Master Training Program on Water (Water Supply, In-house Processing, End-of-Pipe) in Textile and Garment factories

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

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Day 6: Presentation 2

Making Treated effluent fit for recovery systems

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Contents

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Need for advanced treatment before effluent recovery

- Most effluent recovery systems use membranes for purification
- Most membranes are designed to treat saline, but otherwise pure water, as input
- Membranes are prone to fouling (plugging) if treated effluent high in
  - Fine suspended solids (silt)
  - Organic compounds (BOD/COD)
  - Microbial population (mostly bacteria)
  - High hardness
- Make treated effluent fit for membrane systems such as Reverse Osmosis is a major challenge.
- Advanced tertiary treatment systems are useful for this purpose.

Basic concept and overview of advanced treatment

- **Final treatment stage**, to comply with norms and make effluent fit for recycle systems such as Reverse Osmosis.
- **Single stage** or using **combination** of tertiary systems.
- Focus on
  - ✓ Reduction of **color**
  - ✓ Reduction of **turbidity** and **suspended solids**
  - ✓ Destruction of **pathogens**
  - ✓ Removal of residual **organics**
  - ✓ sometimes for aesthetic purpose and as precautionary or complimentary measure

Basic concept and overview of tertiary treatment

Common tertiary treatment systems

- **Disinfection** mainly to kill micro-organisms in treated effluent and some for organic removal.
- **Filters**, using filter media to filter out suspended particles in effluent
- **Adsorption filters** most commonly activated carbon filters to remove organics
- **Oxidation systems** to oxidize residual organics in treated effluent

Basic concept and overview of tertiary treatment

Other tertiary treatment systems

- Chemical precipitation systems for removal of phosphates/metals.
- Softening using lime/soda softening or zeolite softeners
- Membrane based filtrations (using ultra filters or nano-filters) – membrane bio-reactor incorporates ultra filtration in itself.

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Advanced treatment systems

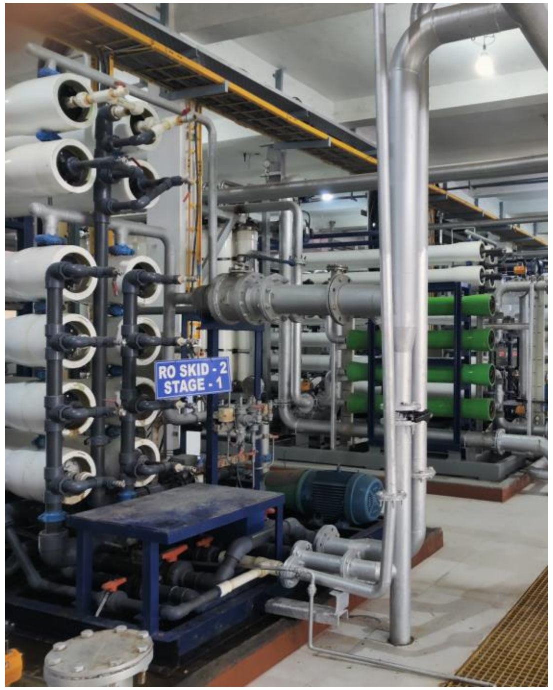
Advanced wastewater treatment

- To overcome the limitations of conventional biological treatment & make it for membranes, improved biological systems developed.
- Recently, many advanced biological treatment systems are being used for textile effluent treatment.
- It comprises of modification of conventional treatment systems such as MBBR/FAB as well as in-situ units such SBR or RBC type units.
- While these systems consumes relatively lesser space and provide better treatment, it does not effectively address issues such as space constraints, pre-treatment requirement for recycling, sludge generation etc.
- Membrane bio-reactor (MBR) is being increasingly considered as an effective biological alternative for this purpose.

