TRAINING OF TRAINERS PROGRAMME ON CAPACITY DEVELOPMENT OF ETP OPERATORS

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

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Day 4: Presentation 4

Tertiary Treatment for Textile Wastewater

Contents

Basic concept and overview of tertiary treatment

- **Final treatment stage**, mostly to comply with norms
- Focus on
  - ✓ Reduction of **color**
  - ✓ Reduction of **suspended solids**
  - ✓ Destruction of **pathogens**
  - ✓ Removal of **organics**
  - ✓ Improvement of treated effluent appearance
  - ✓ sometimes for aesthetic purpose and as precautionary or complimentary measure

Basic concept and overview of tertiary treatment

- Required as **pre-treatment for effluent recovery** using membrane systems by removing turbidity, hardness etc.
- **Single stage** or using **combination** of tertiary systems.
- Often installed as polishing treatment after physico-chemical treatment, in most primary ETPs and referred to as tertiary treatment

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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

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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)

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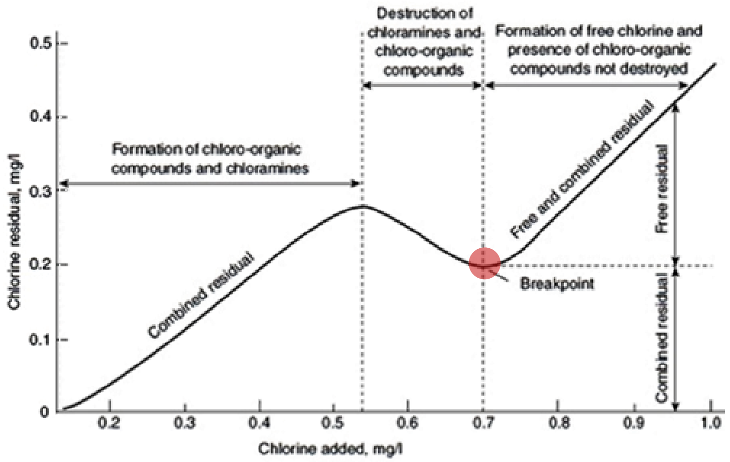
Tertiary treatment systems - Disinfection

Tertiary treatment systems - Disinfection

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
  - ✓ Chlorine killing micro-organisms by breaking their cell walls
  - ✓ In case of sodium or calcium hypo-chlorites, chlorine content to be calculated and dosage fixed accordingly
- Generation of **disinfection-by-products** (DBPs)
  - ✓ haloacetic acid, trihalomethane, and chloral hydrate
  - ✓ controlled by activated carbon filtration or membrane filters.

Tertiary treatment systems - Disinfection



Example of break-point chlorination chart

Disinfection using chlorination

- Chlorination usually based on **break-point chlorination**
  - ✓ Keep adding chlorine (or hypo) to measured quantity of effluent
  - ✓ Check residual chlorine using DPD laboratory tablets
  - ✓ Residual chlorine first increasing, then decreasing and increasing again with more chlorine dosing
  - ✓ Point of increase = break point or correct dosage of chlorination.

Tertiary treatment systems - Disinfection

Disinfection using chlorination

- Storage and dosing chlorine gas **difficult and safety risk**
  - ✓ Use of sodium hypochlorite or calcium hypochlorite in small- and medium ETPs but less preferred due to sludge issues
  - ✓ Sodium hypochlorite generally containing 10% - 12% chlorine
    - ➢ Need to calculate dosage accordingly
- **Increased efficiency** of chlorination with **higher dosage**, **lower pH**, **higher temperature** and **longer contact time** (usually 30 min)
  - ✓ If not effective, take corrective actions such as by increasing dosage, increasing contact time (reduce flow) or reducing pH

Tertiary treatment systems - Disinfection

Disinfection using Ultraviolet (UV) system

- Pathogens killed by exposing effluent to UV radiation damaging DNA of bacteria/virus
  - ✓ effluent passing through chamber illuminated by UV rays from UV lamp
  - ✓ low pressure and medium pressure lamps common.
    - ➢ Medium handling higher flows, but consuming more power
- As per wavelength classification into UV-A, UV-B, UV-C
  - ✓ UVA less powerful, but consuming less power
  - ✓ UV-B with medium efficiency and medium power consumption
  - ✓ UV-C highest power consumption and efficiency

