TRAINING PROGRAMME FOR ETP OPERATORS IN TEXTILE INDUSTRY

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

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Membrane-based treatment

GIZ FABRIC – ETP Operator Course

Contents

- Basic concept
- Use of nano-filtration
- Use of membrane based bioreactors
- Use of reverse osmosis
- Aiming for zero-liquid discharge

Basic concept of membrane technology

Basic concept of membrane treatment

Membranes

- fine filters capable to filter suspended and colloidal solids and sometimes dissolved solids.
- Performance depending on pore size of filters
- Common types of filters
  - **Micron filters** (MF)
  - **Ultrafilters** (UF)
  - **Nano-filters** (NF)
  - **Reverse osmosis membranes** (RO)

Basic concept of membrane treatment

Types of filters

- **Micron filters** (MF)
  - for removing bacteria and viruses
  - generally used in membrane bio reactors (MBR)
- **Ultrafilters** (UF)
  - for removing all suspended and colloidal solids, turbidity and fine-level silt
  - commonly used in pre-treatment for reverse osmosis units

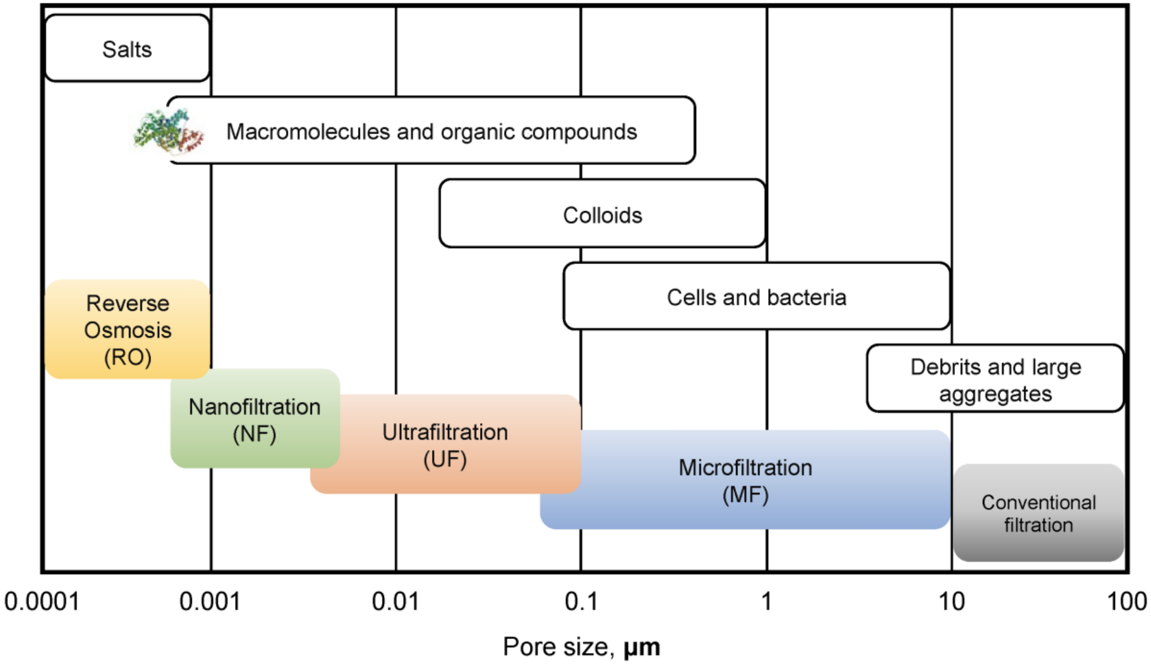
Basic concept of membrane treatment

Types of filters

- **Nano-filters** (NF)
  - for removing organics
  - tighter NF also for multi-valent salts.
- **Reverse osmosis membranes** (RO)
  - for removing salts
  - used in most wastewater recycling systems and zero liquid discharge (ZLD) systems

Basic concept of membrane treatment

Overview of filters by pore size



Basic concept of membrane treatment

Types of membranes

- **Plate** and **frame** modules
- **Tubular** modules
- **Spiral wound** modules
- **Hollow fiber** modules

Basic concept of membrane treatment

Types of membranes

- **Plate and frame membranes**
  - simplest configuration consisting of two end plates (flat sheet membrane spacers)
- **Tubular modules**
  - membrane inside of tube with feed solution pumped through

Basic concept of membrane treatment

Types of membranes

- **Spiral wound module**
  - Most popular for nanofiltration or reverse osmosis membranes with flat sheet membrane wrapped around perforated permeate collection tube.
- **Hollow fiber modules**
  - used for seawater desalination
  - consisting of bundles of hollow fibers in pressure vessel
  - Often shell-side feed configuration with feed passing along outside of fibers and exiting at fiber ends.