Membrane bio-reactor as a solution

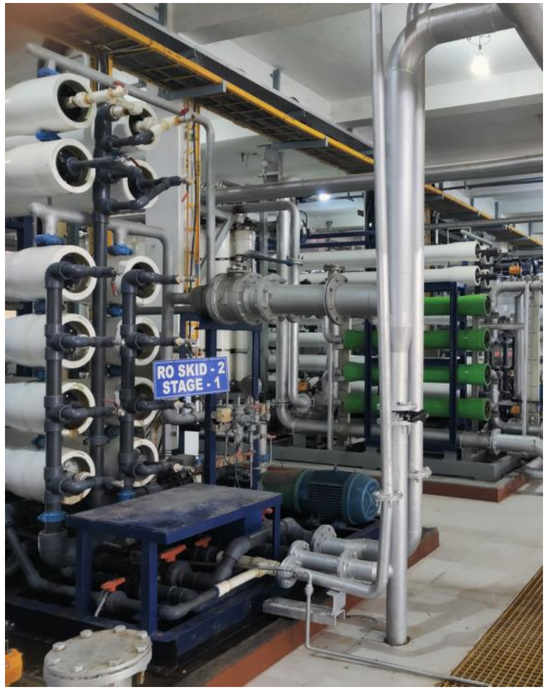
- Membrane bio-reactor is a modified biological treatment which use a membrane filter for solids separation.
- Membranes are fine filters can filter out all suspended and colloidal solids, some times even dissolved solids.
- Membrane bio-reactor consumes much less space and produces effluent with clarity & no suspended solids.
- Due to its high solids retention, it can treat recalcitrant organics much better.
- It does not have much of the operational issues in secondary clarification such as sludge sludge bulking.
- It also produces relatively less sludge and need much lesser pre-treatment for ZLD.

Membrane bio-reactor



- MBR is basically an 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.

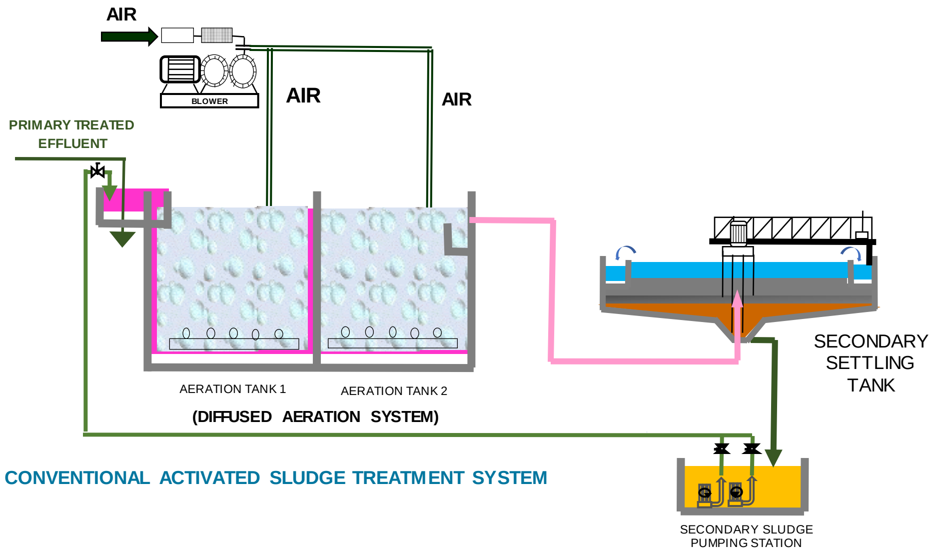
Membrane bio-reactor



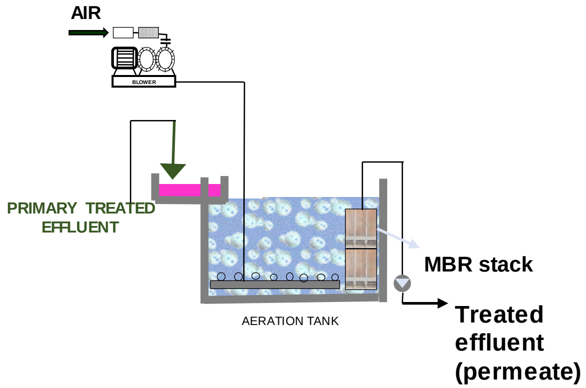
- Submerged MBR use less power. But frequent membranes fouling an issue.
- The external MBR, generally called side stream MBR, continued to be the preferred MBR system for small plants.
- Generally MBR is preferred over conventional system where the space availability is a concern and recycle options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

- MBR has basically two components: aeration tank and set of micro/ultra filter.
- In submerged MBR, membranes, tacked in cassettes, is installed in aeration tank.
- The filtrate is sucked out using vacuum/ pressure pump, leaving MLSS in the tank
- 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

Performance of MBR Vs conventional treatment

- MBR effluent may have zero suspended solids. The treated effluent turbid is generally less than 10 NTU.
- Since only dissolved organics escape the system, the BOD/COD reduction could be 40-60% better than conventional
- The mean cell retention time in MBR can be 80-120 days as against the 25-30 days in conventional. This ensures better reduction of recalcitrant/refractory organics.
- Overall space requirement of MBR based ETP can be about 60% of the conventional ETP.
- The sludge production from the unit can be 30-45% less than conventional treatment.

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
  - aeration tank is constructed in two compartments and membrane stack is installed in one compartment.
- Submerged MBR normally consumes power @ 0.5 kWh/m^3 of effluent treated Vs side stream @ 2-4 kWh/m3 depending on the type of effluent.