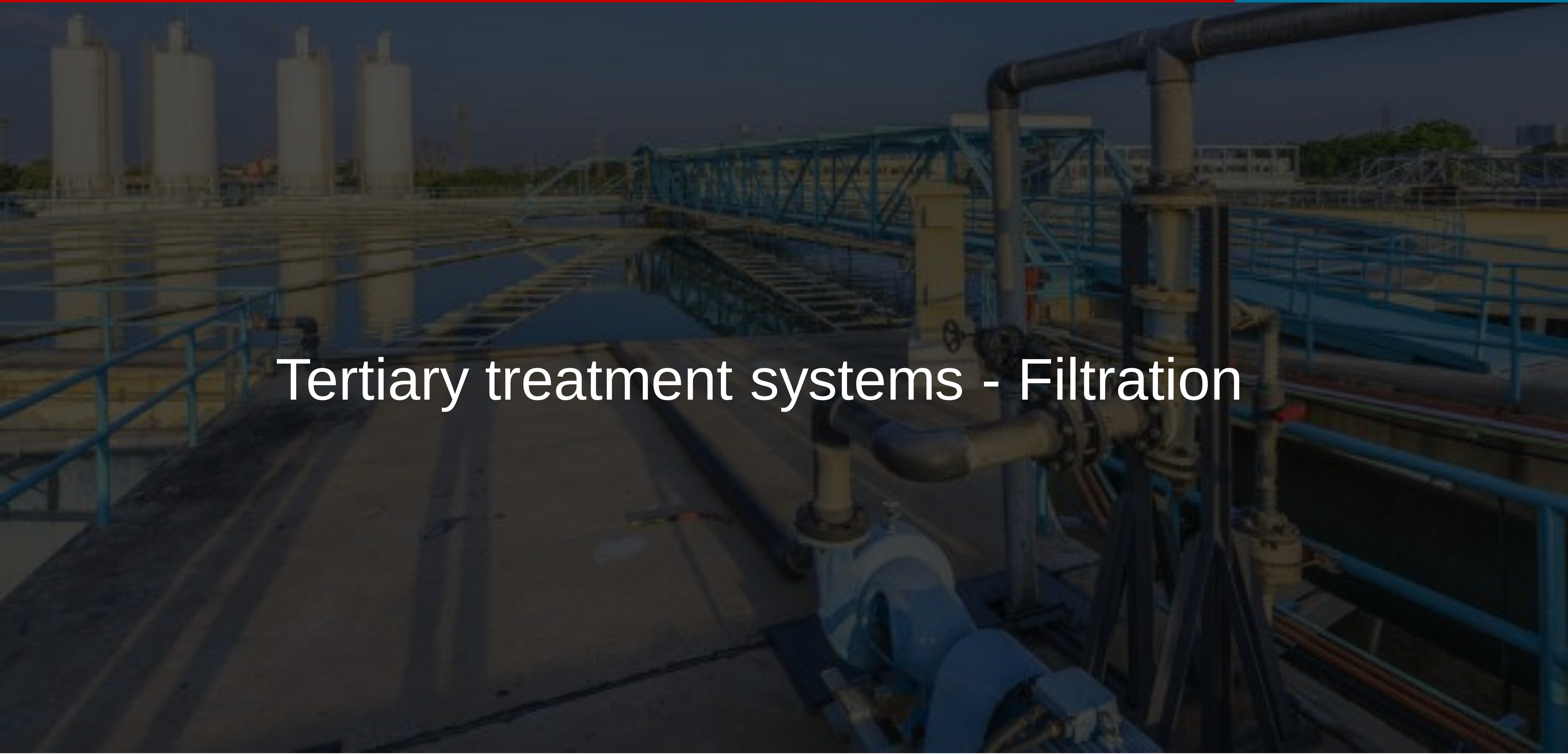
UV disinfection

- Effective in bacteria, viruses and cysts
- No residual effect
- No need to buy, store dangerous chemicals.
- Short contact time (20-30 sec)
- Less space requirement

Rapid sandfilter Advantages

- Low dosage not effective.
- Organisms sometimes surviving
- Frequent cleaning
- Not suitable for TSS levels above 30 mg/l
- Costlier in installation

Rapid sandfilter disadvantages



Tertiary treatment systems - Filtration

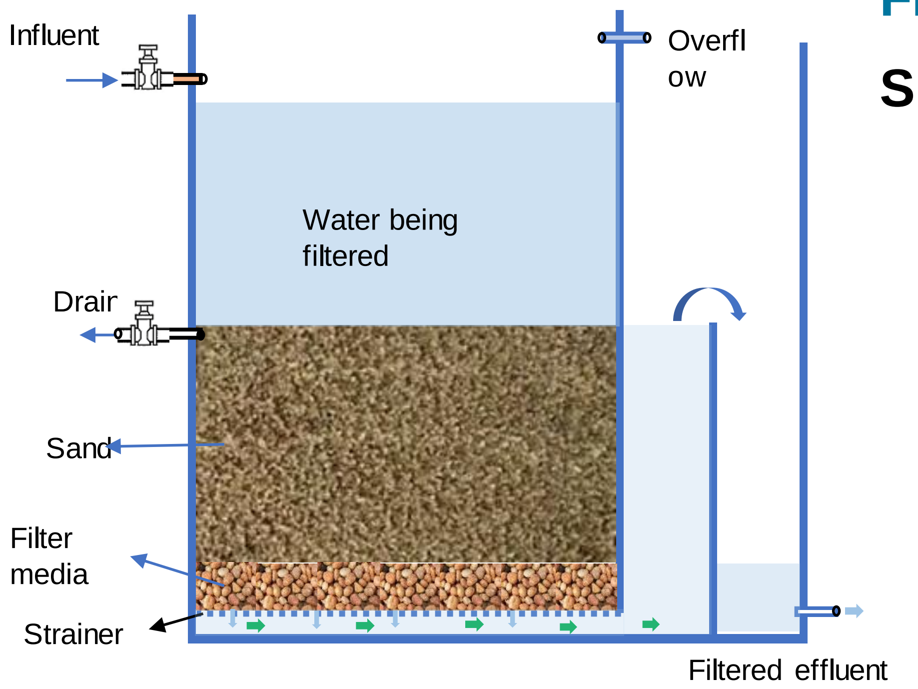
Image: AOS treatment solutions

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 for pressure filters
  - ✓ Slow sand filters using gravity (similar to sludge drying beds)
  - ✓ 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 - Gravity sand filters

Slow sand filters

- similar to sludge drying beds with coarse media at bottom, fine sand at top
- water admitted from top, with pressure by water column speeding filtration
- Solids retained in top sand layer
- Periodically, filter dried and solids scooped out for disposal
- Top sand cleaned and topped up with fresh sand

Slow sand filter

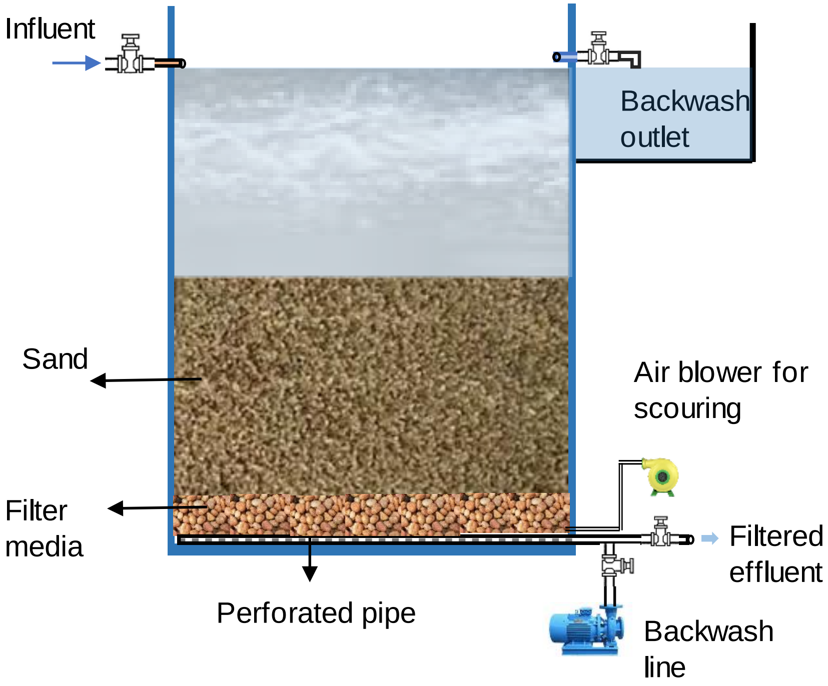
- Simple construction
- very low operating costs
- simple process control
- good efficiency

Slow sandfilter Advantages

- high land requirement
- suitable for small ETP
- potential clogging
- not suitable for effluent with high level of suspended solids

Slow sand filter disadvantages

Tertiary treatment systems - Filtration



Filtration - Gravity sand filters

Rapid sand filters

- **similar to slow sand filter**, provision in filtrate line to admit water at pressure to carry out periodical backwash
- network of net covered perforated pipes for draining & backwashing.
- backwashing with pump or water tank at sufficient height for required head
- Often with air scouring as additional washing aid

Rapid sand filter

Rapid sandfilter Advantages

- higher capacity
- no manual cleaning required
- suitable for medium ETPs
- easy process control
- good efficiency

Rapid sandfilter disadvantages

- Land requirement (less than slow sand filter, higher than pressure filters)
- not suitable for effluent with high suspended solids
- relatively more maintenance

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.

Pressure filters - different vessel materials

Mild Steel (MS)

Fibre reinforced Plastic (FRP)

Stainless Steel (SS)

Tertiary treatment systems - Filtration

Filtration – Pressure filters

- Measurement of **operational efficiency**
  - ✓ **filtration rate** = quantity of water filtered per unit area
  - ✓ **head loss** = difference between inlet and outlet pressure
  - ✓ **frequency of backwashing** needed.
- Backwashing with clean water whenever pressure drop across filter more than 1 bar.
- Sometimes preceded by air scouring for agitating media with scrubbing action and loosens retained solids

Tertiary treatment systems - Filtration

Filtration – Pressure filters

- 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.

