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

Tertiary treatment – Part 2

GIZ FABRIC – ETP Operator Course

Contents

giz

Basic concept and overview of tertiary treatment

giz

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

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
- Do you know?..a teaspoon of activated carbon has more surface area than a football field!

Tertiary treatment systems - Adsorption

Basic concept

Activated carbon

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

=

Tertiary treatment systems - Adsorption

Basic concept

Activated carbon

Produced by

- **Physical activation**
- **Activation/Oxidation**
- **Chemical activation**

Tertiary treatment systems - Adsorption

Basic concept

Activated carbon

- **Physical activation**
  - Carbonization with carbon containing material being pyrolyzed at temperatures in range 600–900 °C
  - usually in an inert atmosphere with gases like argon or nitrogen
- Activation/Oxidation
- Chemical activation

Tertiary treatment systems - Adsorption

Basic concept

Activated carbon

- Physical activation
- **Activation/Oxidation**
  - Raw material exposed to oxidizing atmospheres (oxygen or steam) at temperatures above 250 °C, usually in range of 600-1200 °C.
- Chemical activation

Tertiary treatment systems - Adsorption

Basic concept

Activated carbon

- Physical activation
- Activation/Oxidation
- **Chemical activation**
  - Carbon material impregnated with chemicals (e.g acid, alkali, salt)
  - subjected to higher temperatures (250 – 600°C).
  - temperature activating carbon at this stage by forcing material to open and have more microscopic pores
  - Preferred activation option

giz

Tertiary treatment systems - Adsorption

Activated carbon filters

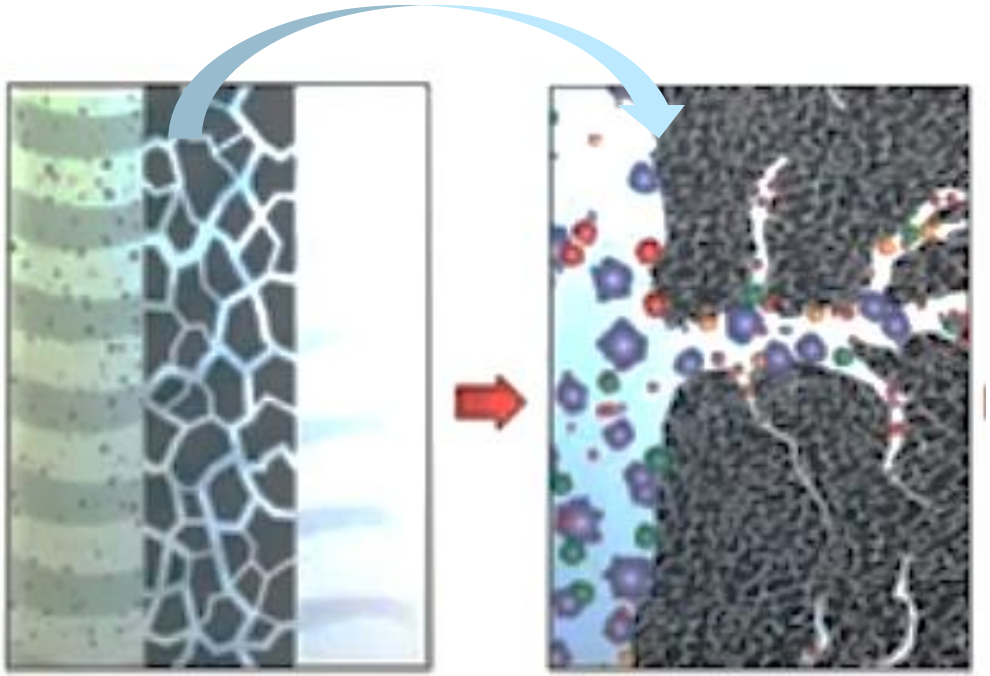
- similar in construction to pressure sand filters (see presentation 11.1)
- activated carbon as filter media
  - commonly **granulated activated carbon** with 0.4 - 1 mm diameter or powdered activated carbon
- backwash process similar to pressure sand filters but without air scouring
- strainers at 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, m^2/g (min)	550

giz

Tertiary treatment systems - Adsorption

Activated carbon filters

Operation and backwashing

- During regular operation…
  - pump inlet water into filter
  - observe filtrate for its clarity