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 bioreactor

MBR Advantages

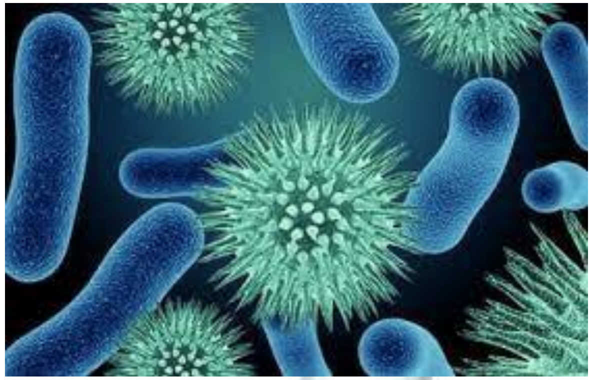
- Better removal of BOD/COD and pathogens .
- With no suspended solids, clear & less turbid treated effluent.
- Lesser pre-treatment when effluent recovery is considered.
- Much less area compared to conventional ASP.

MBR disadvantages

- Higher capital cost
- Higher O & M cost 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 results membrane clogging.

Tertiary treatment systems - Disinfection

Tertiary treatment systems - Disinfection

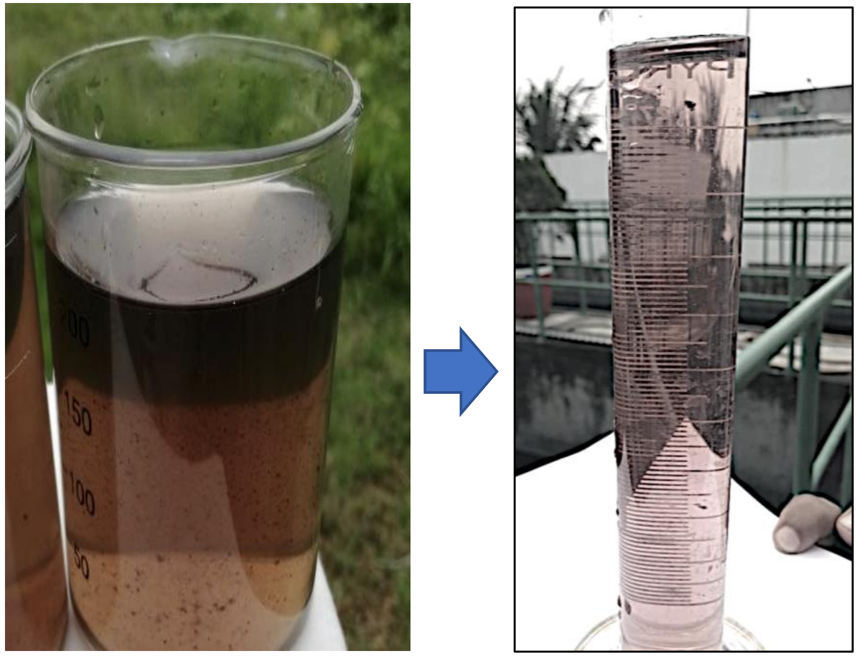


- To **kill micro-organisms**, specifically **pathogens** in treated effluent
- Chlorination **most common** disinfection system - mixing effluent with chlorine gas in contact chambers or dosage of hypo-chlorites.
- **Increased efficiency** of chlorination with **higher dosage, lower pH, higher temperature** and **longer contact time**
- UV radiation can kill pathogen: effluent passing through chamber illuminated by UV rays from UV lamp
- Different types UV-A, UV-B, UV-C : the last more effective & consume more power.

Tertiary treatment systems – Filtration

Image: AOS treatment solutions

Tertiary treatment systems - Filtration



Filtration

- Used for removal of suspended solids in treated effluent
  - ✓ Also partly reducing BOD/COD by removing some organics (like MLSS particle) in the suspended solids
- Done by gravity or pressure filters
  - ✓ Slow sand filters using gravity (only small ETPs)
  - ✓ Pressure sand filters using vessel filled with filter media with effluent being pumped and filter under pressure
  - ✓ Fine filtrations (such as pre-treatment of membrane) with cartridge filters

Tertiary treatment systems - Filtration

Filtration – Pressure filters

- Common types in wastewater treatment:
  - ✓ **Pressure sand** filters
  - ✓ **Multi-grade** filters
  - ✓ **Dual media** filters
- Similar in construction and operational pattern but varying in composition of filter media
- made of FRP, MS (often rubber lined) and stainless steel
- New types of media coming to market every year.

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Tertiary treatment systems - Filtration

Filtration – Pressure filters

- Measurement of **operational efficiency** through parameters like **filtration rate, head loss and frequency of backwashing** needed.
- Backwashing whenever pressure drop more than 1 bar.
- Sometimes preceded by air scouring for agitating media with scrubbing action and loosens retained solids.
- Common **filtration media**
  - ✓ most common **silica sand** and **anthracite coal**
  - ✓ quartz sand, garnet, magnetite
- **Size and shape** of filter media **affecting efficiency**
  - ✓ **Smooth and rounded better** than sharp and angular media
  - ✓ Most suspended solids at surface (top 5 - 10 cms), gradually solids percolating down to prevent rapid pressure drop

Pressure filters: Operation cycle

Service

- Inlet water is pumped down through the media via the distribution tube.
- Collect the drained water as filtered water.

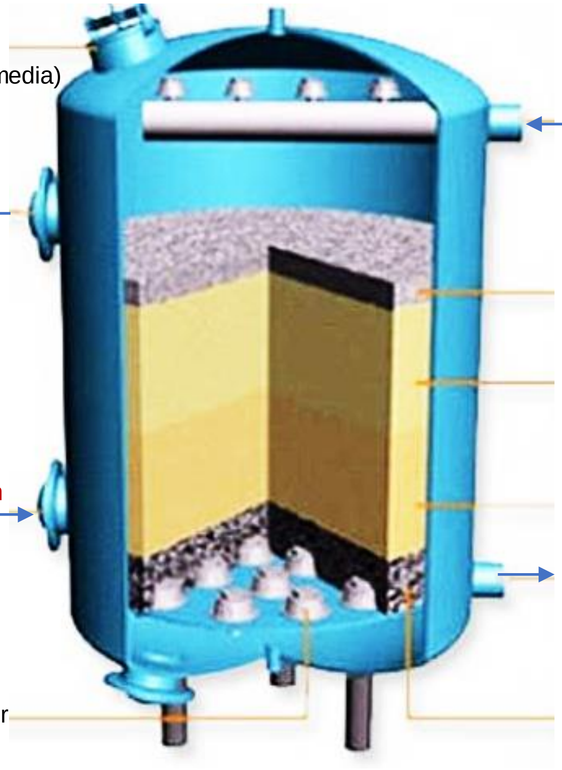
Backwash

- Flow is reversed.
- The flow is forced through the bottom and up through the media.
- Backwash lifts media and causes scouring
- Collected dust and debris is flushed to the drain

Slow Rinse

- Use clean water allowed to flow down through media bed & distribution tube to drain.
- With autovalves and controls, entire backwash & rise can be programmed based on fixed quantity of flow, at scheduled time or based on differential pressure.

Tertiary treatment systems - Filtration



Stainless Steel

Filtration: Pressure sand filters

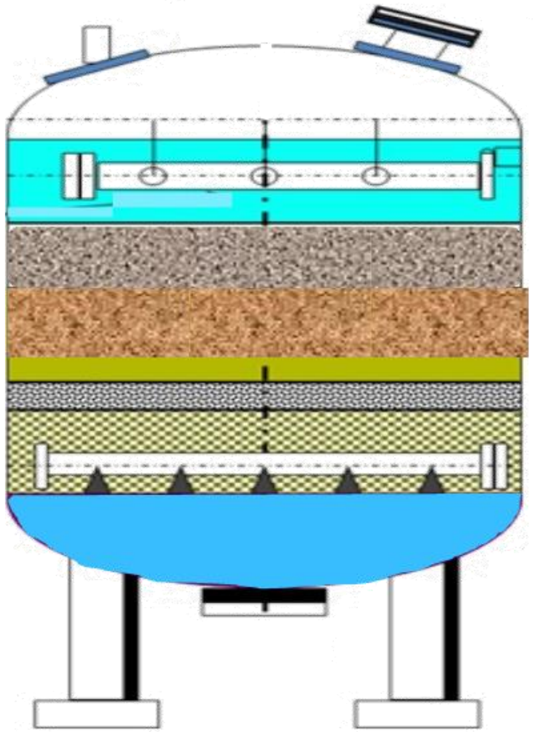
- Usually cylindrical vessel filled with filter media.
- Vertical or horizontal orientation
- Set of frontal pipe work and valves
- Graded silica quartz sand
- Sand layer supported by under-bed of pebble/gravel.
- Water admitted via top distributor
- Under-drain collecting filtered water

Tertiary treatment systems - Filtration

Filtration : Multigrade filters

- similar to pressure sand filter in construction with cylindrical vessel and identical piping/valves
- Same way of operation and backwashing
- coarse and fine media mixed together in fixed proportion.
- **filtration efficiency not as fine** as in pressure sand filter but **turbidity reduction better**
- Higher flow rate and turbidity reduction than pressure sand filter
- Less filtration efficiency, more energy and higher backwash than pressure sand filters.

Tertiary treatment systems - Filtration



Filtration – Dual media filters

- similar to pressure sand filter in construction with cylindrical vessel and identical piping/valves
- Same way of operation and backwashing
- sand-anthracite filter or multi-media used for removal of turbidity and suspended solids
- Remove TSS as low as 10 - 20 microns
- higher filtration rate & flow than other pressure filters.
- Backwash water need & frequency of backwash higher and media has lower life.

Tertiary treatment systems - Filtration

Filtration – Cartridge filters

- used for **very fine filtration** e.g. pre-treatment of membranes
- cartridge filters considered as **consumables**
  - ✓ possible to clean by soaking in cleaning solution
  - ✓ to be replaced once clogged irreversibly
- usually very **small in construction**
- generally **used in-line of pumping lines**
- usually pore sizes in range of **0.2 - 20 microns**
  - ✓ smaller pore size = shorter replacement period
- There are surface filters & depth filters

Tertiary treatment systems – Removal of organics

Image: Center Enamel

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Basic concept and overview of tertiary treatment

Options for management of residual organics

- Treated effluent containing organics not removed in biological treatment since on bio-degradable to lesser extent
- Tertiary treatment systems for removal of residual organics:
  - ✓ Adsorption of organics in adsorbent media, such as activated carbon filters and organic scavengers.
  - ✓ Advanced oxidation systems
  - ✓ Ozonation of treated effluent
  - ✓ Fenton treatment: Oxidation catalyzed by iron

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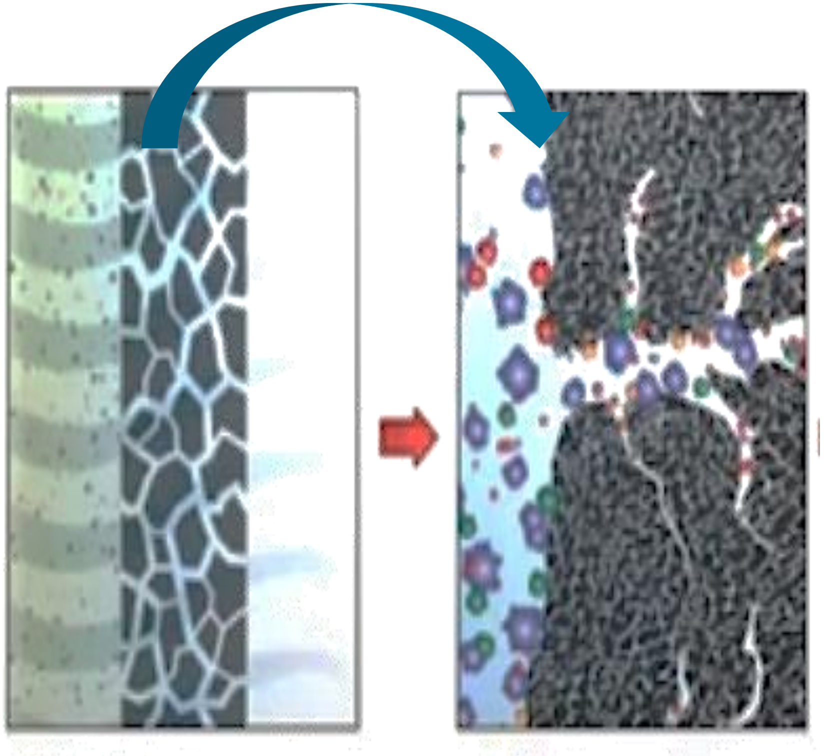
Tertiary treatment systems - Adsorption



Activated carbon filtration

Adsorption = adhesion of ions or molecules to surface

- In effluent treatment **entrapment of organics** (or other contaminants like chlorine) **in adsorbent medium**
- Physical entrapment in voids of porous medium or attachment to surface due to surface charge
- **Activated carbon:** Inert solid adsorbent material made from almost any carbon containing feedstock (e.g. wood, coconut shells and coal)
- Porous, inexpensive and high surface area per gram

Tertiary treatment systems - Adsorption

Activated carbon filters

- similar in construction to pressure sand filters
- activated carbon as filter media
- commonly **granulated activated carbon** with 0.4 - 1 mm diameter or powdered activated carbon
- backwash process similar to pressure sand filters but without air scouring
- strainers at bottom to prevent carbon from flowing out with filtered and at top to prevent loss of carbon during backwash
- carbon media to be replaced once exhausted
- regeneration presently not economical

