Training Program for Operators of Effluent Treatment Plants in Textile Factories

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

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Biological treatement – Introduction

GIZ FABRIC – ETP Operator Course

Contents

Basic concept of biological treatment

Basic concept of biological treatment

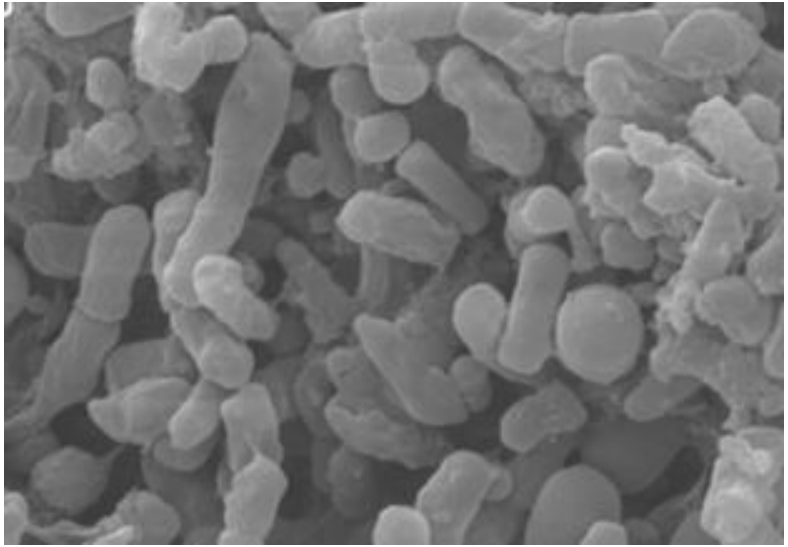
- Destruction of organics **using micro-organisms**, such as
  - **Bacteria** (primarily)
  - Protozoa
  - Fungus
- Use of **aerobic and anaerobic** bacteria
  - Aerobic bacteria consuming oxygen dissolved in wastewater
  - Anaerobic bacteria not needing/tolerating oxygen in wastewater, instead using oxygen organic material itself

Basic concept of biological treatment

Micro-organisms in wastewater

Bacteria

- Aerobic & anaerobic
- Removing organics and nutrients

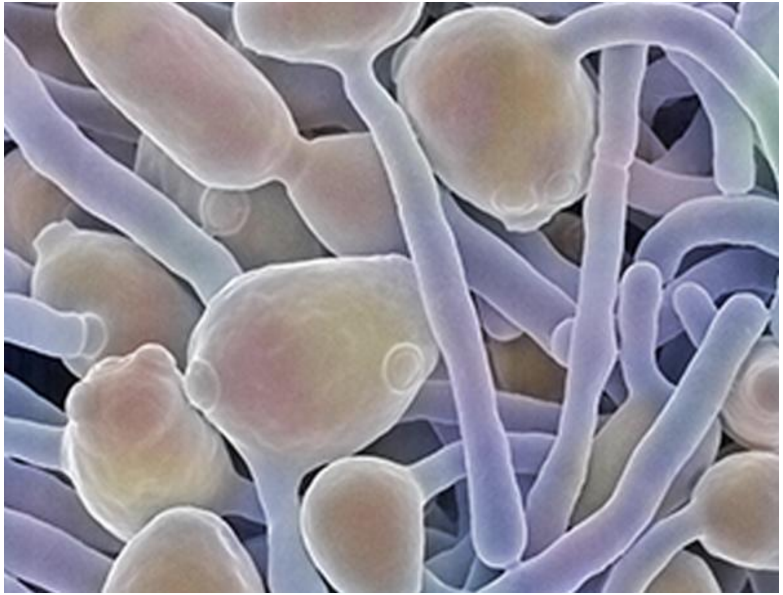


Basic concept of biological treatment

Micro-organisms in wastewater

Fungus

- Algae and fungi
- indicating problems of pH and older sludge

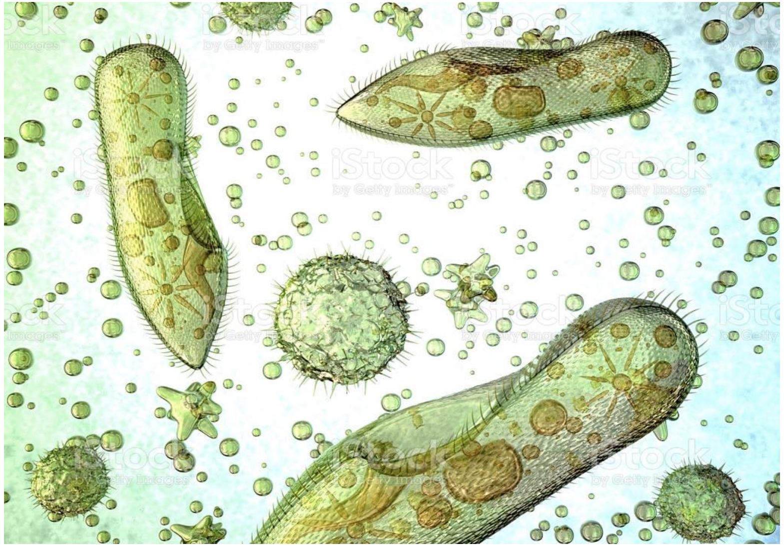


Basic concept of biological treatment

Micro-organisms in wastewater

Protozoa

- Amoebae, flagellates and ciliates
- Removing and digesting
  - dispersed bacteria
  - suspended particles

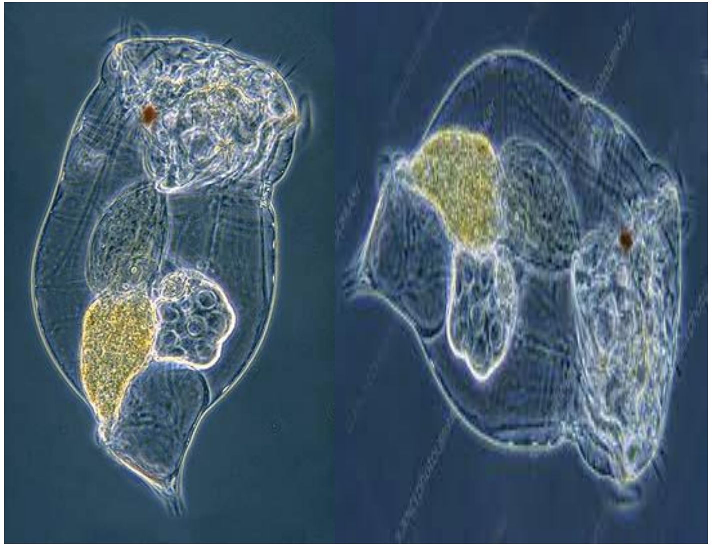


Basic concept of biological treatment

Micro-organisms in wastewater

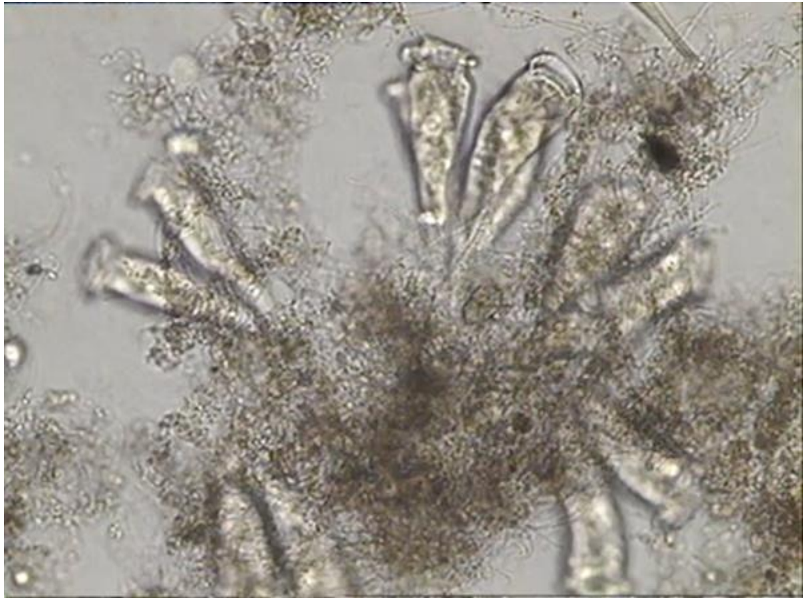
Metozoa

- Rotifers, nematodes and tardigrades
- Eating
  - excess bacteria
  - fungus
  - algae
  - other protozoa



Basic concept of biological treatment

Micro-organisms in ETP bio-sludge



Basic concept of biological treatment

Treatment process

- Usually part of **secondary treatment** systems
- To remove **non-settling and dissolved organic** load from effluents using microbial populations
  - Degrade organic matter
  - Stabilize organic wastes

Basic concept of biological treatment

Treatment process

- Micro-organisms
  - commonly using organic content as energy source
  - disintegrating organic material present wastewater in similar fashion.
- Processes classified as
  - **Aerobic** (requiring oxygen for their metabolism),
  - **Anaerobic** (growing in absence of oxygen
  - **Facultative** (operating with or without oxygen using different metabolic processes)

Basic concept of biological treatment

Treatment process

Most common biological treatment system

- **aeration tank** working on principle of **activated sludge** system

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Aerobic and anaerobic processes

Aerobic and anaerobic processes

Aerobic and anaerobic processes

- Organic materials containing **carbon, hydrogen and oxygen**, nitrogen, sulphur and other
- Examples
  - Sugar with chemical formula C12 H22 O11.
    - 12 carbon atoms
    - 22 hydrogen atoms
    - 11 oxygen atoms.
  - Common alcohol with chemical formula C2 H5 OH, which means
    - two carbon atoms
    - six hydrogen atoms
    - one oxygen atom

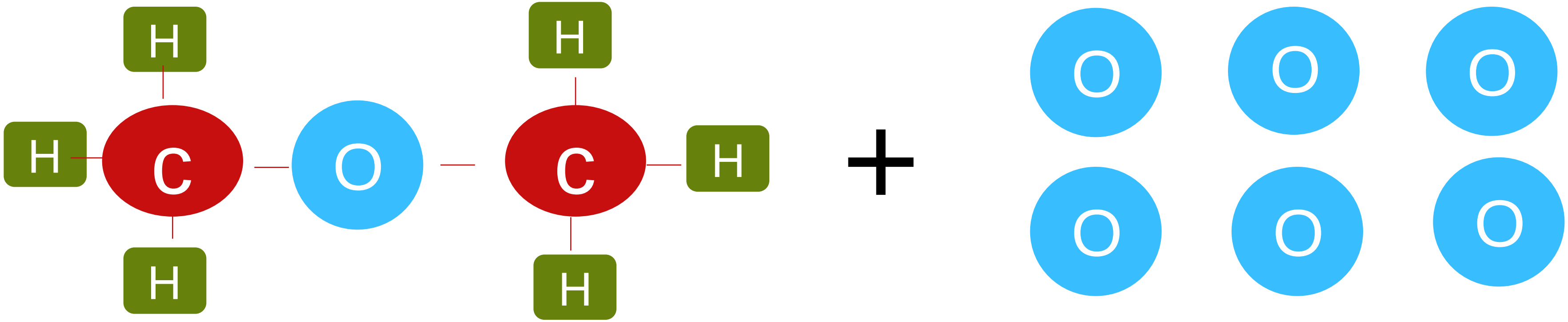
Aerobic and anaerobic processes

Biological treatment

- **degrading organics** to
  - **water** (H_2O, two atoms of hydrogen and one atom of oxygen)
  - **carbon dioxide** (CO_2, two atoms of oxygen and one atom of carbon)
- In **anaerobic treatment,**
  - **methane gas** (CH_4, one atom of carbon and four atoms of hydrogen)
  - **carbon dioxide**
    - Methane gas is a fuel.

Aerobic processes

Degradation $C2H5OH$ (common alcohol) using **excess oxygen**

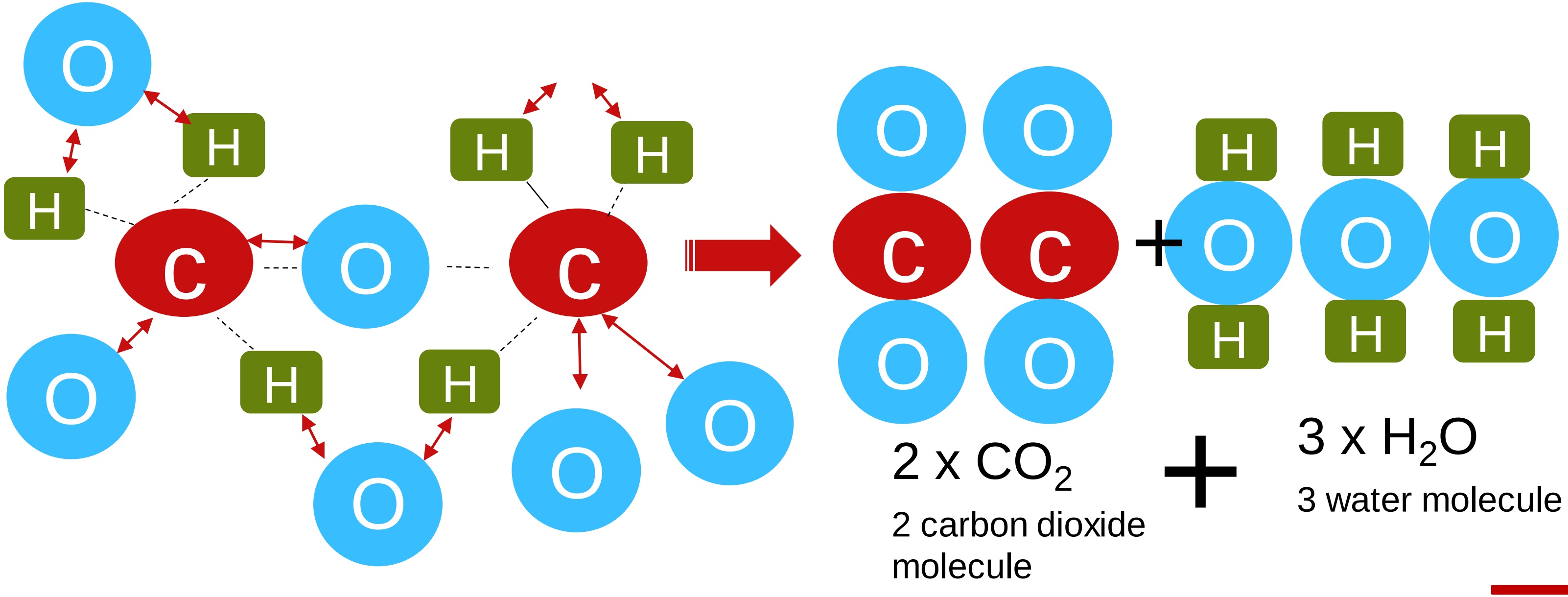


Alcohol (consisting of 2 carbon atoms, 6 hydrogen atoms, 1 oxygen atom)

6 more oxygen atoms

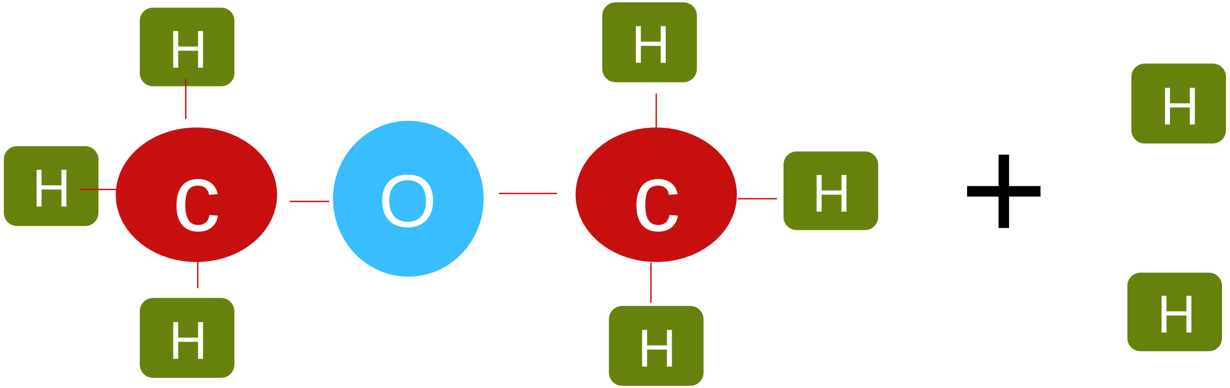
Aerobic processes

Degradation C2H5OH (common alcohol) using **excess oxygen**



Anaerobic processes

Degradation C_2H_5OH (common alcohol) using **excess hydrogen**

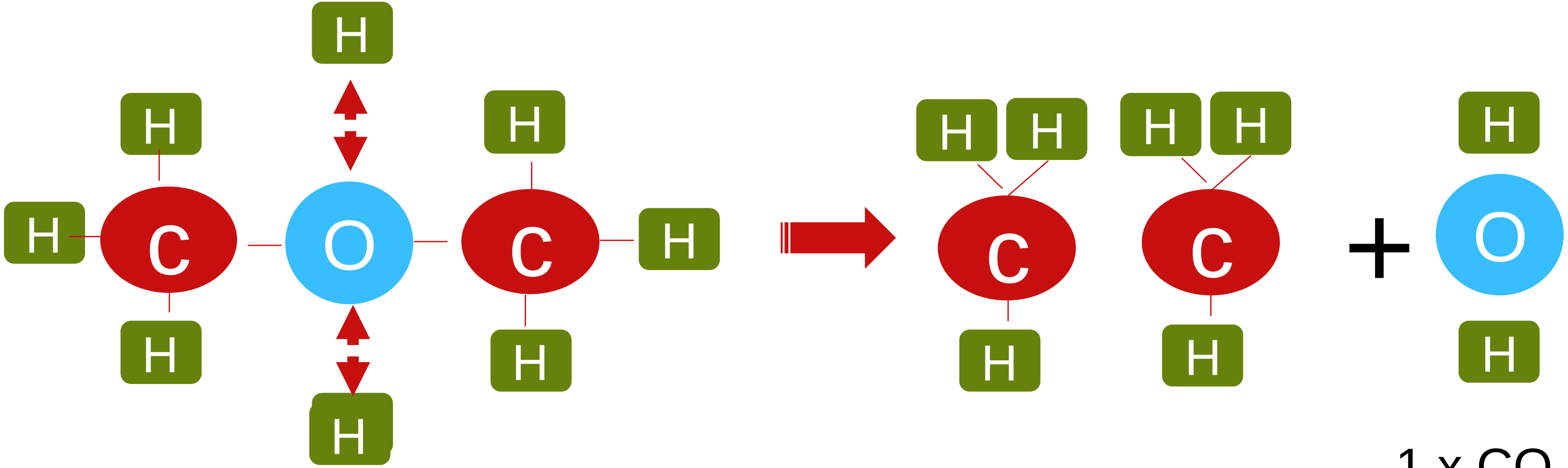


Alcohol: 2 carbon atoms, 6 hydrogen atoms, 1 oxygen atom

2 more Hydrogen atoms

Anaerobic processes

Degradation C_2H_5OH (common alcohol) using **excess hydrogen**



Alcohol: 1 carbon atoms, 6 hydrogen atoms 1 oxygen atom

2 x CH_3
2 methane molecules

1 x CO_2
One carbon dioxide molecule

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Overview of biological treatment systems

Overview of biological treatment systems

Anaerobic treatment systems

- Working **without external oxygen** supply
- Suitable for **high organic content** readily bio-degradable.
- **Not** preferred option for **textile effluent**

Overview of biological treatment systems

Anaerobic treatment systems

Popular treatment systems include the following:

- Anaerobic **lagoon**
- Anaerobic **digestors**
- Anaerobic **filter** with natural media or synthetic media.
- **Upflow anaerobic sludge blanket reactor** (UASB) reactor.

Less popular

- Bulk volume fermenter reactors with synthetic cover.
- Anaerobic fluidised bed reactor.

Overview of biological treatment systems

Anaerobic lagoon

- Wastewater kept in large pond for long time
- Naturally present bacteria naturally treating organic matter
- Gentle mixing by gases produced
- Lagoon set-up
  - Depth of 3-5 meters in center and shallow sides
  - Retention time 20 - 40 days depending on organics content and temperature

Overview of biological treatment systems

Anaerobic lagoon

Example of determining size

- 500 m3 of wastewater
- Proposed retention time 32 days
- Average depth of lagoon 4 m

- Volume: 500m3 x 32 days = 16000 m3
- Size: 16000m3/4 m = 4000 m2

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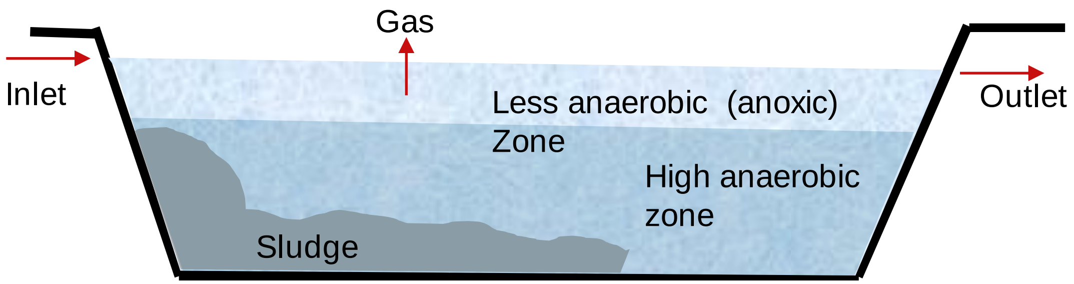
Overview of biological treatment systems

Anaerobic lagoon

- moderate efficiency of 40 - 70% organics reduction
  - Depending on biodegradability
- Efficiency depending on temperature
  - higher temperature better.



Overview of biological treatment systems

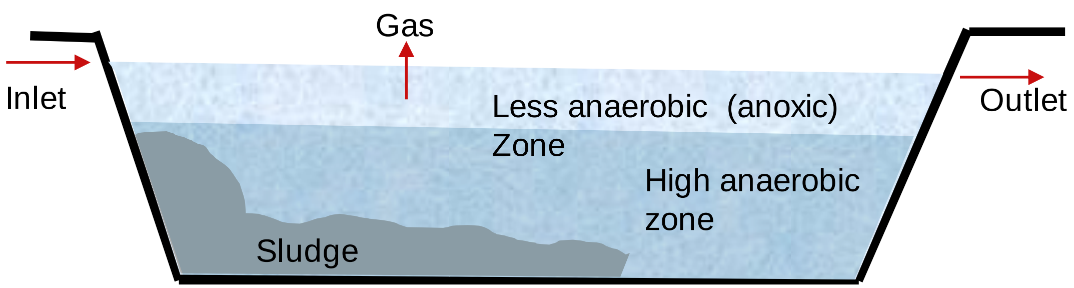
Anaerobic lagoon

Advantage

- Very easy operation
- Assured efficiency.

Disadvantages:

- high land area
- potential for smell
- vector (mosquito) breeding



Not for textile effluent because of
- large effluent volumes
- low degradable organics

Overview of biological treatment systems

Anaerobic digestor

- **Less retention time** because of **high bacteria population**
  - 3 -15 days retention
- Set-up
  - Deep tank with mixing system (about 5 - 8 m)
  - Width or diameter depending on desired capacity
  - Provisions for **collecting bio-gas** and further use as fuel.
    - 1 - 2 m on top for bio-gas collection

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Overview of biological treatment systems

Anaerobic digestor

- **Not suitable** suited for **combined textile wastewater** because of
  - large volume
  - low degradable organics
- **Suitable** for treatment of segregated wastestreams
  - high organic **desizing effluent**

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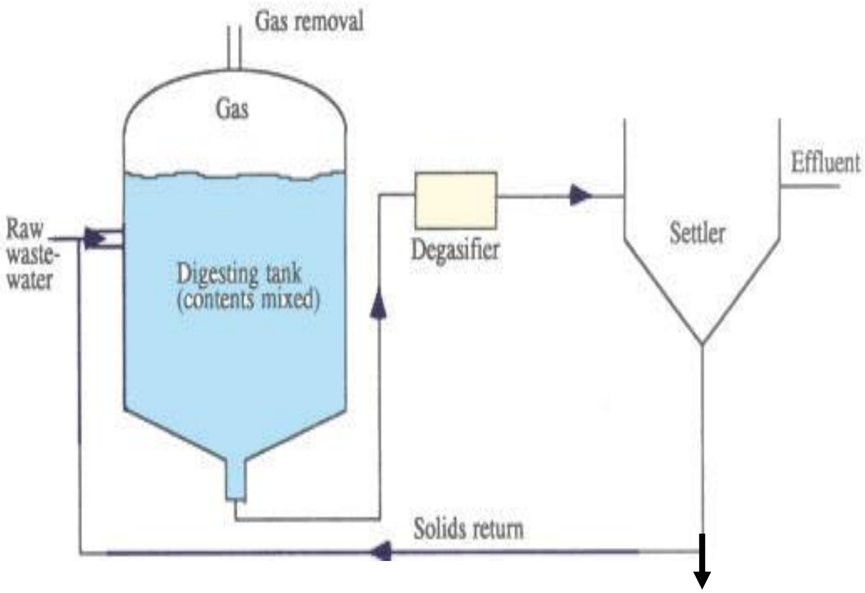
Overview of biological treatment systems

Anaerobic digestor

- Process sensitive to temperature.
  - Sometimes heating upto 40°C.
- Working without settling & sludge return.
- Degassifier needed for removing dispersed gases
  - including hydrogen sulphide (!)



Wasted solid

Overview of biological treatment systems

Anaerobic filters

- Bacteria growing on reactor media
- Bacteria ‘eating’ and destroying organic when passing through filter
- Suitable for small ETPs with lower suspended solids in effluent
- Natural or synthetic filter media
  - Natural: rubble chips and
  - Synthetic: plastic balls or (New) corrugated plastic media
- Fixed (old) or (new) movable filter media
  - fluidised synthetic polymer media.

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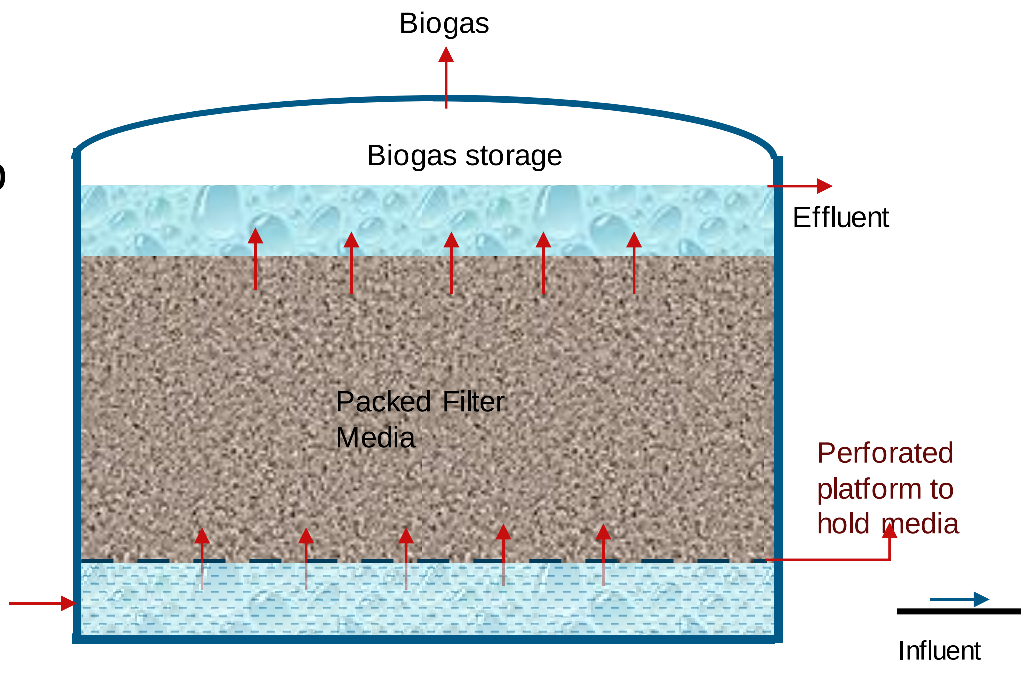
Overview of biological treatment systems

Anaerobic filters

Fixed bed

- bottom feed and overflows at top
- Perforated slab at 0.75 m from bottom
- media filled on leaving 0.5 m on top to prevent choking
- Biogas at top

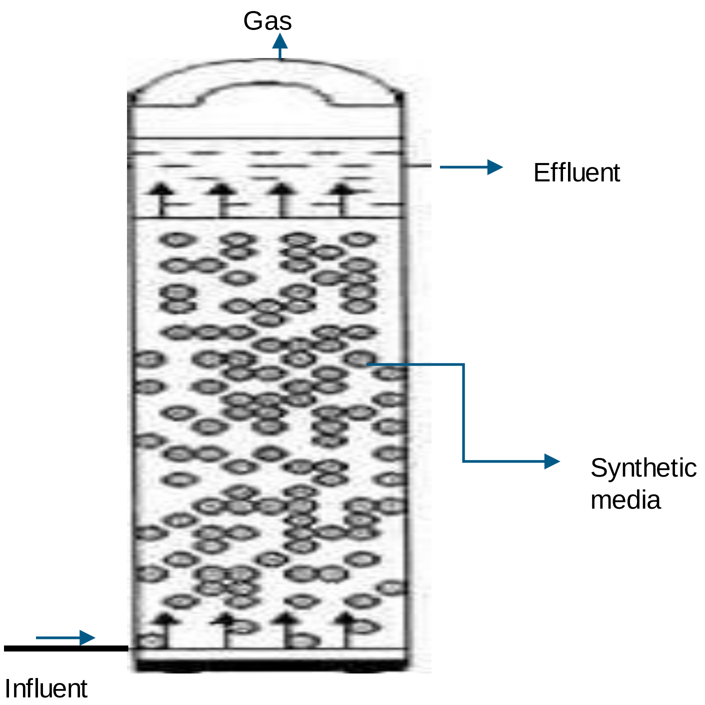


Overview of biological treatment systems

Anaerobic filters

Fluidised bed

- Feeding from bottom
- Usually with strainer at top to prevent wash over of media.
- Some units mixers
- Bio-gas collected at top



Overview of biological treatment systems

Anaerobic filters

Advantages

- Cheaper in operation
- Good efficiency with high degradable organics,
- Potential of biogas in organic rich effluent (use as fuel)

Disadvantages

- Choking potential
- Not very effective with low and difficult to degrade organics
- Not popular for textile effluent treatment

Overview of biological treatment systems

Up flow anaerobic sludge blanket reactor (UASB)

- Newer and popular system
- Few operating in Bangladesh textile ETPs
- Anaerobic bacteria concentrated in blanket of bio-sludge (similar to the activated sludge, but anaerobic)

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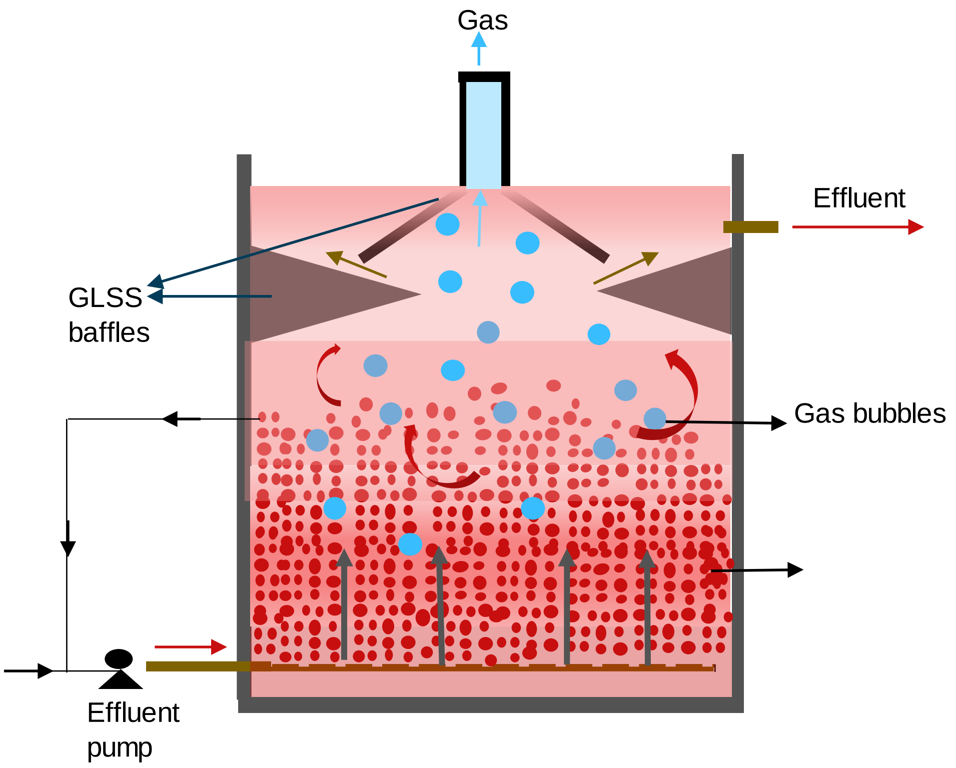
Overview of biological treatment systems

UASB concept

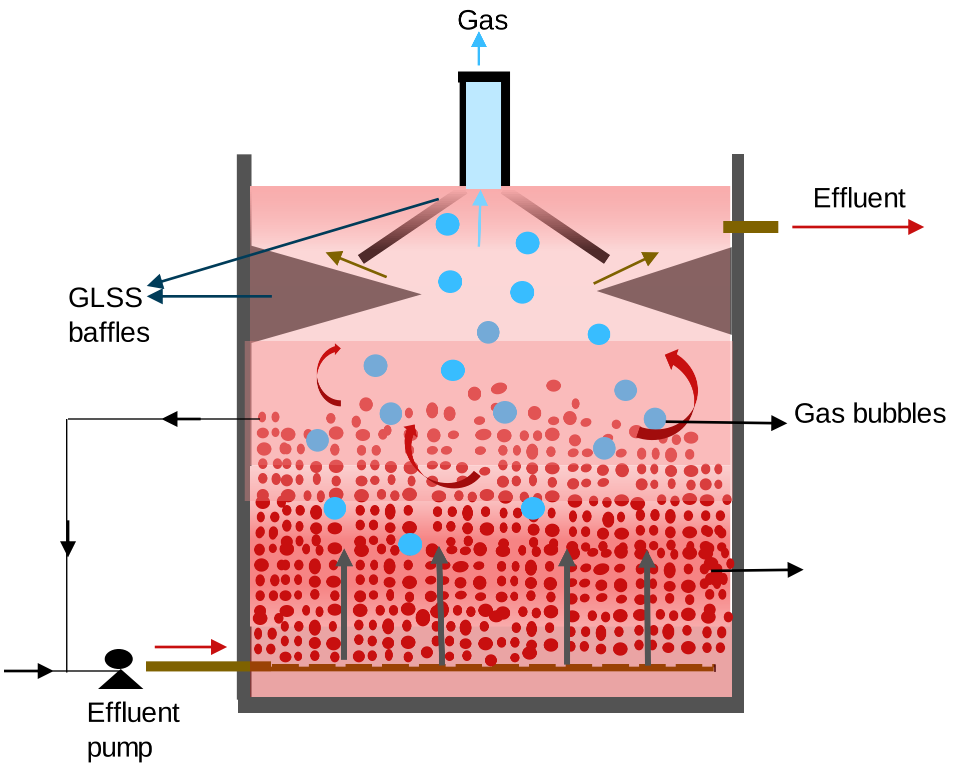
- Effluent passing through sludge blanket
- Organics treated by bacteria
- Sludge blanket in suspension due to upflow of effluent
- Sufficient upflow velocity with inflow pump and recycle (when no flow).
- Sludge blanket with 3-6% of solids concentration of bio-sludge.



Overview of biological treatment systems

UASB concept

- Sludge blanket with flocs of suspended solids, undigested organics and micro-organisms.
- Turbulence and upflow movement also by gas produced
- Separation of solids (to be retained) from liquid and gas with special baffle
  - GLSS (gas-liquid-solids separator) at top



Overview of biological treatment systems

UASB

Advantages

- Comparatively higher efficiency (upto 70% BOD reduction)
- Lower hydraulic retention times (4-8 hours)
- Potential for gas generation in organic rich effluents.

Disadvantages

- Low efficiency with difficult to degrade effluents (e.g. textile effluent)
- Relatively high operating cost

Overview of biological treatment systems

Aerobic treatment systems

- Bacteria requiring constant **external oxygen** supply
  - bacteria using oxygen dissolved in water
  - dissolved oxygen (DO) reducing in water
  - aeration systems replacing oxygen

Overview of biological treatment systems

Aerobic treatment systems

Three categories

(1) **Attached growth systems** with bacteria attached to media

(2) **Suspended growth systems with** bacteria growing on suspended mass of sludge

- Activated sludge system most popular

(3) **Hybrid systems** with fluidised media.

Overview of biological treatment systems

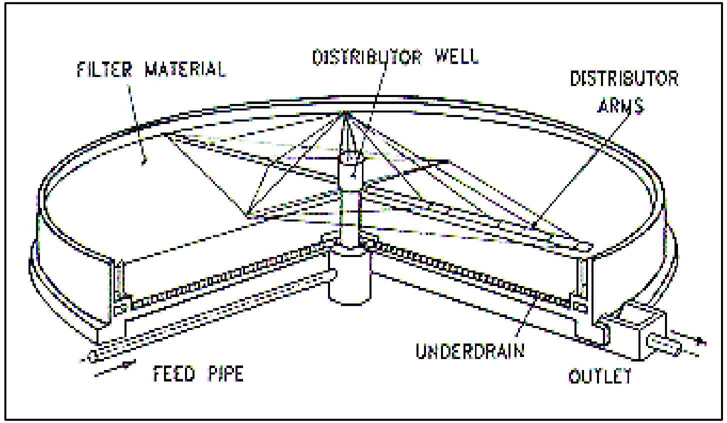
Attached growth systems: trickling filter

- Oldest established system
- Simple concept:
  - Effluent sprayed over bed of fixed media using rotating arm.
  - Natural media (gravel, sand) or plastic media with high surface area
  - Aeration by air being sucked in water downflow (also with fans)

Overview of biological treatment systems

Attached growth systems: trickling filter

- Low depth of media for aerobic condition
  - anaerobic conditions if too deep.
- Settling basins for recirculating some treated effluent to keep media wet.
- Dead bacteria forming sludge being settled and wasted.



Overview of biological treatment systems

Trickling filter at
Brunswick Sewer District

Overview of biological treatment systems

Attached growth systems: trickling filter

Advantages

- Good for low strength effluents
- Low operating and maintenance costs.

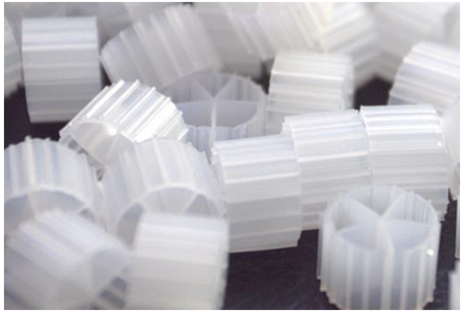
Disadvantages

- High construction cost
- Relatively low efficiency

Overview of biological treatment systems

Attached growth systems: Moving Bed Bio Reactors (MBBR)

- Modernized' version of trickling filter
- Special **plastic media** with high surface area
  - Up to thousands of m2 per cubic meter of media
- Bacterial slime growing over media **disintegrating organics** in wastewater into **carbon dioxide** and **water**



Typical MBBR media

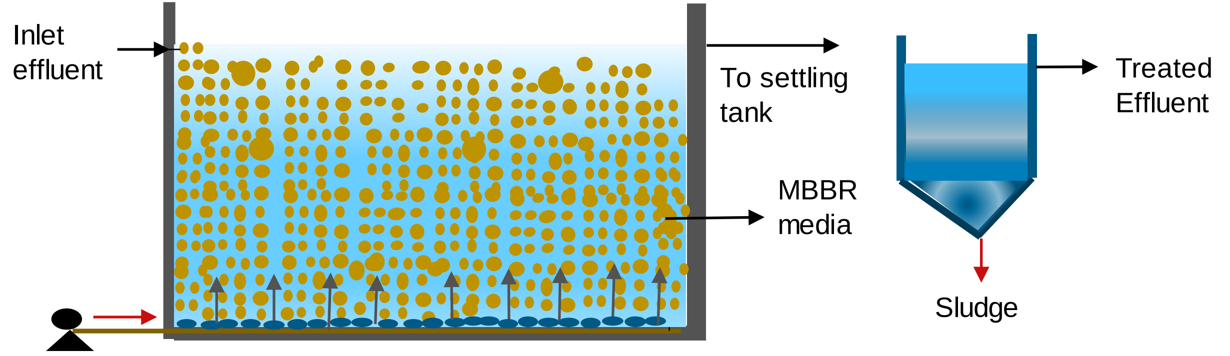
Overview of biological treatment systems

Attached growth systems: Moving Bed Bio Reactors (MBBR)

- Two versions:
  - **Fluidised Aerobic Bed (FAB)** reactor with larger size media
  - Normal MBBR using small (10-25 mm diameter) media
- Outlet to settling tank with overflow for treated effluent discharge
- Small FAB reactors with integrated settling compartment.

Overview of biological treatment systems

Attached growth systems: Moving Bed Bio Reactors (MBBR)



Overview of biological treatment systems

Attached growth systems: Moving Bed Bio Reactors (MBBR)

Advantages

- Smaller area compared to conventional treatment
- High efficiency in BOD/COD removal.

Disadvantages

- Higher operation and maintenance requirement
- Care for maintaining biomass

Overview of biological treatment systems

Attached growth systems: Rotating Biological Contactors (RBC)

- Series of closely spaced, parallel discs mounted on rotating shaft just above surface of waste water
- Microorganisms growing on plastic disc surfaces
- Discs rotating in tank at 2 to 5 revolutions per minute.
  - at right angles to wastewater flow
  - with several packs
  - About 40% of disc area immersed the wastewater.

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Overview of biological treatment systems

Attached growth systems: Rotating Biological Contactors (RBC)

- Biological attached to disc surface forming slime layer
  - discs made of plastic sheets (2 to 4 m diameter, 10 mm thickness
- Discs contacting wastewater with atmospheric air for oxidation during rotation
  - helping to slough off excess solids
  - About 95% of surface area alternately submerged in waste water and exposed to air

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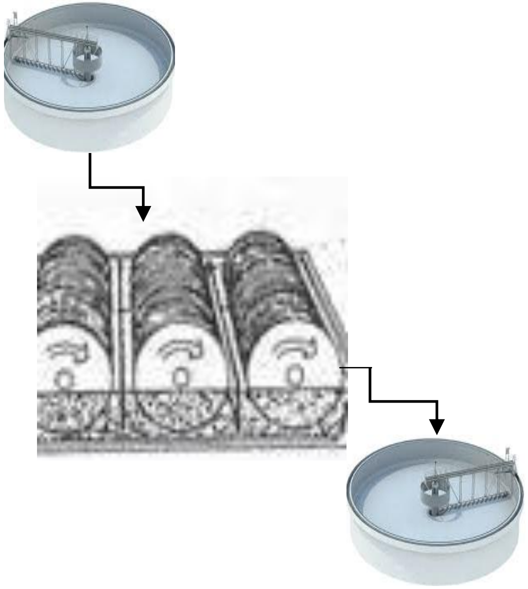
Overview of biological treatment systems

Attached growth systems: Rotating Biological Contactors (RBC)

- Minimum 4 - 5 modules in series to obtain nitrification of waste water.
- Enhanced with external aeration (sometimes) for adjustment of operation parameters
- Inflow well settled to remove all suspended solids to prevent settlement of solids in RBC trough.
  - Absence of any mixing making solid removal difficult
- Effluent with sloughed off solids taken to settling tank for sludge settling and treated effluent overflow



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Overview of biological treatment systems

Attached growth systems: Rotating Biological Contactors (RBC)

Advantages

- High efficiency
- Low power cost (operating cost)
- Low space requirement (compared to aerated lagoons)

Disadvantages

- Potential clogging and bypassing of effluent
- Difficulty generation of bio-film
- Need for primary removal of suspended solid

Overview of biological treatment systems

Suspended Growth Systems: Activated Sludge Process (ASP) Systems

- Most popular wastewater treatment system all over the world (also in Bangladesh)
- Involving development of ‘activated sludge’ as interim product of bacterial organic degradation
- Activated sludge = ‘mixed liquor suspended solids’ (MLSS).
  - mixture of untreated wastewater and (returned) bio-sludge.

Overview of biological treatment systems

Suspended Growth Systems: Activated Sludge Process (ASP) Systems

- Aeration for keeping bio-sludge alive and mixing inside tank
- Efficiency depending on bacteria concentration and
  - MLSS quantity in tank

▶ More details in presentation 5.3

Overview of biological treatment systems

Suspended Growth Systems: Aerated lagoons

- Oldest and simplest aerobic treatment system
- Usually half of tank (top) only fully aerobic with bottom part anoxic (facultative) or mildly anaerobic
- Aeration with
  - Floating type, jet aerators, aspirators or fixed aerators mounted on floats
  - diffused aeration net work

Overview of biological treatment systems

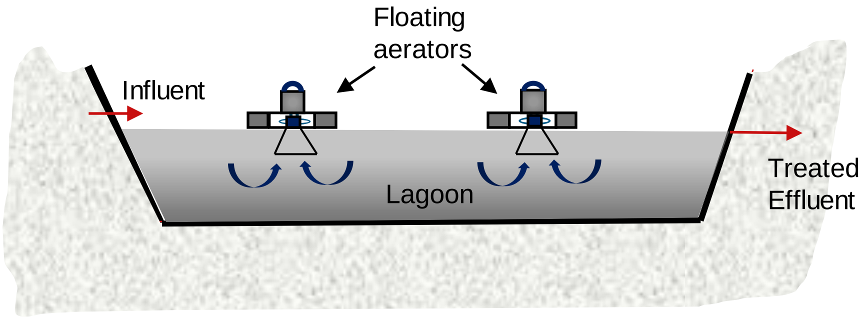
Suspended Growth Systems: Aerated lagoons

- Usually shallow to prevent anaerobic conditions at locations not covered by aeration
  - Depths 2 - 3 m.
  - Efficiency of aerators less at lower depth.
- Key difference aerated lagoons and conventional activated sludge systems
  - Higher retention time in aerated lagoons
  - Aeration in aerated lagoons not for keeping suspended solids in suspension

Overview of biological treatment systems

Suspended Growth Systems: Aerated lagoons

- Retention times 3 - 5 days (depending on effluent type)
- Suitable for low suspended solids' effluent only or where suspended solids organic.
- Viability influenced by sunlight and temperature



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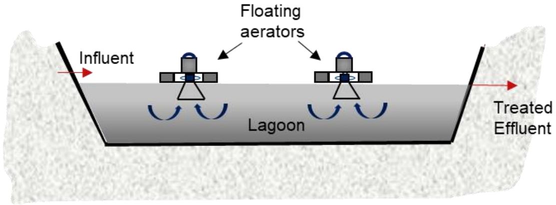
Overview of biological treatment systems

Suspended Growth Systems: Aerated lagoons



Advantages

- Simple construction
- Easy operation with relatively lower O & M cost
- Assured minimum efficiency

Disadvantages

- Higher land area requirement
- Cost of construction
- Mosquito breeding and algal bloom
- Odour problems if operated improperly
- Sludge accumulation with effluent with high inorganic suspended solids.

Overview of biological treatment systems

Suspended Growth Systems: Sequential Batch Reactors (SBR)

Conventional activated sludge system	Sequential Batch Reactors (SBR)
Sequential system	Batch process system
Effluent from aeration tank settled in settling tank	Sludge allowed to settle within same aeration tank called SBR
Settled sludge returned to aeration tank to maintain necessary bio-sludge	Several parallel units operated in turn with automatic control

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Overview of biological treatment systems

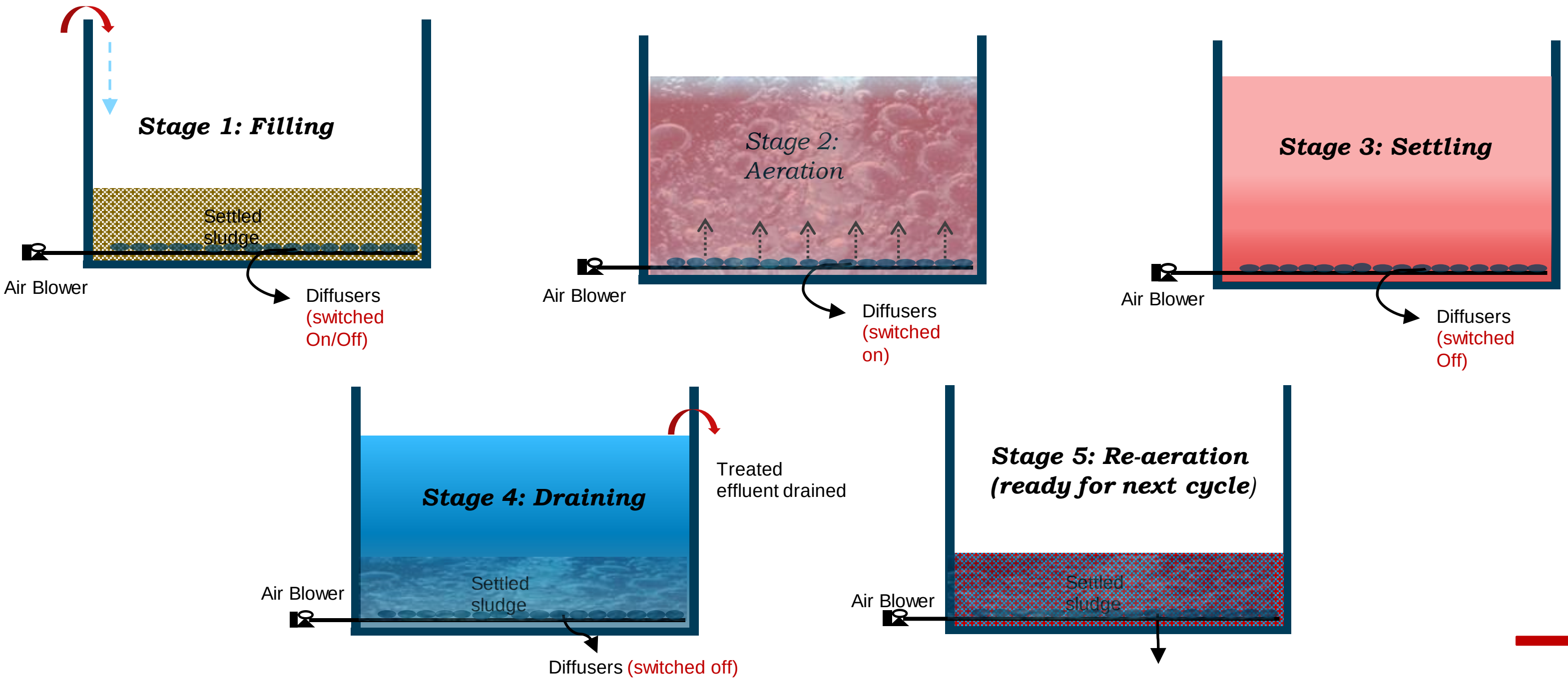
Suspended Growth Systems: Sequential Batch Reactors (SBR)

SBR operation

1. Effluent admitted into aeration tank with bio-sludge
2. Aeration for fixed period (4 - 6 hours)
3. Aeration switched off with bio-sludge allowed to be settle.
4. Clear supernatant drained off (but sludge retained)
5. After draining of supernatant refilling of SBR with fresh effluent

Overview of biological treatment systems

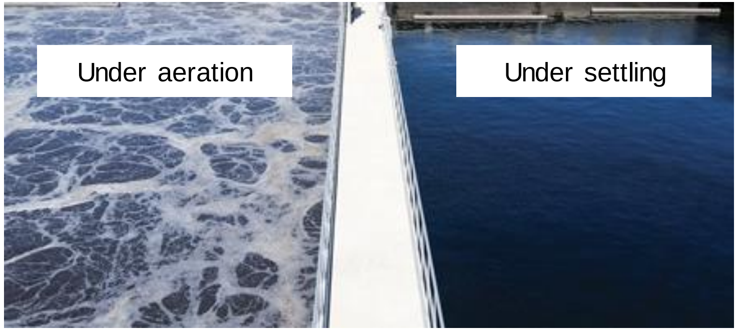
Suspended Growth Systems: Sequential Batch Reactors (SBR)



Overview of biological treatment systems

Suspended Growth Systems:
Sequential Batch Reactors (SBR)

- Outlet pipe mounted on float to decant supernatant after settling
  - saving time and sludge carry over
- Some wasting of excess sludge after decanting of treated effluent.
- Typical cycle time 8 - 14 hours.
- Some SBRs are with mixers to add stage for anoxic treatment too.
- More suited for small and medium scale ETPs.



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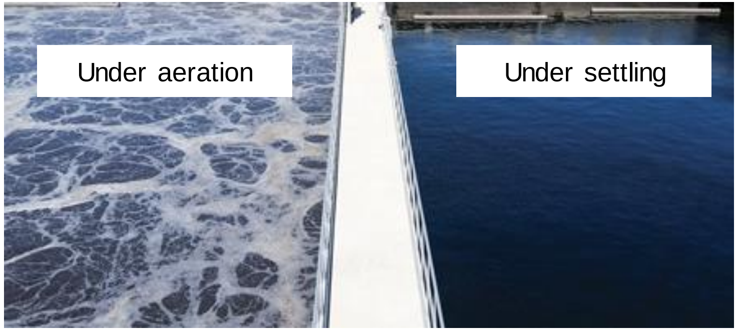
Overview of biological treatment systems

Suspended Growth Systems: Sequential Batch Reactors (SBR)

Advantages

- Lower capital cost,
- Relatively lower area requirement
- High treatment efficiency
- Flexibility in operation



Disadvantages

- Higher operation and maintenance efforts
- Need for automation
- Need for uninterrupted power for effective operation

To remember

- Most ETPs around world with one or other biological treatment system
- Anaerobic systems for organic rich effluents (distillery, brewery, starch industries and UASBs in sewage)
- Anaerobic system not suitable for composite textile effluent but for selected waste streams
- Most ETPs using activated sludge systems.
- System to be selected on consideration of cost (capital, O&M) and local factors (e.g. availability of land, power supply, operator skills)

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