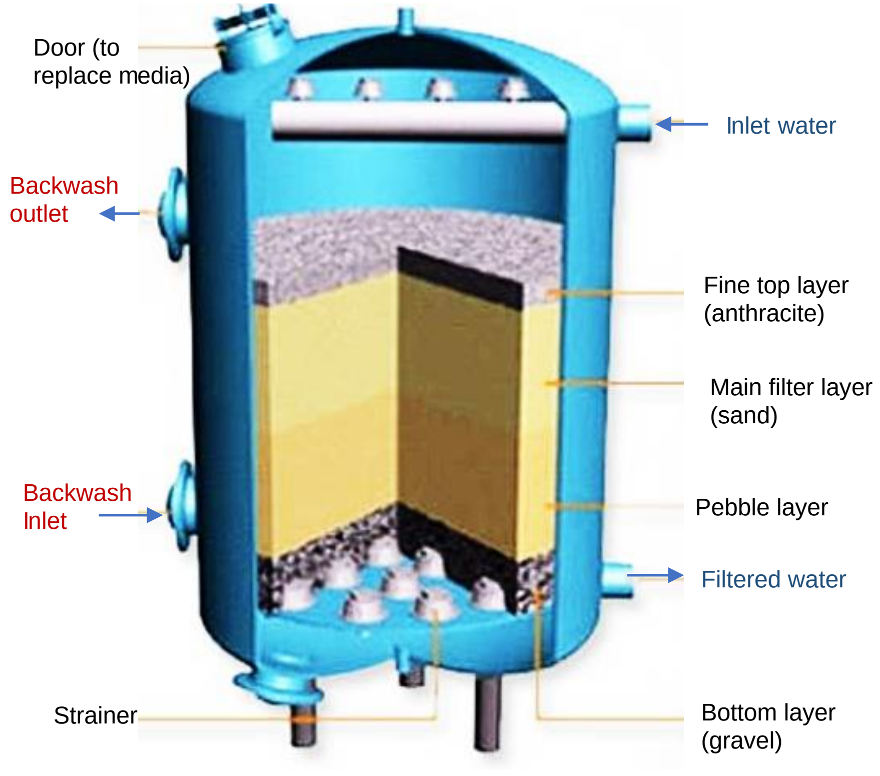
Backwash

- 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

Pressure sand filter

- High flow rate
- no manual cleaning needed
- suitable for medium/large ETPs
- easy process control
- Low land requirement

Pressure sand filter Advantages

- Less fine solids removal than slow sand filters.
- Need energy for its operation.
- Backwash water requirement high.

Pressure sand filter disadvantages

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**

Multi grade filter

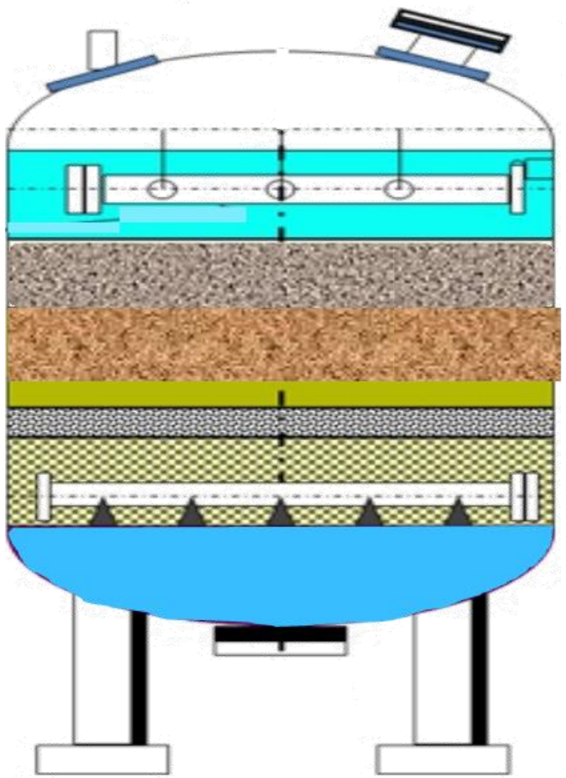
- Substantially higher specific flow rate than pressure sand filter
- Turbidity reduction better than PSF
- no manual cleaning needed
- Low land requirement

Pressure sand filter Advantages

- filtration efficiency not as fine as in pressure sand filter
- Need more energy for its operation.
- Backwash water requirement high.

Pressure sand filter disadvantages

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

Dual media filter

- Very efficient particle removal
- high filtration rate
- higher specific flow rate than PSF & MGF
- number of filters and size for ETP still smaller

Pressure sand filter Advantages

- Backwashing frequency needed for DMF is higher than PSF and MGF
- Backwash water consumption is much higher.
- Life of media is lesser.

Pressure sand filter disadvantages

Tertiary treatment systems - Filtration

Pressure Filters

Maintenance requirements

- If made in mild steel, **periodical painting with epoxy coating** needed
- Once a week:
  - ✓ Check of all valves, flanges and gaskets for its tightness.
  - ✓ Check for any leaks => to be arrested promptly
  - ✓ Check of pressure gauges, auto valves for their correct operation.

Tertiary treatment systems - Filtration

Pressure Filters

Maintenance requirements

- Irrespective of media, **media degradation over period of time**
  - ✓ more predominant with natural media
  - ✓ salt in effluent, pH variations etc. chemically degrading media
  - ✓ abrasion by flowing water physically degrading media
- **Need to replenish or replace** after period of time
  - ✓ Media removed through bottom door
  - ✓ Refilled through trap door at top

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Tertiary treatment systems - Filtration

(2) Filtration – Pre-coat filters

- filters or flexible screens on which coat of filter medium given
- temporary or fixed to mechanical screen
- Filter media
  - ✓ inert materials of fine fibrous or granular structure e.g. diatomaceous earth (diatomite).
  - ✓ Other media: Perlite, powered organic rock, activated carbon, asbestos and cellulose

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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

To remember

- Filters common in tertiary or polishing treatment
- **High efficiency** of suspended solids and turbidity removal and **easiness of control** advantages of filtration vis-à-vis other tertiary treatment options
- Filters **susceptible to clogging** by suspended solids and not suitable if high TSS levels
- Recent developments in design of filters using light weight media with high uniformity coefficients
- **Pressure filters** ideal for tertiary treatment units in Bangladesh because of **low space requirements**

Tertiary treatment systems - Filtration

Image: Center Enamel

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

Tertiary treatment systems - Adsorption

Basic concept

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

Basic concept

Activated carbon

- One teaspoon of activated carbon more surface area than one football field!

=

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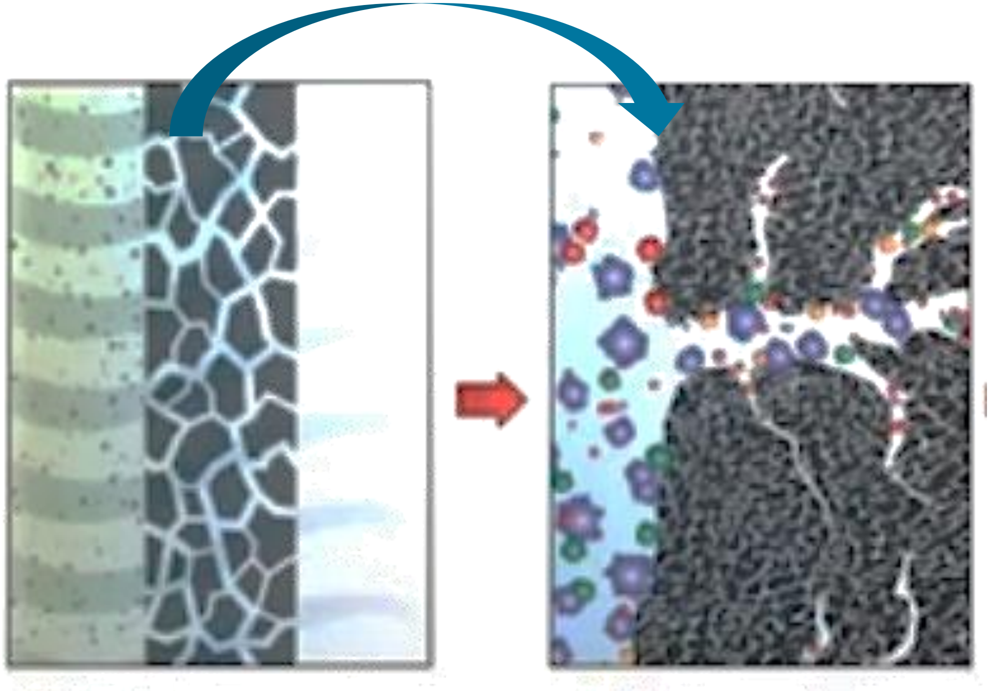
Tertiary treatment systems - Adsorption

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 - Adsorption



Activated carbon filters

Concept

- Organic molecules trapped in pores of carbon media
- Subsequent organic inflow pushing trapped material into micropores
- Process continuing till media fully exhausted

Tertiary treatment systems - Adsorption

Activated carbon filters

General specification for activated carbon suitable to textile effluent

Parameter	Value needed
Min Moisture, percent by mass (max)	5
Ash, percent by mass (max)	2
Hardness number, Min	90
Min Adsorption capacity- iodine number	450
Half dichlorination value, cm (max)	7
Surface area, m2/g (min)	550

Advantages of Activated carbon filter

High efficiency : Can remove colour and residual organics simple & easy to control manner.

Low residuals: No sludge, exhausted carbon at the end of cycle is the only residue.

Natural filter: it is made from natural materials like bituminous, wood, and coconut shell

Easy maintenance: ACF don't require much care in terms of maintenance.

ACF can remove complex organics/metal salts which is difficult to get removed in other treatments.

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DIsadvantages of Activated carbon filter

Cannot remove dissolved salts. Less effective against bacteria/virus/ pathogens.

Limited life: need replacement once media is exhausted

Disposal of exhausted media is still a concern.