Tertiary treatment systems – Advanced oxidation

Advanced oxidation processes = **chemical treatment** process for **removing organic** (and sometimes inorganic) **pollutants**

- Common systems
  - ✓ **Ozone**
  - ✓ **Hydrogen peroxide** with or without UV radiation
  - ✓ **Fenton treatment**
- Concept
  - ✓ Hydroxyl radical (OH-) and nascent oxygen as active reactants
  - ✓ Hydroxyl radicals produced in water with primary oxidants like oxygen, ozone and peroxides enhanced with energy sources or catalysts

Tertiary treatment systems – Advanced oxidation

AOP system by NOVEXX

Photochemical oxidation process

- Hydroxyl radicals present in chemicals with extra oxygen atoms
  - ✓ generation enhanced by radiation with UV rays
    - ➢ $H_2O_2 + UV \rightarrow 2 \cdot OH$
- Organics pollutants oxidized by hydroxyl radical and broken into simpler organics and further oxidized into carbon dioxide
  - ✓ **Higher efficiency in acidic conditions** (optimal pH 3 – 6)
  - ✓ **Natural organic matter** or carbonate species **reducing effectiveness**
  - ✓ Reduced metal ions (e.g. Ferrous and Manganous) reducing effectiveness since consuming excess oxygen

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Advanced oxidation

Advanced oxidation Advantages

- Low space requirement
- Complete degradation of organics
- Fast reaction and very lower retention times vis-à-vis others
- Treatment of wide range of organics
- Complete disinfection too
- No sludge production

Advanced oxidation disadvantages

- Need for highly skilled labor to operate and control
- High capital and operating & maintenance costs
- Complex chemistry
- Need to control and remove of product of oxidation.
- Residuals affecting membranes if proper anti-oxidant control not ensured

Tertiary treatment systems – Advanced oxidation

Fenton treatment

- Popular variant type of advanced oxidation (also as further advanced photo Fenton system.
- Based on liberation of OH radicals from H_2O_2 **catalyzed by ferrous ions** (in photo Fenton with use of UV radiation)
- Oxides of iron produced in reaction catalyzing oxidation of organics by OH radicals

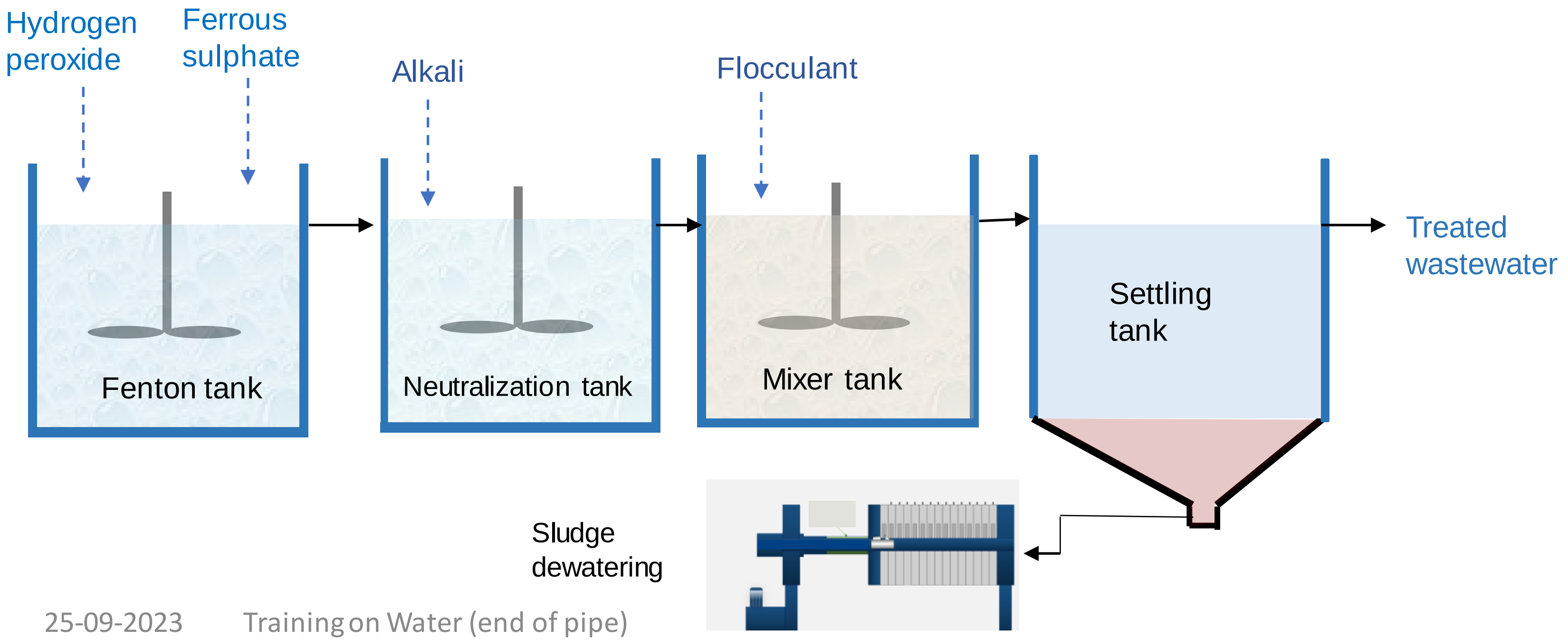


Photo Fenton reactor
(Model: ENVIOLET)

Fenton Treatment

- Relatively lower capital cost
- Simple and easy process
- Suitable for all organic materials and some heavy metals
- No concentration of contaminants like salts

Fenton system Advantages

- Generation of ferric sludge for dewatering/disposal
- High operation and maintenance costs: peroxide and pH management
- Need to adhere to strict pH range

Fenton system disadvantages

Tertiary treatment systems – Ozone treatment

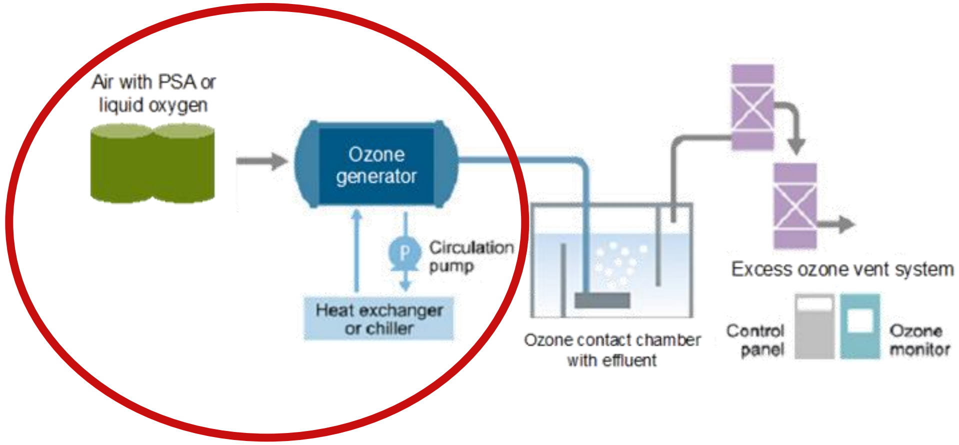
Basic concept

- Ozone (O3) = oxygen gas with additional oxygen atom
  - ✓ **pale blue gas** with distinctively **pungent smell** and **potentially toxic**
- Ozone **generated** in most ETPs from **oxygen-bearing gas subjected to electric field or UV**
  - ✓ done on-site since unstable and quickly decomposing to oxygen
  - ✓ Ozone generators using air or oxygen as source, with occasional oxygen concentrators
- when generated from air usual concentration 0.5-2% ozone
- with oxygen gas usual concentration 4 - 7% ozone

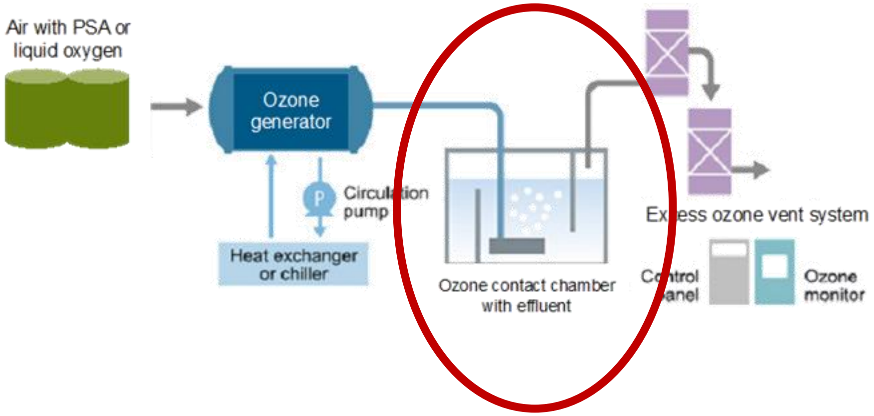
Tertiary treatment systems – Ozone treatment

Use in effluent treatment

- Electrical discharge method most common source for generating ozone
    - ✓ Extremely dry air or pure oxygen exposed to controlled, uniform high-voltage discharge



Tertiary treatment systems – Ozone treatment



Use in effluent treatment

- After generation, ozone fed into **down-flow contact chamber** containing wastewater to be treated
  - ✓ Aim to transfer ozone from gas bubble into bulk liquid with sufficient contact time for disinfection.
  - ✓ Commonly used contactor type **diffused bubble**
- co-current and counter-current
- variants: positive pressure injection, ventury, mechanically agitated and packed tower.

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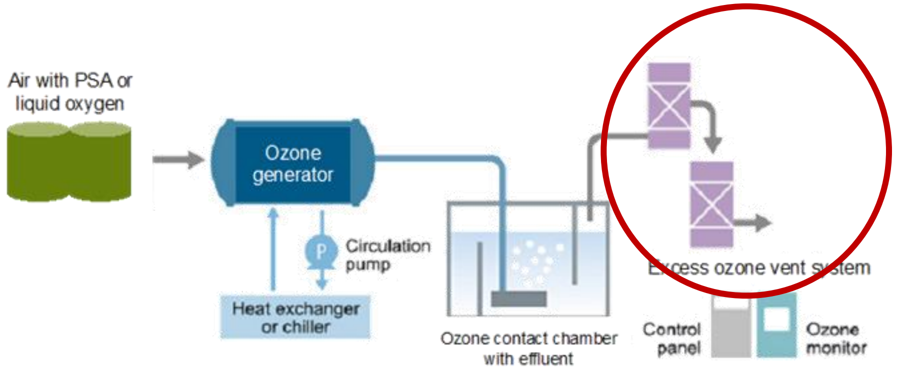
Tertiary treatment systems – Ozone treatment



Use in effluent treatment

- **Treatment of off-gases** from to destroy any remaining ozone
  - ✓ In case of pure oxygen as feed-gas, recycling of off-gases from contact chamber possible to generate ozone or reuse in aeration tank.

Tertiary treatment systems – Ozone treatment

Example

Ozonator
(at Wylie Water Treatment Plant, North Texas)

Ozone Treatment

- Little space required
- Destroy pathogens & organics
- Fast: less than 30 min
- No harmful residuals
- No bacteria regrowth
- Onsite generation of ozone
- Increase in dissolved oxygen

Ozone treatment Advantages

- High capital and operation & maintenance costs
- Need for highly skilled labor
- More complex than others
- Need for corrosion-resistant material (e.g. stainless steel)
- Not economical for removal of high levels of TSS/COD

Ozone treatment disadvantages

Quality of tertiary treated effluent

- Quality of tertiary treated effluent depends on **efficiency** of basic effluent treatment, **type of tertiary** treatment & its management.
- Generally, the treated effluent after tertiary is nearly colourless, very low suspended solids and low level of organics.
- Still, the quality of this water may **not conform to inlet requirements** of membrane filtration such as Reverse Osmosis.
- Hence **pre-treatment to membranes** are required additionally for any recovery.

Table - Treated effluent quality Vs requirement for RO

Parameter	Unit	Effluent after tertiary	Required at inlet of RO
pH		6.5 – 7.5	6.5-7.0
Suspended solids	mg/l	5-15	<1
BOD/TOC	mg/l	5-10	<2
Total Nitrogen	mg/l	1-5	<5
Total hardness	mg/l	100-200	<250
Turbidity	NTU	10-20	<5
Calcium hardness	mg/l	75-150	<200
Silica	mg/l	15-20	<30
Oil & Grease	mg/l	0.3 -2	<1

To remember

- While recovery & re-use of effluent seems attractive, it need high level of treatment efficiency in ETP.
- Presence of residual organics, fine suspended solids etc. need extensive pre-treatment for any recovery options.
- **Membrane bio-reactors** can be an effective modification to address these issues.
- **Pressure filtrations** are simple common tertiary treatment.
- **Activated carbon treatment** quite common in Bangladesh textile ETPs as polishing treatment
- **Fenton treatment** installed in few ETPs, preferred due to **No sludge** generation and **low space** requirement
- **Advanced oxidation** though costlier than other tertiary systems can remove **residual organics**

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

Friedrich-Ebert-Allee 32 + 36
53113 Bonn, Germany
T +49 228 44 60 - 0
F +49 228 44 60 - 17 66

Dag-Hammarskjöld-Weg 1 - 5
65760 Eschborn, Germany
T +49 61 96 79 - 0
F +49 61 96 79 - 11 15

E info@giz.de
I www.giz.de

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH