM

Zero-Liquid Discharge

Many came up with idea of ZLD as ideal solution for both - Pollution & water.

ZLD is literally that- no drop of effluent discharged, all recovered.

Recovery & re-use after tertiary without membranes: failed due to quality issues.

ZLD is achieved in stages: Conventional treatment, membrane pre-treatment, desalination and management of rejects.

Zero-Liquid Discharge

The treated effluent is subjected to series of pre-treatment to make it fit for RO.

The pre-treatment usually involves softening (if hardness is high), pre-filtrations in MGF/ACF/ Micron filters.

Bangladesh ETPs are now made considering future ZLD: more number of MBR, UF post treatment, salt recovery…

Many new technological developments makes its easier: membrane distillation, forward osmosis, EDR etc.

Zero-Liquid Discharge

Understanding ZLD

- Some cases, advanced oxidation methods are employed to control organics.
- Often inlet to RO is protected with an ulta-filtration membrane.
- The RO system is in multiple stages to optimise the recovery and minimise the reject to handle.
- While first stages use brackish water membranes later stages use sea water membranes.
- In cases reject evaporation of is done, often further concentrated using a high pressure RO system.

Zero-Liquid Discharge

Technical challenges: making effluent fit for RO, managing rejects.- Can be managed by advanced treatments & partial re-use of salts.

Managerial challenge: need for high expertise in deign, implementation, O & M. - Can be managed by initial outsourcing, training & institutional strengthening.

Financial challenge: ZLD is the costliest in installation & operation: need management of costs, support from buyers.

Logistical challenges: Mainly huge requirement of land: need very intelligent planning.

Zero-Liquid Discharge

Management of RO Rejects in ZLD

- Management of rejects (about 8-15% of inlet volume) are done in multiple ways.
- In some cases, reject is purified through a nano filter and brine re-used. Rejects of nano needs evaporation.
- In most cases, entire rejects needs evaporation since salt recovery is not always feasible.
- Cotton processing units can recover sodium sulphate using adiabatic chiller and re-use
- The rest of saline liquor - multiple salts are evaporated and disposed.

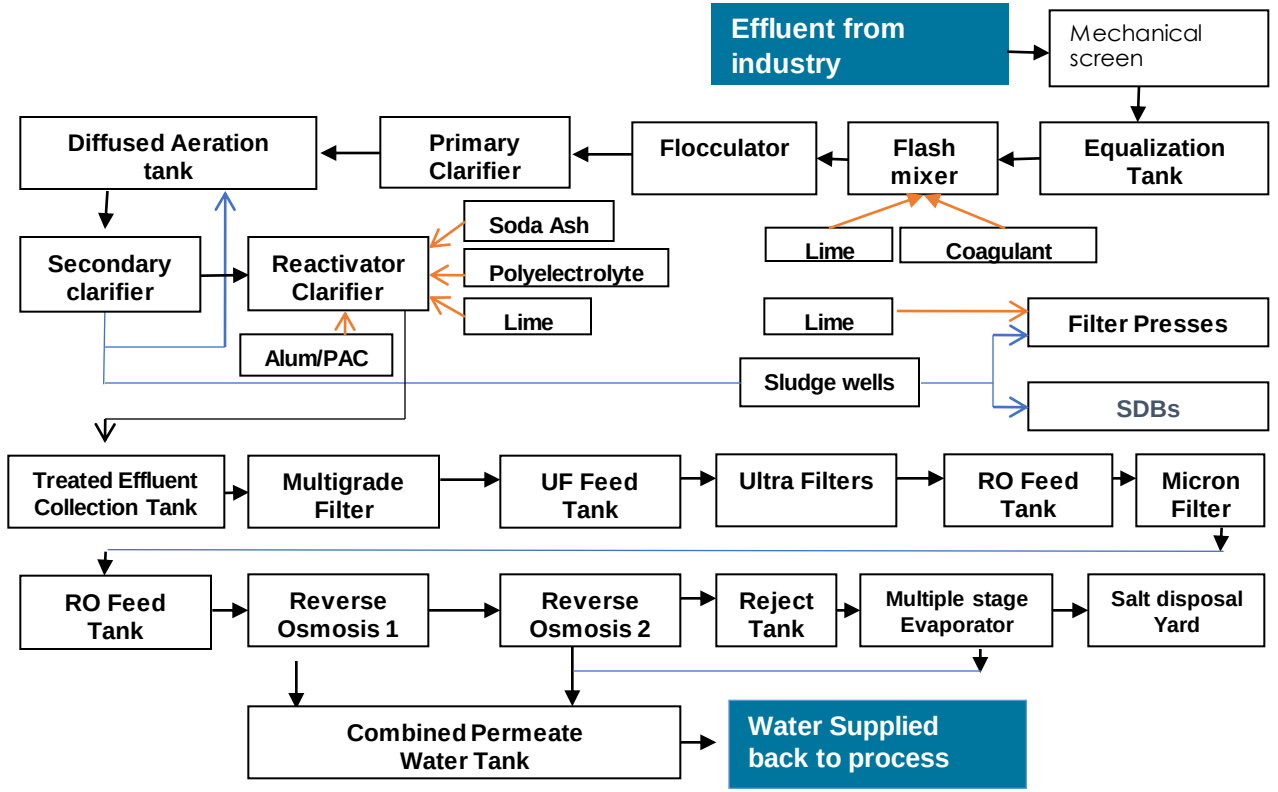
Zero-Liquid Discharge

General Issues with dyeing/denim effluent

- Presence of sizing agents (PVA or CMC and others) make serious issues with membranes.
- Binders used in process can clog membranes.
- Presence of pumice stones if any in the effluent makes problems in membrane operation.
- Many enzymes used in washing operations can make chelating reactions with membrane materials.
- Lastly, an indigo presence in the effluent decreases the membrane flux and reduces the output.
- Proper design needed.

Zero-Liquid Discharge

TYPCIAL ZLD SCHEME



Zero-Liquid Discharge

Advantages of ZLD

- It will provide full legal compliance,
- There will be water security for the industry,
- The industry will have better image with buyers/public/ NGOs/DoE,
- ZLD will ensure protection of environment,
- Water recovery ensure zero loss of production.
- ZLD ensure consistency in product quality too

Zero-Liquid Discharge

Disadvantages of ZLD

- Ensuring ‘zero‘is very difficult
- It is the costliest treatment in installation and prohibitively costly in operation, could affect the competitiveness of the industry.
- Disposal of evaporated mixed salt is always a challenge.
- Lack of adequate technical support.
- Need for trained staff for operation.
- Consumes lot of space, which is an issue for Bangladesh Industry.

Zero-Liquid Discharge

General Issues with Water recovery

- Suppliers offering simpler design like tertiary oxidation and nano filtration.
- Such units often give impure recovered water and eventually got discarded.
- Water recovery is costly. Installation cost a high as Tk 1-1.5 Lakh per m3 and O & M cost Tk 50-100 per m3.
- If evaporation included, O & M cost Tk 150-250 per m3.
- Many consultants/suppliers offer cheaper installation and O & M costs, but such systems seldom works.
- Need high technical expertise in design, installation and operation.

Conclusion

- Many new membrane based technologies evolves every day . For instance membrane distillation, EDR, Forward Osmosis etc.
- Due to time limitations only MBR, NF & RO discussed here.
- Effluent treatment using membranes are useful, but sensitive.
- MBR can be considered where land is scare & ZLD being planned.

Conclusion

- Effluent recovery through RO can be a good step to manage water scarcity and discharge issues.
- Zero Liquid discharge is very costly in installation & costly and need lot of land area.
- Avoiding evaporation is crucial in keeping ZLD economically viable.

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