Basic concept of membrane treatment

Common applications for textile wastewater

- Membrane bio reactors using micro/ultrafilters for **separation of bio-solids**
- **Pre-treatment for RO systems** with ultrafilter as part of water recycling/ZLD systems
- Nano-filtration **segregation of salt solution from dye bath**, enabling salt re-use in dyeing
- Reverse Osmosis as main component in **water recycling / ZLD** for removing salts from effluent.
- High pressure RO or membrane distillation for **concentrating saline rejects from main RO** unit

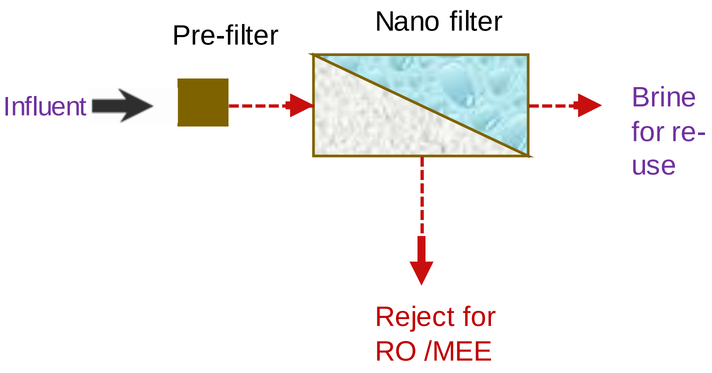
Use of nano-filtration

Use of nano-filtration

- Filtration of salt laden exhaust dye bath through nano-membrane:
  - salt allowed to pass
  - filtering out organics, colour and other impurities

Use of nano-filtration

- **Pre-treatment** of exhaust dye bath with 4 to 7% salt concentration
- Nanofiltration with clear salt solution and reject containing all colour and multivalent ions
- **Decent recovery of salt solution without contamination** with nano-filter of 400-500 Daltons (about 0.0008 microns)
- **Control not easy**!
- Mass balance of recovery process complicated
  - Recovered salt more than salt used (due to extra salt produced through reaction of acid/alkali in production)



Use of nano-filtration

Issues for consideration

- Only mono/divalent ions and water passing while hydrolized dyes and multivalent salts being retained.
- Theoretically possible to recover all salts; in practice recovery affected by various factors:
  - **Large pore size** (> 500 daltons) for **good recovery** of more than 70% of salt liquor, but passage of smaller organic molecules
    - recovered **salt solution coloured** and potentially **unsafe for re-use**
  - **Narrow pore sizes** (< 300 daltons) for good **recovery of clear salt** liquor safe for re-use but **recovery rate low** (less than 35%)
  - **Presence** of **reacted salts**

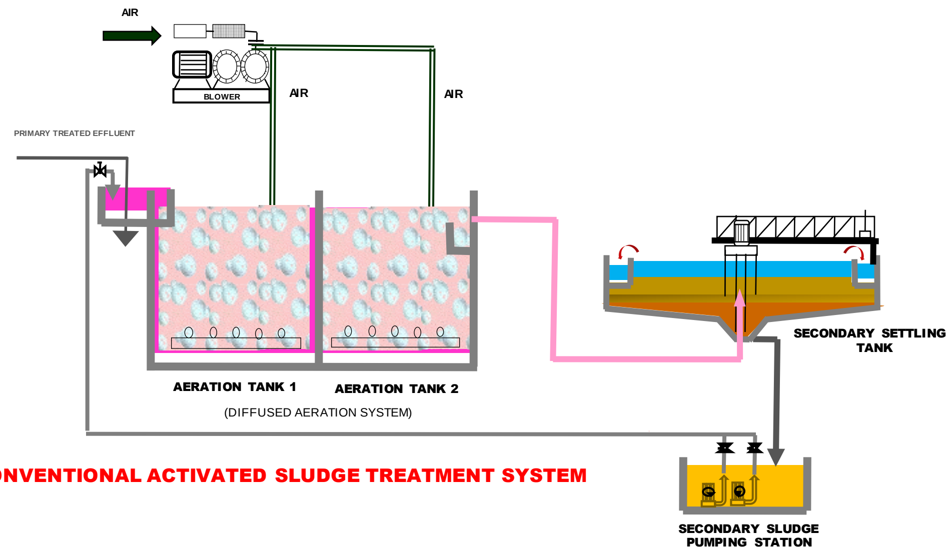
Use of membrane bio-reactors (MBR)

Use of membrane bio reactor (MBR)

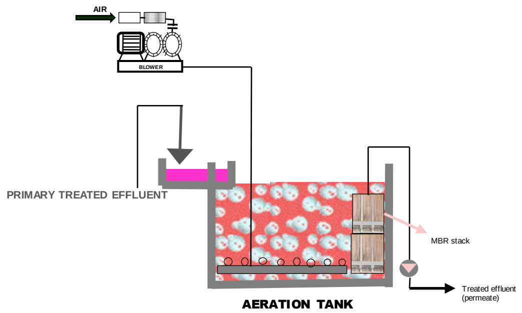
- MBR = Type of **activated sludge treatment with micro or ultra filtration** of biosolids instead of secondary settling tank
  - **Higher MLSS in aeration tank** possible (10000-15000 mg/l) since no limitations due to MLSS settling characteristics
  - **Smaller size** of units and **less area required** for ETP
- Development of **submerged MBRs** (with less power consumption) making MBR more popular
- Frequent **fouling of membranes challenging**
- External MBR (or side stream MBR) preferred system for small ETPs

Use of membrane bio reactor (MBR)

Comparison of conventional activated sludge system and MBR



CONVENTIONAL ACTIVATED SLUDGE TREATMENT SYSTEM



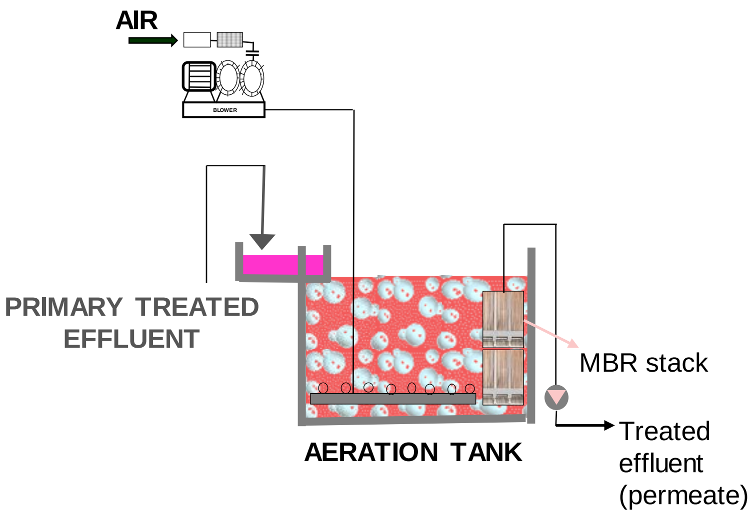
MEMBRANE BIO-REACTOR (MBR)

Use of membrane bio reactor (MBR)

Operation of MBR

Focus on

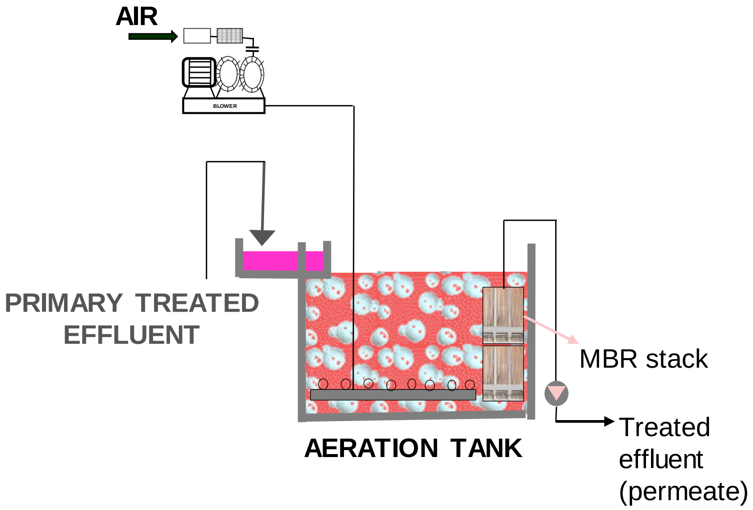
- **Aerating** in aeration tank
- **Filtering** effluent with set of micro/ultra filter
- **Pumping back** filtered MLSS into aeration tank



Use of membrane bio reactor (MBR)

Operation of MBR

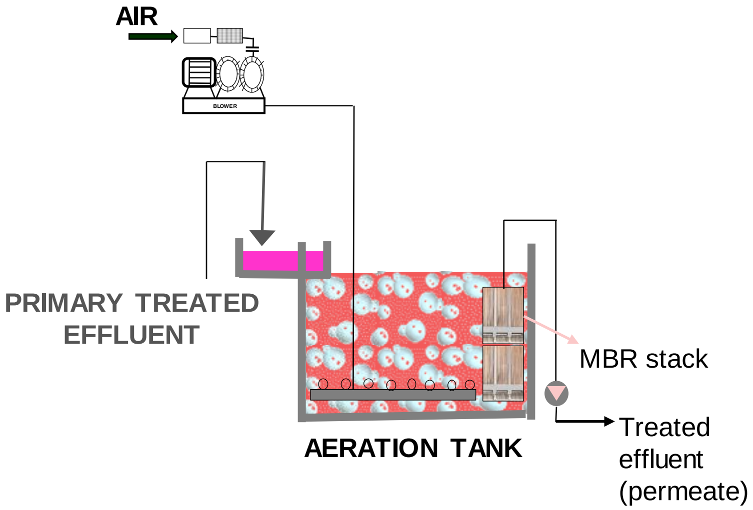
- **Side stream MBR**
  - Aeration tank contents pumped into external MBR mounted on skid.
- **Submerged MBR**
  - Ultrafilters stacked in cassettes and installed in aeration tank
  - Filtrate sucked out using vacuum or pressure pump



Use of membrane bio reactor (MBR)

Operation of MBR

- Submerged membranes:
  - Airflow calculated with purpose of (a) aerating aeration tank and (b) continuously scouring and cleaning membrane surface.
- **Back washing using air** done to remove bio-solids sticking to membrane surface
- **Side stream MBR** cleaned with **"clean-in-process (CIP)** using chemicals like caustic soda and acid



Use of membrane bio reactor (MBR)

Variations of MBR

- Possible set-up of submerged MBR:
  - Membrane cassettes installed directly in aeration tank
  - aeration tank constructed with two compartments with membrane stack in one compartment
- Side stream MBR and air-lift MBR
  - Sidestream is external MBR, operates like a conventional UF.
  - In air-lift, scouring by air used as an additional backwash step. It is less common.

Submerged MBR with placement of membranes; photo: Courtesy Koch

Use of membrane bio reactor (MBR)

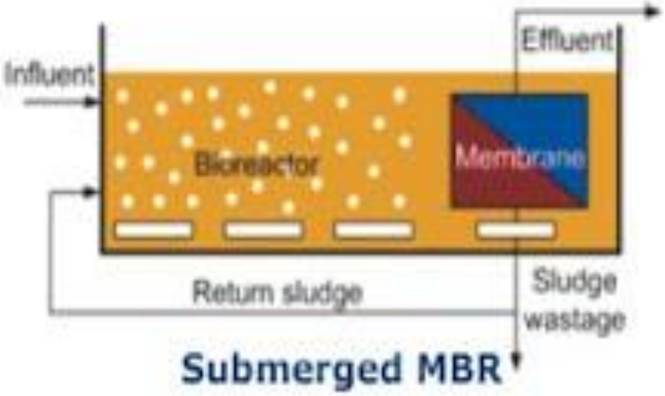
Power consumption of different MBRs

- Submerged MBR:
  - 0.5 kWh/m^3 of effluent treated.
  - Side stream MBR:
  - 2-4 kWh/m^3 depending on the type of effluent.
- Side stream MBR with air lift:
  - 1 - 1.5 kWh/m^3 depending on of type of effluent treated

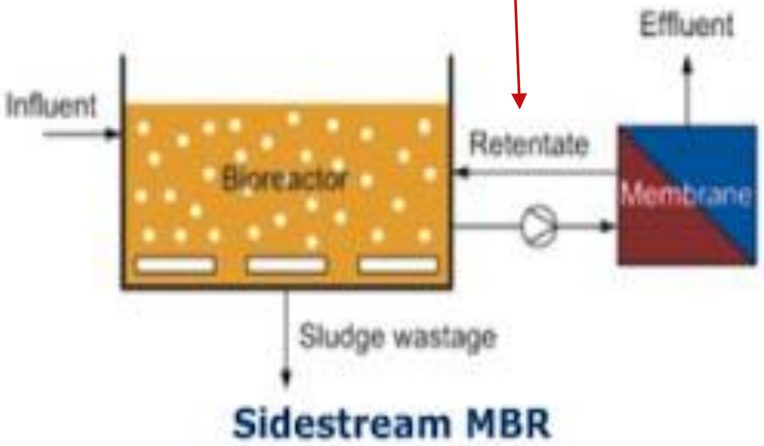
Submerged MBR with placement of membranes; photo: Courtesy Koch

Use of membrane bio reactor (MBR)

Comparison of MBR system set-ups



Return sludge



Use of membrane bio reactor (MBR)

Operational aspects to consider

- **Sludge retention** time (SRT) in MBR high (**30-50 days**)
  - Solids filtered and retained in aeration tank
  - **Higher SRT** increasing chance of **membrane fouling =>** membrane fouling reducing flow
- Two **MBR operating modes**
  (1) Keeping constant pumping pressure with varying permeate flow
  (2) Keeping **constant permeate flow with varying pressure** (better!)
- **Better MBR performance at higher temperature** (up to 450C)
  - Lower temperature increasing operating pressure due to higher viscosity

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Use of membrane bio reactor (MBR)

Common fouling control techniques

1. Membrane backwashing
2. Intermittent operation of submerged membranes
3. Air backwashing
4. Use of better membranes
5. Chemical cleaning

Use of membrane bio reactor (MBR)

Common fouling control techniques

1. **Membrane backwashing**
   – permeate water pumped back to membrane
   – flows through pores to feed channel dislodging internal and external foulants
2. **Intermittent operation of submerged membranes**
   – Stoppage of filtration at regular time intervals while continuing aeration
   – Particles deposited on membrane surface dislodged in absence of suction

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Use of membrane bio reactor (MBR)

Common fouling control techniques

3. **Air backwashing**
   - pressurized air in membrane's permeate side building up and releasing significant pressure within very short period of time.
4. **Use of better membranes**
   - Use of advanced anti-fouling membrane materials for ultrafiltration

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Use of membrane bio reactor (MBR)

Common fouling control techniques

5. Chemical cleaning

- Daily chemically enhanced backwash
- Weekly maintenance cleaning with higher chemical concentration
- Intensive chemical cleaning (once or twice a year)

Use of membrane bio reactor (MBR)

Advantages of MBR

- Better **removal of BOD/COD** and pathogens compared to conventional activated sludge systems
- Better **degradation of complex organics**/Oils & Grease due to higher sludge retention time
- **Treated effluent** very **clear and less turbid**
- **Lesser pre-treatment** when considering effluent recovery
- Good for ETPs with limited space and considering future recycling options

Use of membrane bio reactor (MBR)

Disadvantages of MBR

- **Higher capital cost** for good system
- **Higher operation and maintenance cost** due to additional power and membrane cleaning/replacement
- System more sensitive and **complex in operation**
- Membrane replacement adding to list of consumables.

Use of reverse osmosis

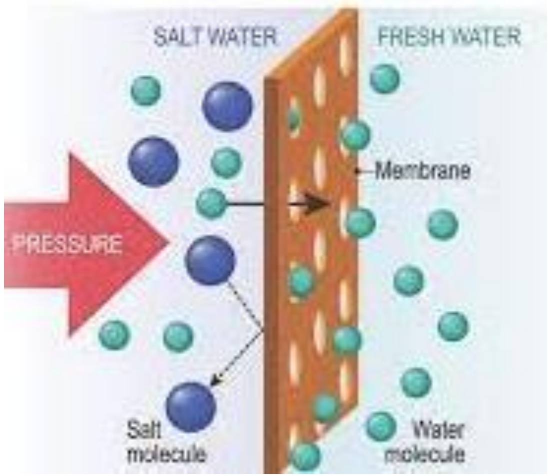
Use of reverse osmosis

Process **separating saline water from fresh water** by membrane

- Membrane allowing passage of fresh water only
- pressure exerted by salt water called 'osmotic pressure'
- Reverse Osmosis (RO)
  - reversal of process by applying pressure on salt side to overcome osmotic pressure)
  - water from saline side passing to fresh water side

Use of reverse osmosis

- Reverse Osmosis membranes **finest pore size**
  - Small enough to filter salt molecules and only allowing passage of water
- RO operating under very **high pressure**
  - pressure depending on salt concentration at system inlet
- Unlike MF or UF, in RO units **no backwashing** but only **cleaning using chemicals**



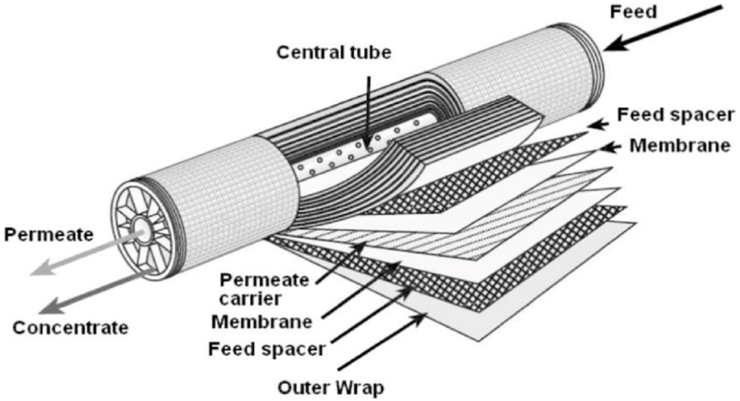
Use of reverse osmosis

- RO system elements:
  - **pre-treatment**
  - **high pressure pump**
  - **RO membranes** stacked in a vessel
  - **permeate collection**

Use of reverse osmosis

RO membranes

- Initially made of cellulose acetate
- Today mostly made of polyamide layer placed over poly sulfone layer and mounted on polyester base.
- Specialty coating on membranes to reduce membrane fouling

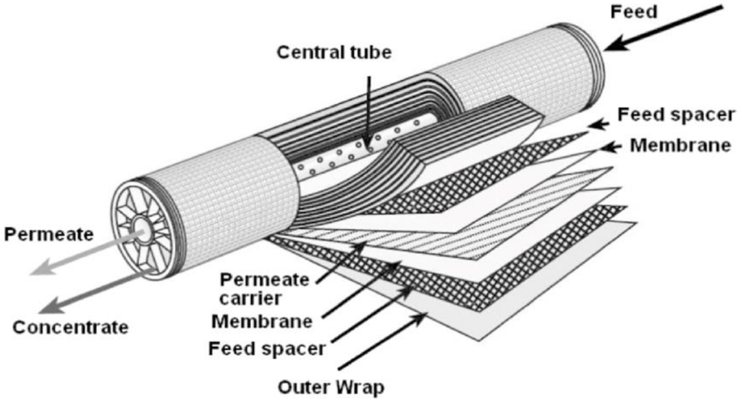


Spiral wound RO configuration

Use of reverse osmosis

RO membranes

- Manufactured by modified polymerization process leaving openings in plastic (pore size)
- Different configuration depending on how membranes arranged in vessel
  - **Spiral wound** (most common)
  - **Disc & tube** or **tubular**



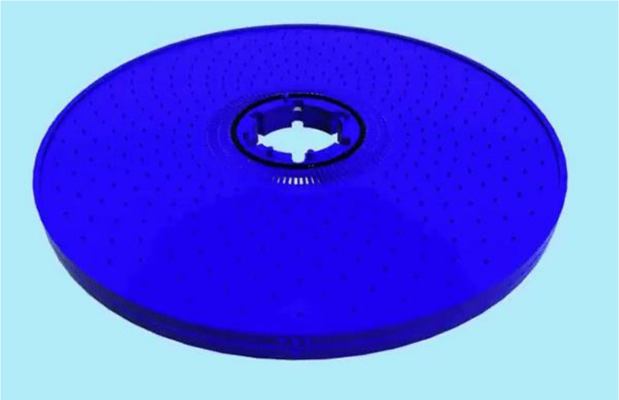
Spiral wound RO configuration

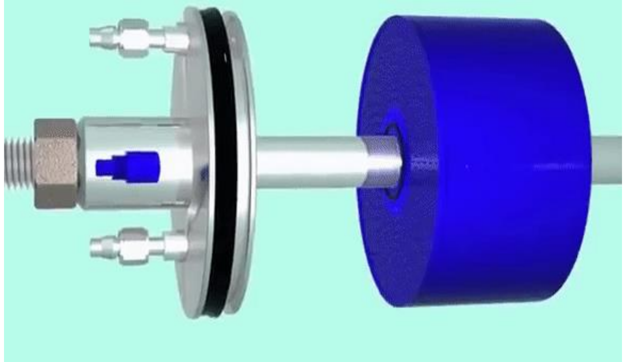
Use of reverse osmosis

RO membranes – set-ups

Disc & tube (DT) RO configuration

- For DT membrane stack
  - RO membranes cut in hexagonal shape
  - placed on disk
  - process repeated to form cassette





Use of reverse osmosis

- Need for **extensive pre-treatment**
  - **Softening**
    - needed to prevent fouling or scaling, if high hardness of treated effluent
    - use of zeolite softener, lime soda softener, pelletizer
  - **Dosing of anti-scalants** at RO to control scaling from calcium carbonate/sulfate
    - inlet kept at slightly acidic side

Use of reverse osmosis

- Need for **periodical membrane cleaning**
  - RO recovery rate (flux rate) reducing due to scaling
  - **cleaning-in-process** (CIP) using special CIP chemicals with acid/alkali
    - Special membrane cleaning chemicals available
- Need for **membrane replacement** generally every **2 - 4 years**
  - Earlier when cleaning not improving recovery rate

Aiming for zero-liquid discharge (ZLD)

Zero-liquid discharge

“No drop of water discharged”

- Objectives
  - to **prevent wastewater discharge**
  - To **recover water for re-use**
- Achieved in multiple stages

Zero-liquid discharge

Steps involved

1. **Conventional physico-chemical and/or biological treatment** for making effluent fit for RO
2. **Pre-treatment** processes removing hardness, silt, turbidity and organics to level preventing fouling of membranes
   - involving softening
   - pre-filtrations in MGF/ACF/ Micron filters

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Zero-liquid discharge

Steps involved

- **Advanced oxidation** methods to control organics
- Often inlet to RO protected with additional **ultra-filtration** membrane
- **Multiple stage RO** system to optimize recovery and minimize reject
  - initially, use of brackish water membranes
  - later stages, use of sea water membranes
- **Evaporation of reject** often after further concentration using high pressure RO system

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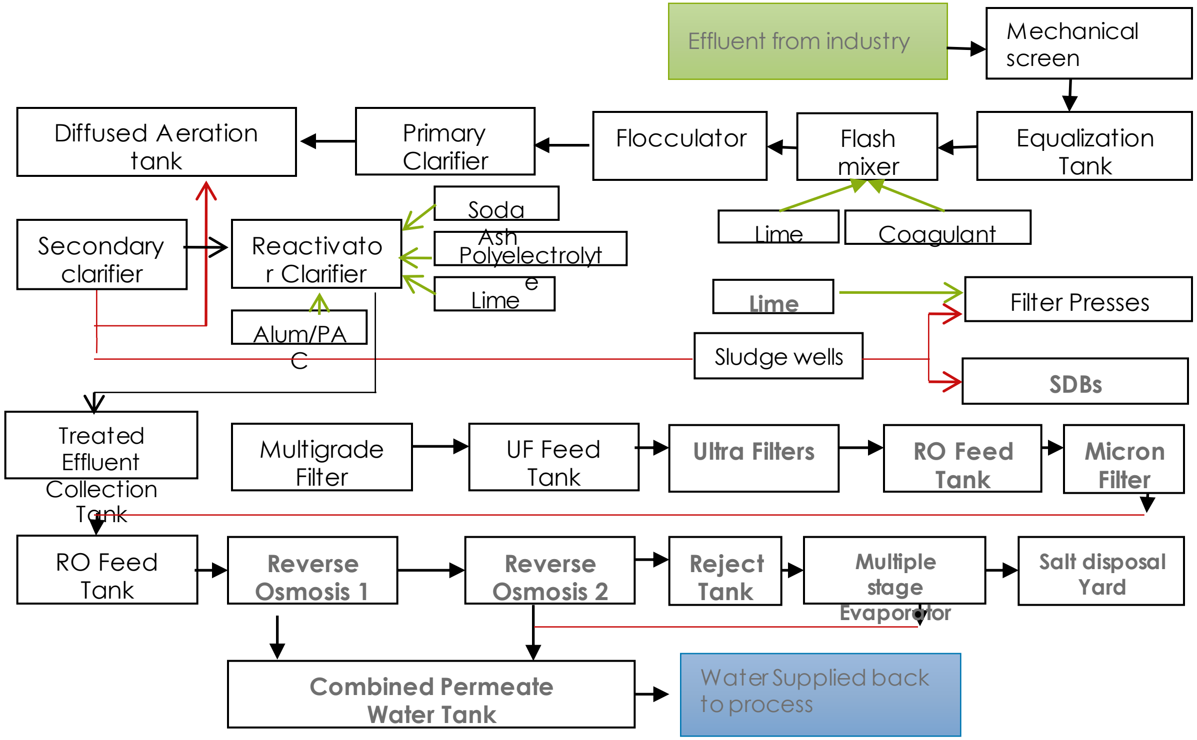
Zero-liquid discharge

Management of RO rejects

- Rejects about **8-15% of inlet volume**
- Common approaches:
  - **Purification with nano-filter** and subsequent **reuse of brine**
    - Rejects of nano-filtration evaporated
  - **Evaporation of entire reject** and disposal of salts (since salt recovery not always feasible)
    - In cotton processing units feasible to recover sodium sulphate using adiabatic chiller and re-use in dyeing

Zero-liquid discharge

Process overview



Zero-liquid discharge

Common issues with Denim effluent

Membranes affected by

- **sizing agents** (PVA or CMC and others)
- **pumice stones** residuals
- **enzymes** used in washing operations leading to chelating reactions with membrane materials
- **indigo** decreasing membrane flux and reducing output

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Zero-liquid discharge

Issues for consideration

- Always **verify system performance promises** by system suppliers
  - Often simpler designs (without membrane systems) using only tertiary oxidation and nano-level filtration.
- Need for high quality water in most textile operations, usually met by water recovered through membranes
- **High cost of installation** and **operation & maintenance** of ZLD
  - Initial **investment Tk 1 - 1.5 Lakh per m^3**
  - **O & M cost Tk 150 - 400 per m^3** depending on need for and type of evaporation of RO reject (e.g. energy need, solar use)

Zero-liquid discharge

Importance of good system design

- **Proper and tailored system** design for industrial use aiming for maximum recovery in RO and lowest quantity of saline reject
  - RO systems usually manufactured for saline, but clean water => risk of fouling
- **Pre-requisites** for good RO life (> 2 - 3 years) and decent recovery (>75%):
  - **low COD**
  - **low hardness** (particularly Calcium)
  - **pre-treatments** to reduce COD and hardness

Zero-liquid discharge

Importance of good system design

- Control of turbidity in inlet water
  - pre-treatment of RO inlet using ultrafiltration to reduce **Silt Density Index** (SDI) to **less than 5**.
- Maximize recovery using **three stage RO system**
  - Membranes to be selected for each stage (brackish vs seawater, special coating to make it fouling resistant, high pressure etc.)

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Zero-liquid discharge

Advantages of ZLD

- Provision of **full legal compliance** with discharge standards as well as **conformance to customer requirements**
- **Water securit**y for industry facing critical water scenarios
- **Better image** with buyers, public, NGOs and authorities
- Important positive impact on **protection of environment**
- Water recovery ensuring zero loss of production
- Use of water from ZLD ensuring **consistency and control in product quality**

Zero-liquid discharge

Disadvantages of ZLD

- Ensuring 100% ‘zero‘ very difficult
- Costliest treatment in installation and prohibitively costly in operation affecting competitiveness of industry
- Disposal of evaporated mixed salt challenging.
- Need for adequate and ready technical support
- Need for trained staff for operation

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