Carbon can get exhausted fast if or chlorine level/pollutant load is high .

Operating Cost: depending on pollutant type/load, it can be cheap or costly.

Tertiary treatment systems – Advanced oxidation

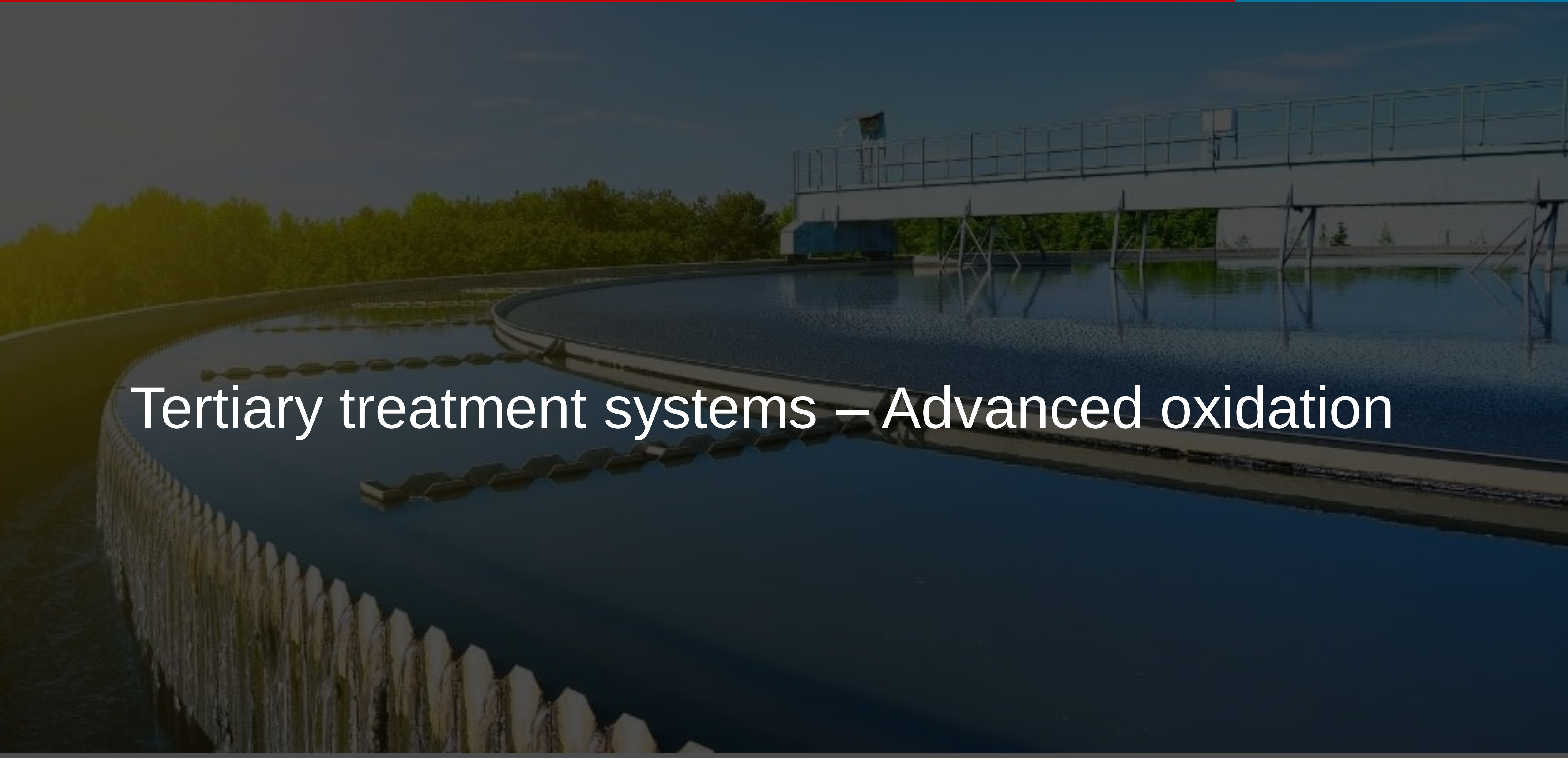

Image: NCH Asia

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

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

Tertiary treatment systems – Advanced oxidation

Example views of advanced oxidation systems

AOP system by NOVEXX

AOP system by Enviro Chemie

Tertiary treatment systems – Advanced oxidation

By-product management

- Concerns about **toxic by-products** despite oxidization and neutralization of toxic and hazardous organics present in textile effluent
  - ✓ Possibility of highly toxic by-products from partial degradation of dissolved organic
  - ✓ Bromate and excess peroxide
  - ✓ If chlorine used, halogenated organic by-products. e.g. toxic chlorophenols.
- **By-products depending on composition of effluent (!)**
  - ✓ Consider of advanced oxidation based on prior analysis of treated effluent and analysis of effluent from advanced oxidation processes

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Tertiary treatment systems – Advanced oxidation

Advantages

- **Low space requirement** even for high capacity units
- **Complete degradation of organics** into water, carbon dioxide, and salts (Mineralization)
- **Fast reaction** and very **lower retention times** compared to conventional treatment processes
- Treatment of wide range of organics (all organic materials, some heavy metals)
- **Complete disinfection** besides organic degradation
- **No sludge** production

Tertiary treatment systems – Advanced oxidation

Disadvantages

- Need for **highly skilled labor** to operate and control
- **High capital and operating & maintenance costs** (energy, chemical reagents)
- **Complex** chemistry tailored to specific contaminants
- Good understanding required for selection of technology because of several different variants
- Need to control and remove of residual peroxide, if hydrogen peroxide based system used
- Residuals affecting membranes if proper anti-oxidant control not ensured

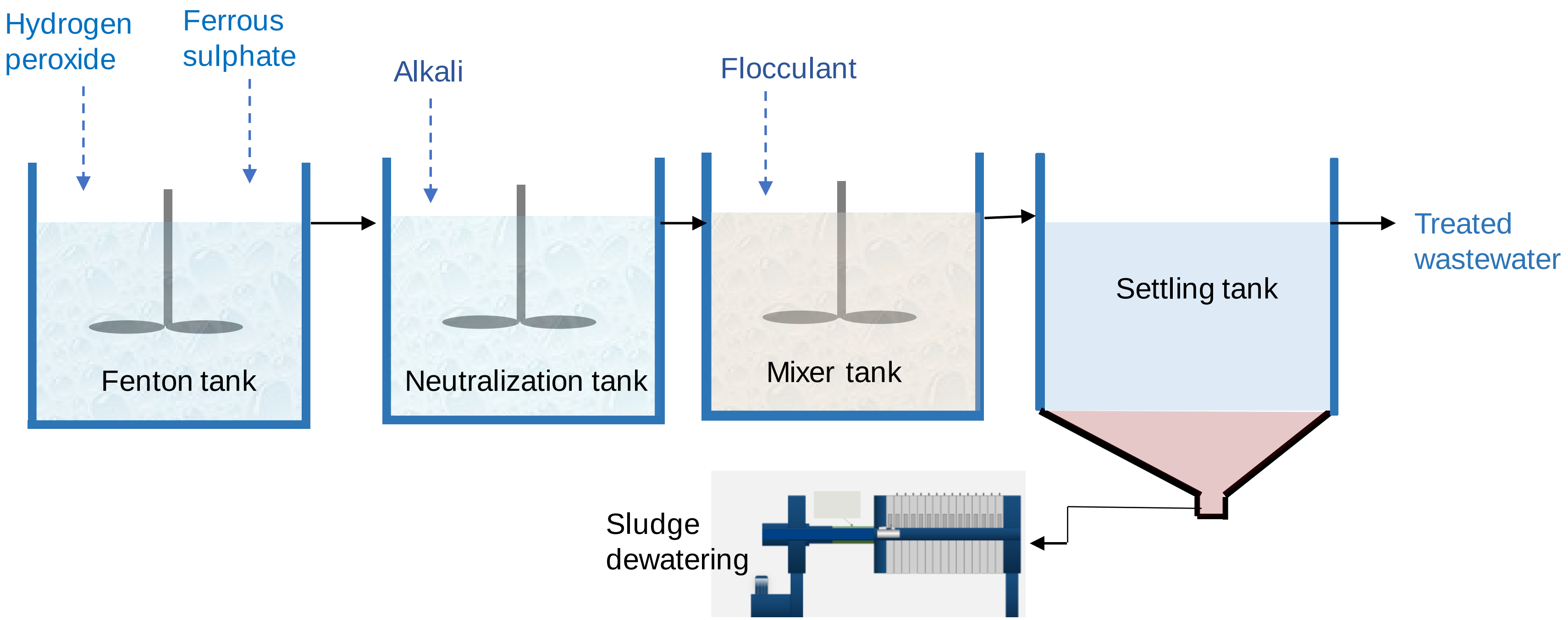
Tertiary treatment systems – Advanced oxidation

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

Tertiary treatment systems – Advanced oxidation

Fenton treatment



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Tertiary treatment systems – Advanced oxidation

Fenton treatment

Fenton treatment unit by *Xh2o Solutions Pvt. Ltd*

Tertiary treatment systems – Advanced oxidation

Fenton treatment with modified Fenton reactors

Fluidized Fenton reactor
(Source: Science Direct)

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

Image: https://www.yazhl.com/

Tertiary treatment systems – Ozone treatment

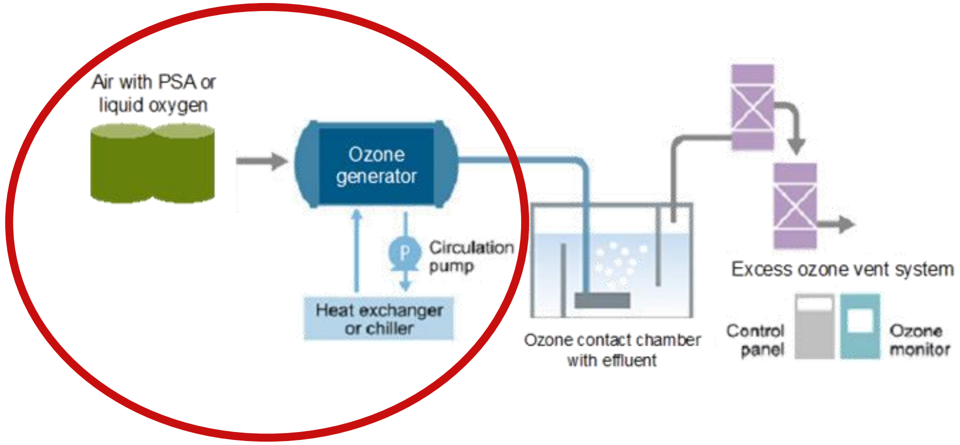
Basic concept

- 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

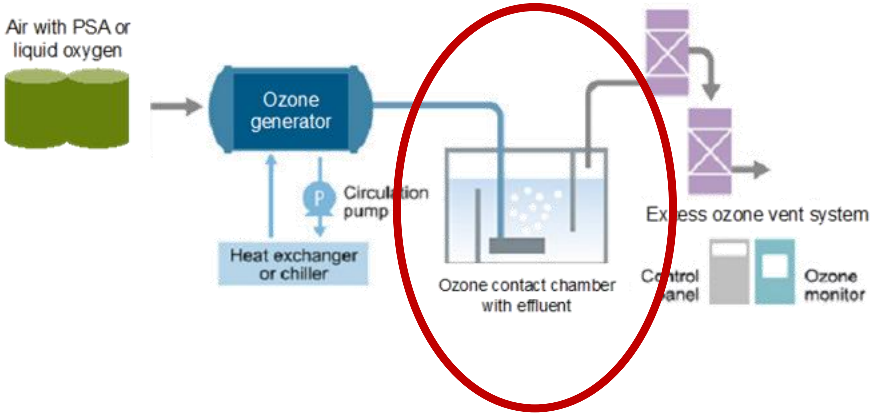
Tertiary treatment systems – Ozone treatment

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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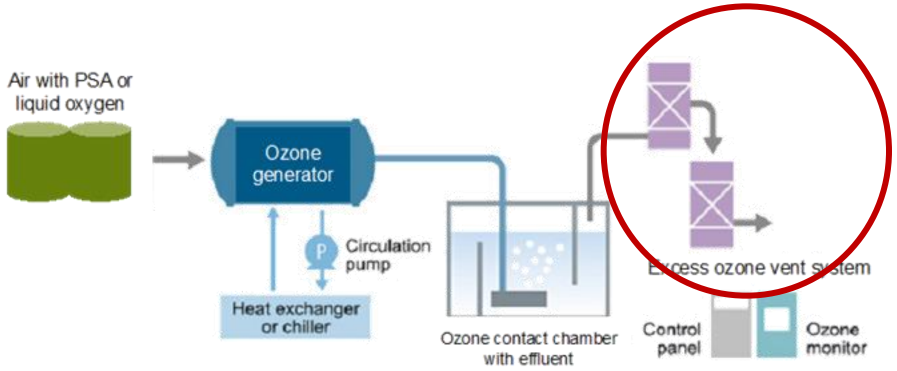
Tertiary treatment systems – Ozone treatment



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)

Tertiary treatment systems – Ozone treatment

Advantages

- **Little space required**
- Very **effective in destroying pathogens** and residual organics
- **Short treatment time** of less than 30 min
- **No harmful residuals** since ozone decomposing rapidly
- No bacteria regrowth
- Onsite generation of ozone **avoiding safety issues** with shipping and handling
- **Increase in dissolved oxygen (DO) concentration** of effluent eliminating need for reaeration positively affecting DO in receiving stream

Tertiary treatment systems – Ozone treatment

Disadvantages

- **High capital and operation & maintenance costs** (high power consumption)
- Need for **highly skilled labor** to operate and control
- Not very effective at low concentration
- **More complex** than other tertiary units requiring complicated equipment and efficient contacting systems
- **Need for corrosion-resistant material** (e.g. stainless steel)
- Not economical for removal of high levels of TSS/COD
- **Very toxic nature** of ozone and off-gases

To remember

- **Adsorption and oxidation** common options for **removing organics**
- **Activated carbon treatment** quite common in Bangladesh textile ETPs as polishing treatment
  - ✓ **Need to replenish carbon** after media exhausted (!)
- **Fenton treatment** installed in few ETPs
  - ✓ internationally preferred advanced oxidation method
  - ✓ **No sludge** generation and **low space** requirement
- **Advanced oxidation** technologies
  - ✓ **costlier** than other tertiary systems
  - ✓ suitable for effluent with **low residual organics**

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