Tertiary treatment systems - Adsorption

Activated carbon filters

Operation and backwashing

- For backwashing…
  - take filter off line by switching off feed line and close feed valve
  - open backwash line and backwash drain valves
  - pass clean backwash water upwards through filter bed and allow to drain
  - observe clarity of drained water and ensure no carbon drained out
    - once carbon powder coming out, first indication of media`s lifetime end
  - close drain valve and backwash valves and open feed/filtrate lines

Tertiary treatment systems - Adsorption

Activated carbon filters

Maintenance

- If filters made of mild steel, periodical painting (**epoxy coating**) needed
- **Weekly checks** of
  - all valves, flanges and gaskets for its tightness.
  - for any leaks => to be arrested promptly
  - pressure gauges, auto valves for correct operation.

Tertiary treatment systems - Adsorption

Activated carbon filters

Maintenance

- **Replacement of media**
  - Since adsorption based on available voids in activated carbon, voids getting filled up and stopping further organic removal
  - Indicated by **increased color** and **turbidity in filtered water**
    - Removal of exhausted media through trapdoor at top
    - Cleaning of filter inside and flushing pipelines
    - Check and, if necessary replacement of strainers
    - Filling of filter with fresh granular media

giz

Tertiary treatment systems - Adsorption

Activated carbon filters

Advantages

- **High efficiency** removing color and residual organics
- **Simple and easy to control and maintain**
- **Low residuals** without sludge => exhausted carbon only residual
- Filter made of natural materials like bituminous, wood, coconut shell
- **Ability to remove difficult contaminants** e.g. complex organics or metal salts

Tertiary treatment systems - Adsorption

Activated carbon filters

Disadvantages

- **No removal of dissolved salts**
- **Limited life of media** requiring replacement
  - Fast exhaustion with high pollutant load or high chlorine levels at inlet
- Limited effectiveness against bacteria, virus, pathogens
- **Disposal of exhausted media** of concern
- High operating cost depending on pollutant type and load
  - In general inexpensive treatment (!)

Tertiary treatment systems – Advanced oxidation

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
    - $H2O2 + UV \rightarrow 2 \cdot OH$
- Organics pollutants oxidized by hydroxyl radical and broken into simpler organics and further oxidized into carbon dioxide
  - **Higher efficiency in acidic condit**ions (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

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

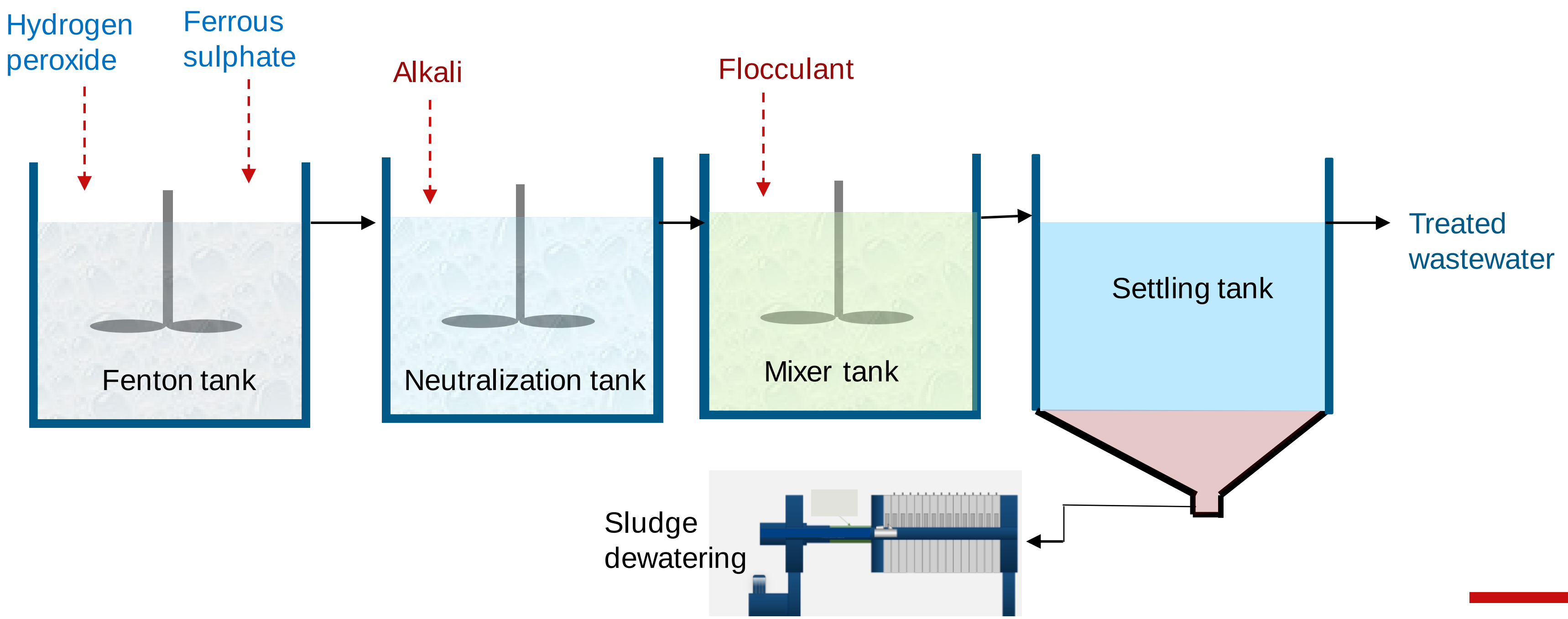
Tertiary treatment systems – Advanced oxidation

Fenton treatment

- **Optimum pH 3 - 5**
  - At higher pH, less effective because of iron precipitation as ferric hydroxide
  - At lower pH, OH radicals using excess H+ ions and affecting treatment
  - Note: pH of mixture dropping during reaction process by partly prevented by using ferrous sulphate and adding H_2O_2 in stages.

Tertiary treatment systems – Advanced oxidation

Fenton treatment



Tertiary treatment systems – Advanced oxidation

Fenton treatment

Fenton treament 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)

Tertiary treatment systems – Advanced oxidation

Fenton treatment

Advantages

- Relatively **lower capital cost** compared to other advanced oxidation processes
- Simple and **easy process control** with less automation needed
- **High efficiency** with high level of organics degradation into carbon dioxide
- **Suitable for all organic materials** and **some heavy metals**
- No concentration of contaminants like salts

giz

Tertiary treatment systems – Advanced oxidation

Fenton treatment

Disadvantages

- **Generation of ferric sludge** to be dewatered and disposed off
- **High operation and maintenance costs** due to peroxide and pH manageme
- Need to adhere to **strict pH range**

Tertiary treatment systems – Ozone treatment

Tertiary treatment systems – Ozone treatment

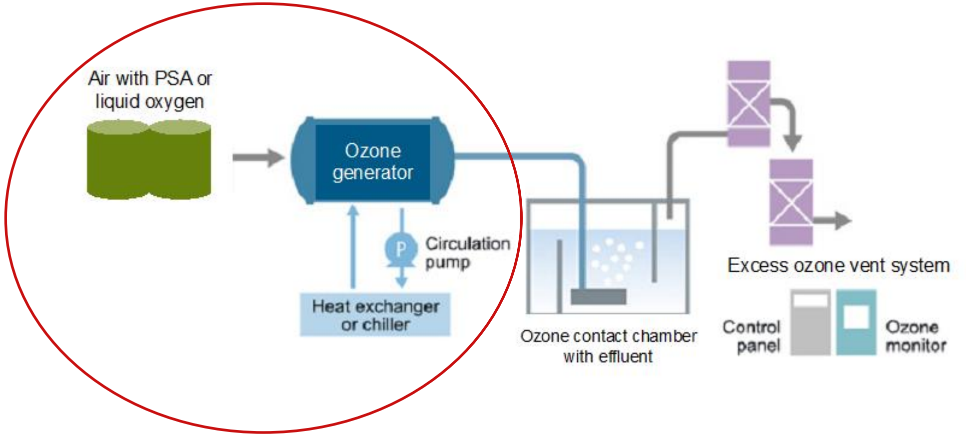
Basic concept

- 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

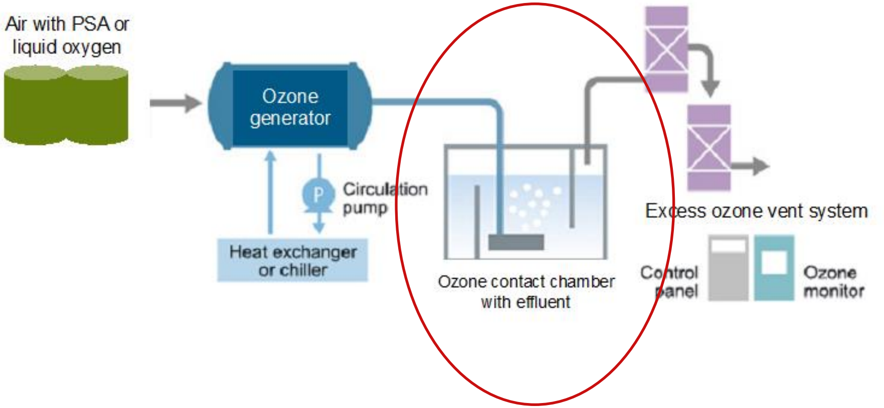
- Electrical discharge method most common source for generating ozone
  - Extremely dry air or pure oxygen exposed to controlled, uniform high-voltage discharge



Tertiary treatment systems – Ozone treatment

Use in effluent treatment

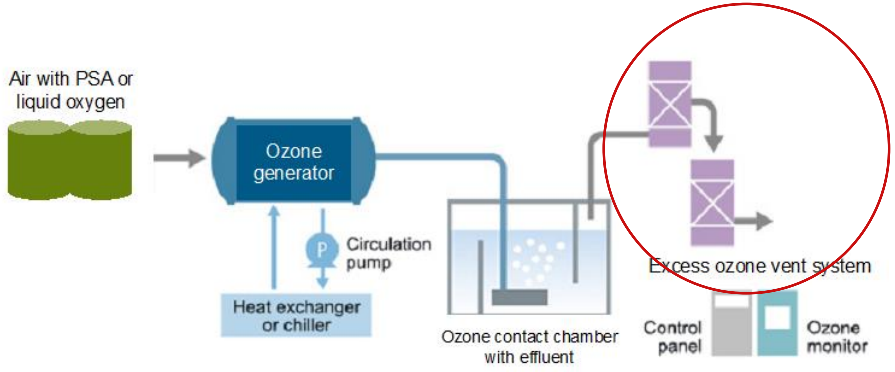
- After generation, ozone fed into **down-flow contact chamber** containing wastewater to be treated
  - Aim to transfer ozone from gas bubble into bulk liquid with sufficient contact time for disinfection.
  - Commonly used contactor type **diffused bubble**
    - co-current and counter-current
   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



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**

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonnand Eschborn

GIZ Bangladesh
PO Box 6091, Gulshan 1
Dhaka 1212, Bangladesh
T +880 2 5506 8744-52, +880 9666 701 000
F +880 2 5506 8753
E giz-Bangladesh@giz.de
I www.giz.de/bangladesh

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH