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 2: Presentation 3

Biological Treatment for Textile Wastewater

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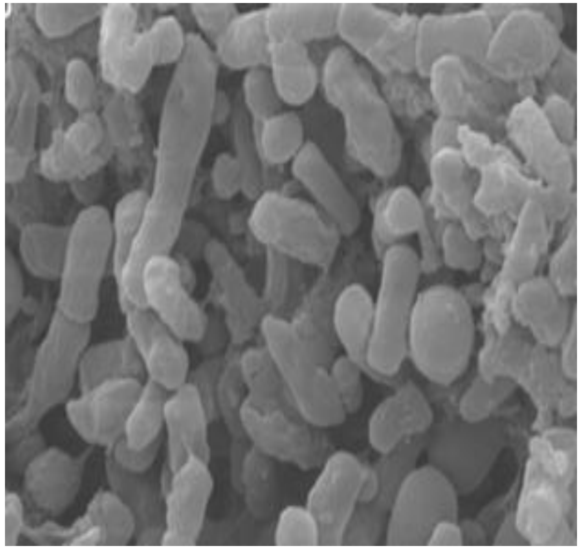
Basic concept of biological treatment

Image: textile today

Basic concept of biological treatment



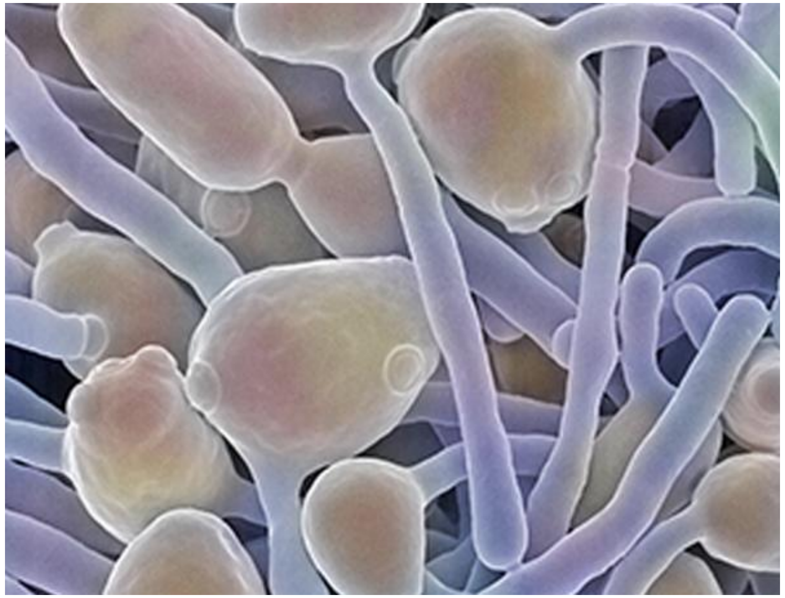
Destruction of organics using micro-organisms, such as

- **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

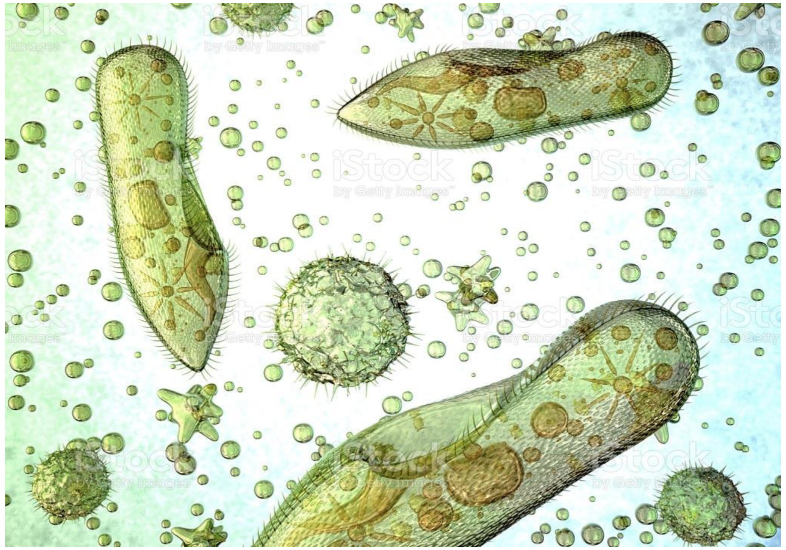


Micro-organisms in wastewater

Fungus

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

Basic concept of biological treatment

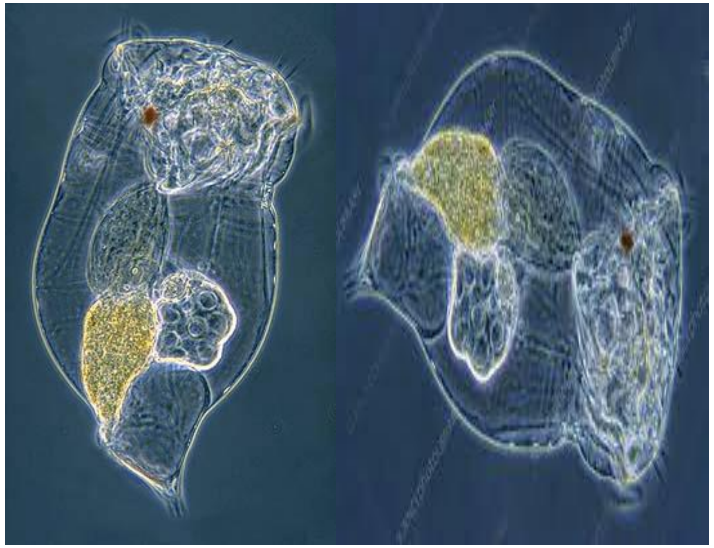


Micro-organisms in wastewater

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

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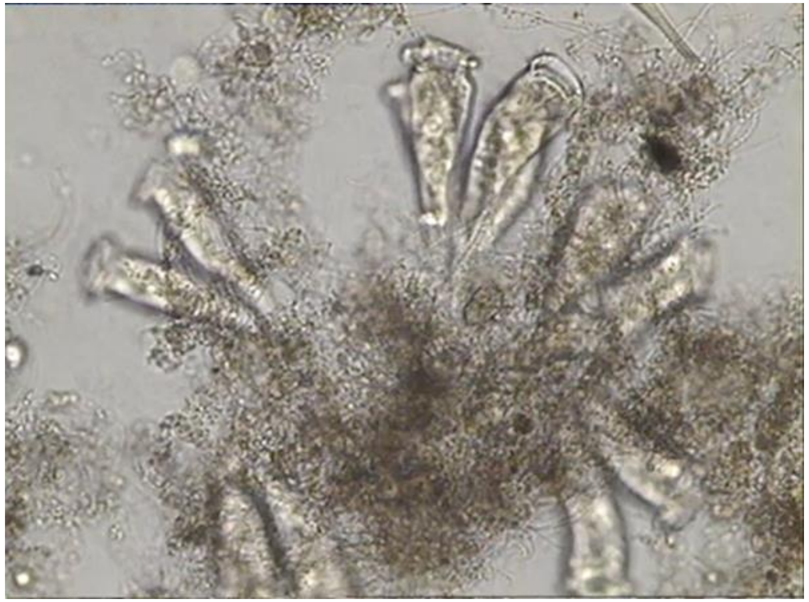
Basic concept of biological treatment

Micro-organisms in ETP bio-sludge



QUIZ

What are the type Biological treatment systems in ETPs?

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)

Principle of aerobic and anaerobic processes

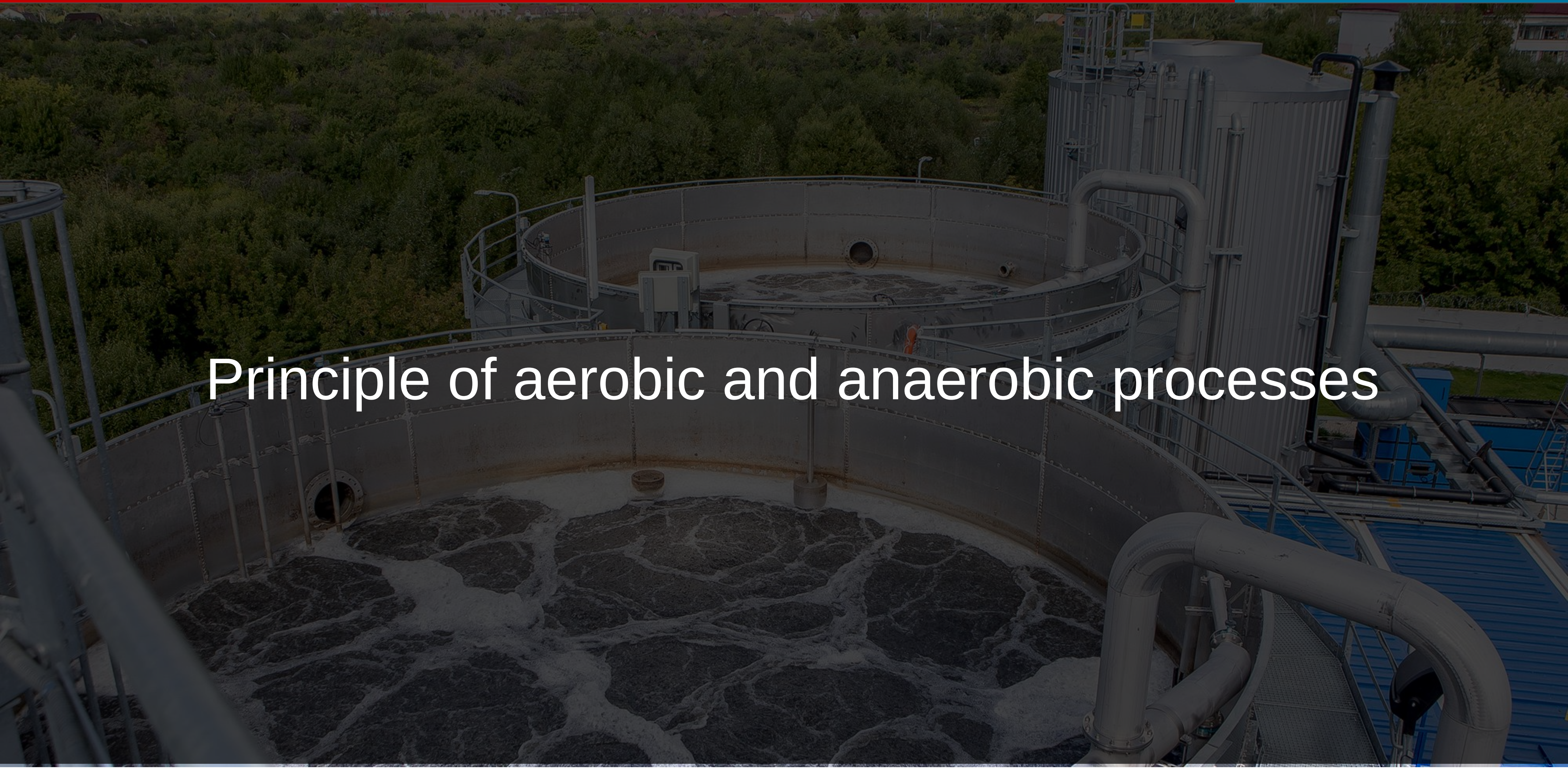
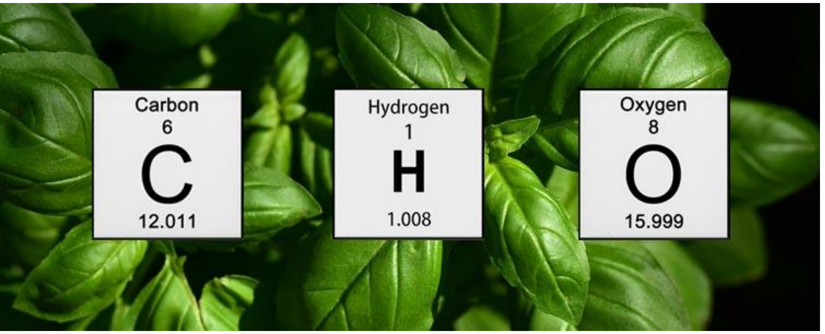


Image: envirochemie

Aerobic and anaerobic processes



Organic materials containing carbon, hydrogen and oxygen, nitrogen, sulphur and other

Examples

- Sugar with chemical formula $C_{12} H_{22} O_{11}$.
  - ✓ 12 carbon atoms
  - ✓ 22 hydrogen atoms
  - ✓ 11 oxygen atoms.
- Common alcohol with chemical formula $C_2 H_5 OH$, which means
  - ✓ two carbon atoms
  - ✓ six hydrogen atoms
  - ✓ one oxygen atom

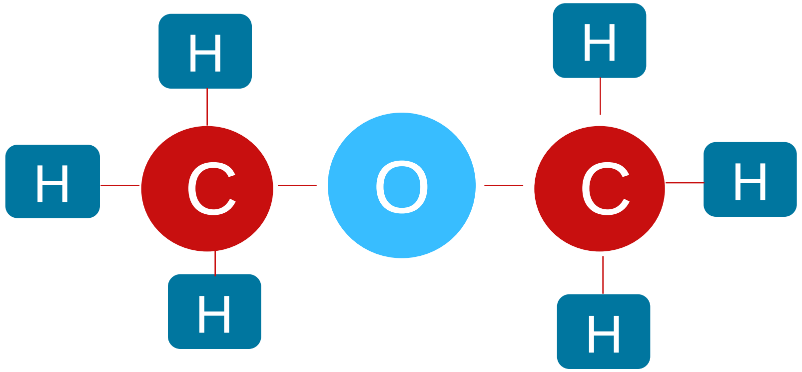
Aerobic and anaerobic processes

Biological treatment

- In **aerobic 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 C_2H_5OH (common alcohol) using **excess hydrogen**



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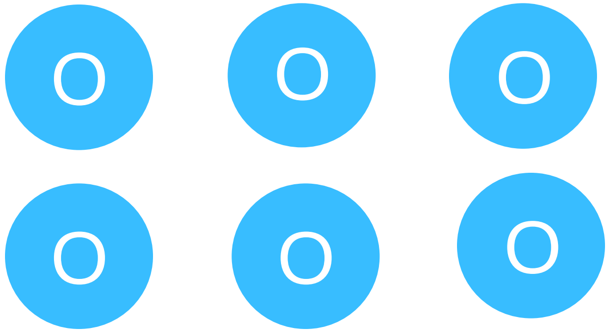
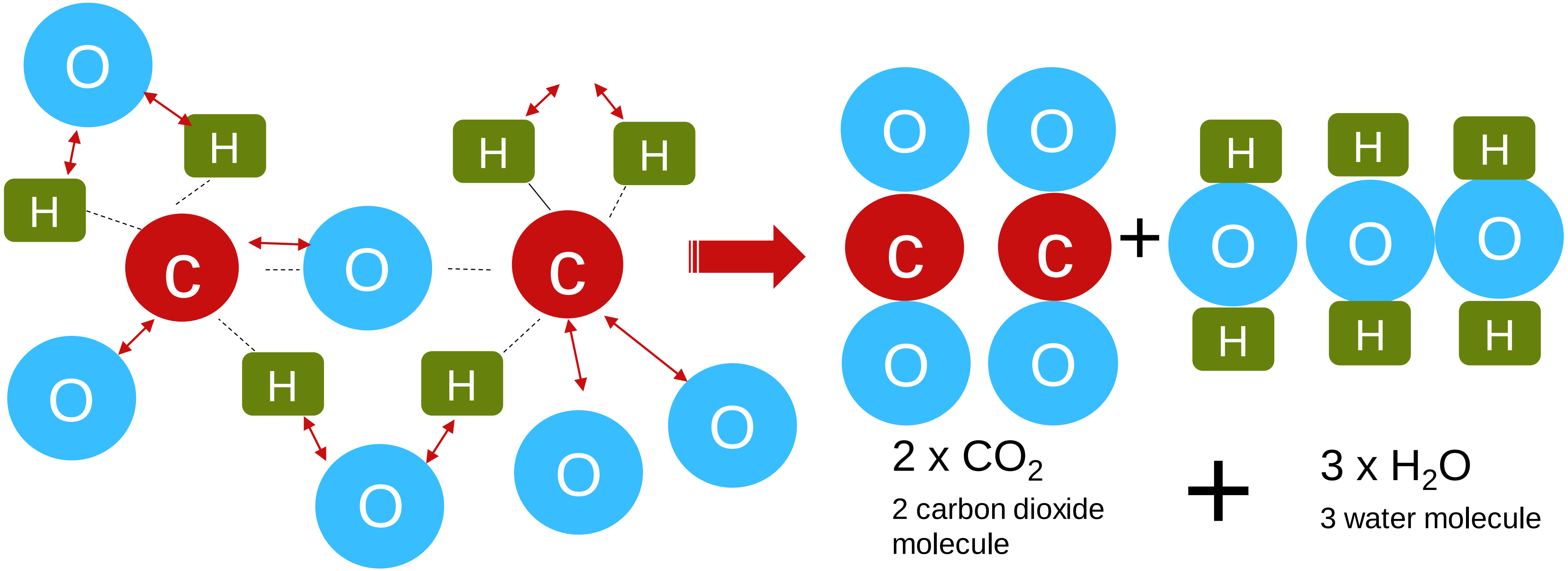


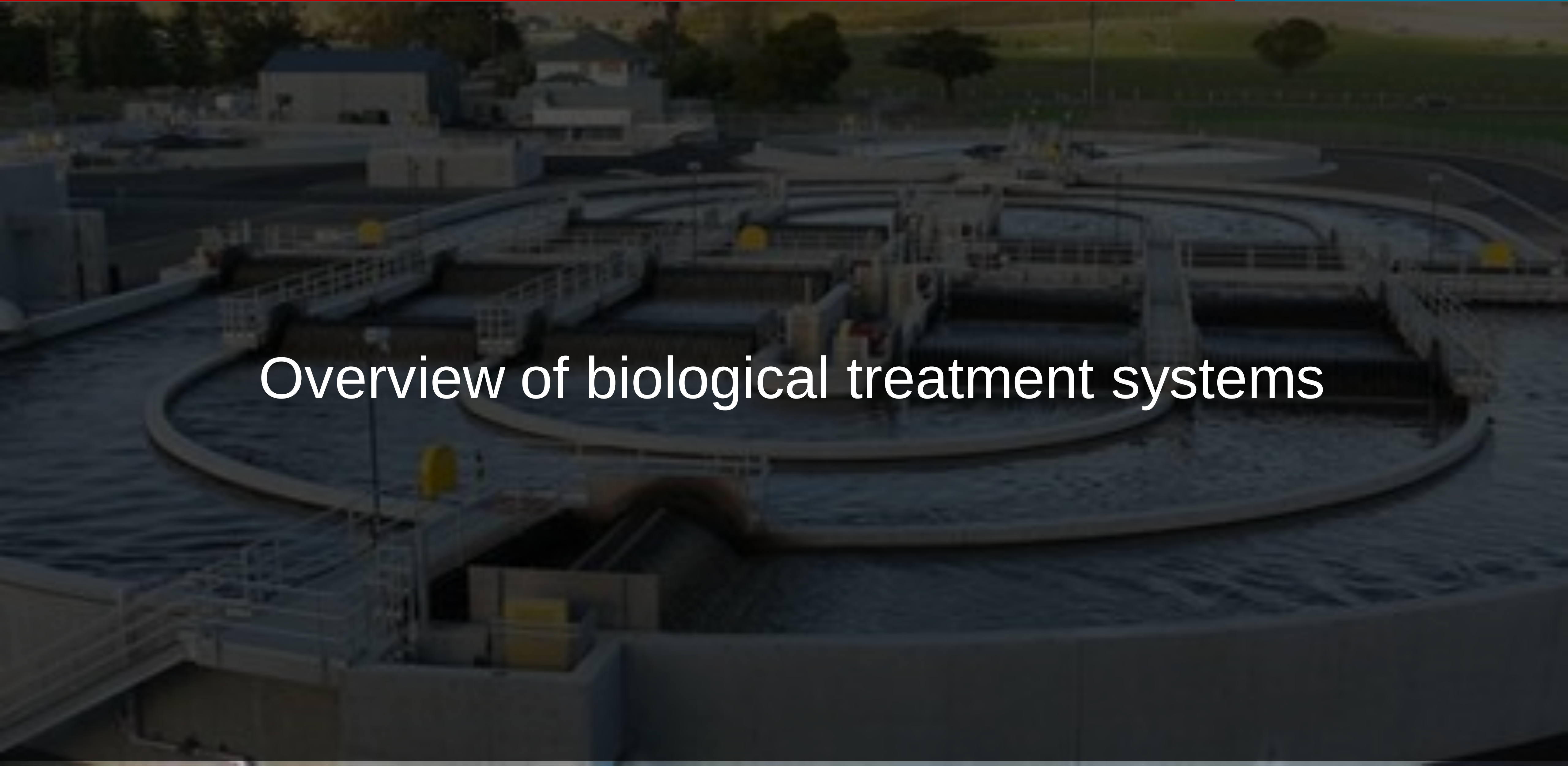
Alcohol (consisting of 2 carbon atoms, 6 hydrogen atoms, 1 oxygen atom)

6 more oxygen atoms

Aerobic processes

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





Overview of biological treatment systems

Image: water online

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QUIZ

What are some anaerobic biological treatment systems?

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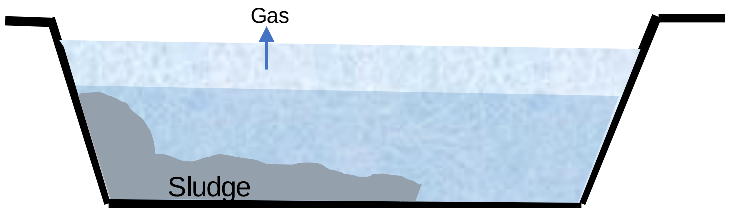
Overview of biological treatment systems

Anaerobic treatment systems

- Working **without external oxygen** supply
- Suitable for **high organic content** readily bio-degradable.
- **Not** preferred option for **textile effluent**
- Popular systems include Anaerobic **lagoon**, Anaerobic **digestors**, Anaerobic **filter** with natural media or synthetic media.
- Newer versions include **Upflow anaerobic sludge blanket reactor** (UASB) 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
- moderate efficiency of 40 -70% organics reduction.

Overview of biological treatment systems

Image: Lakeside equipment

Anaerobic lagoon

- 3 -15 days retention time - high bacteria population
- Set-up
    - ✓ Deep tank with mixing system (about 5 - 8 m)
- Provisions for collecting bio-gas and further use as fuel.
- Not suitable suited for combined textile wastewater because of
    - ✓ large volume
    - ✓ low degradable organics
- Maybe used for **high organic desizing effluent**

Overview of biological treatment systems

Image: Lakeside equipment

Anaerobic lagoon

- Bacteria growing on reactor media
- Bacteria 'eat' & destroying organic when it pass through
- Suitable for small ETPs with lower suspended solids
- 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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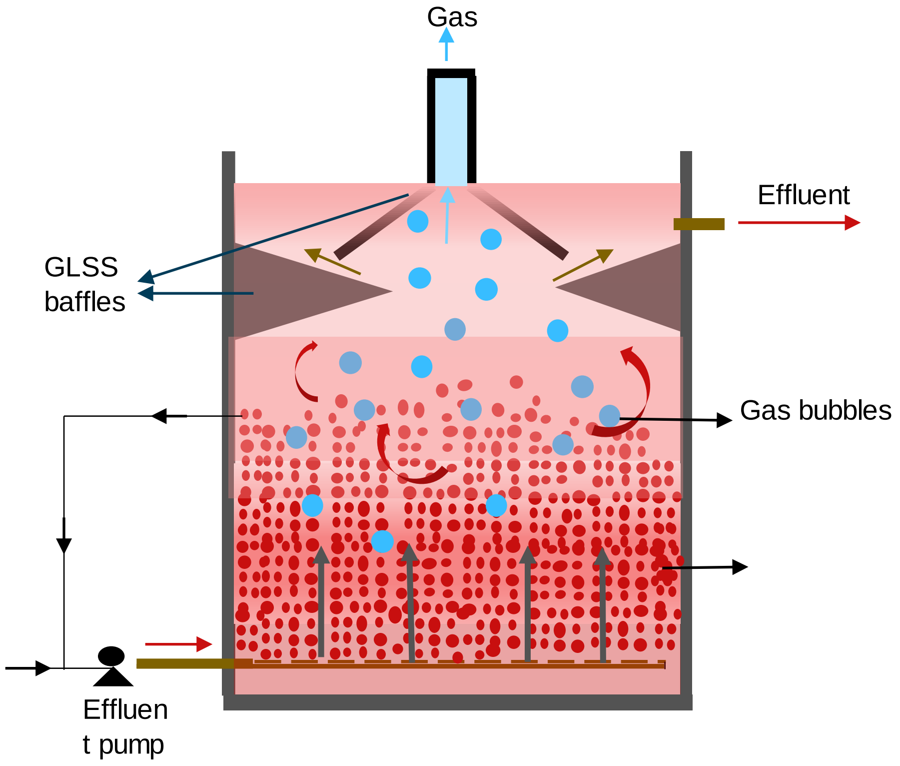
Overview of biological treatment systems



UASB concept

- Uses Sludge blanket with flocs of suspended solids, organics and micro-organisms.
- Turbulence and upflow movement also by gas produced
- Organics treated by bacteria in blanket
- Sufficient upflow velocity with inflow pump and recycle (when no flow).
- Sludge blanket with 3-6% of solids concentration of bio-sludge.
- GLSS (gas-liquid-solids separator) at top

Overview of biological treatment systems

Image: evoqua water technologies

Aerobic treatment systems

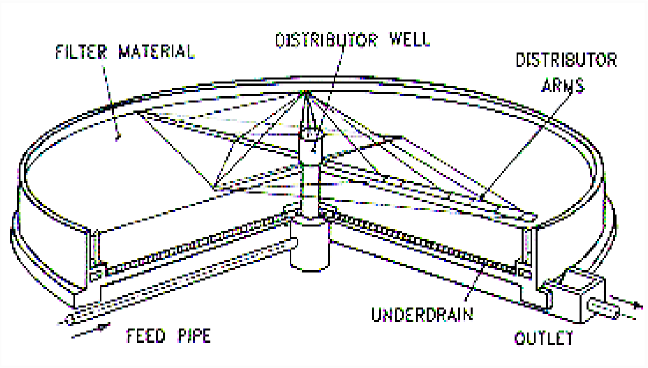
Bacteria requiring constant external oxygen supply

- bacteria using oxygen dissolved in water, reduces it
- aeration systems replacing oxygen

Three categories

- **Attached growth systems** with bacteria attached to media
- **Suspended growth systems with** bacteria growing on suspended mass of sludge e.g. activated sludge system
- **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

Trickling filter at Brunswick Sewer District

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 & wasted.

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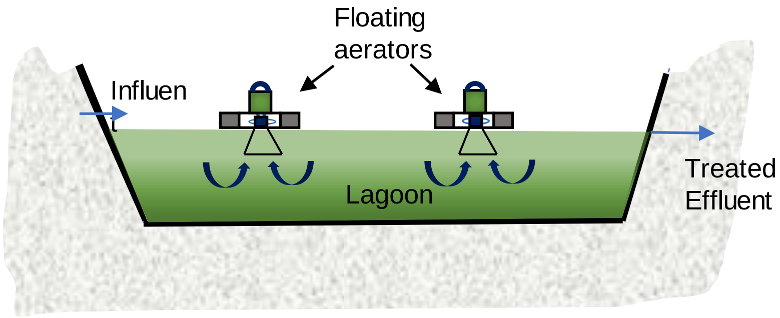
Overview of biological treatment systems



Suspended Growth Systems: Aerated lagoons

- Oldest and simplest aerobic treatment system
- Usually half of tank (top) only fully aerobic with bottom anoxic (facultative) or mildly anaerobic
- Aeration with floating type, jet aerators, aspirators or fixed aerators mounted on floats.
- Retention times 3 - 5 days (depending on effluent type)
- Suitable for low suspended solids' effluent only or where suspended solids organic.

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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
- Need aeration for keeping bio-sludge alive and mixing inside tank.

Activated Sludge process

Image: water online

QUIZ

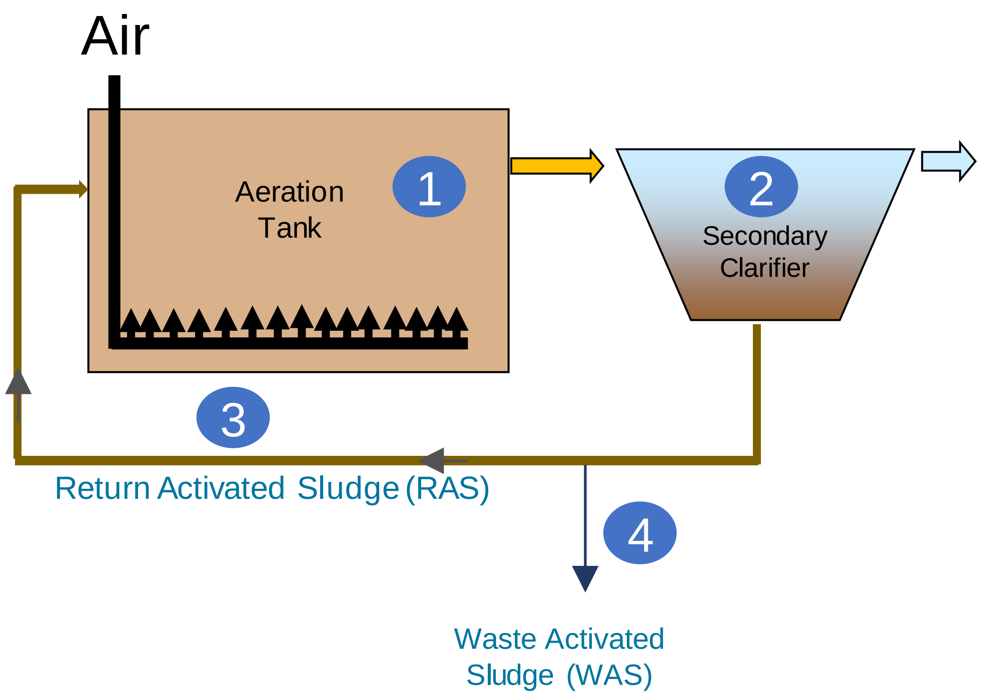
What is activated sludge?

Why is called so?

Basic concept

- treatment of organics using micro-organisms in biologically ‘activated’ sludge.
- Mixed liquor = raw effluent + returned bio-sludge - mixed liquor suspended solids, in short MLSS, housing bacteria
- intermittent product formed during degradation of organics in effluent.
- Usually dark brown in color, varying with micro-organisms health and nature of organics
- Consisting of 95% variety of mostly aerobic bacteria species, 5% fungi, protozoa and higher forms of invertebrates

Basic concept



- Effluent mixed with activated sludge and aerated for treatment in aeration tank
- Bio-sludge separated from clear effluent in secondary clarifier
- Separated bio-sludge returned to aeration tank to maintain required quantity of bio-sludge.
- Some excess bio-sludge wasted to keep bio-sludge fresh and healthy

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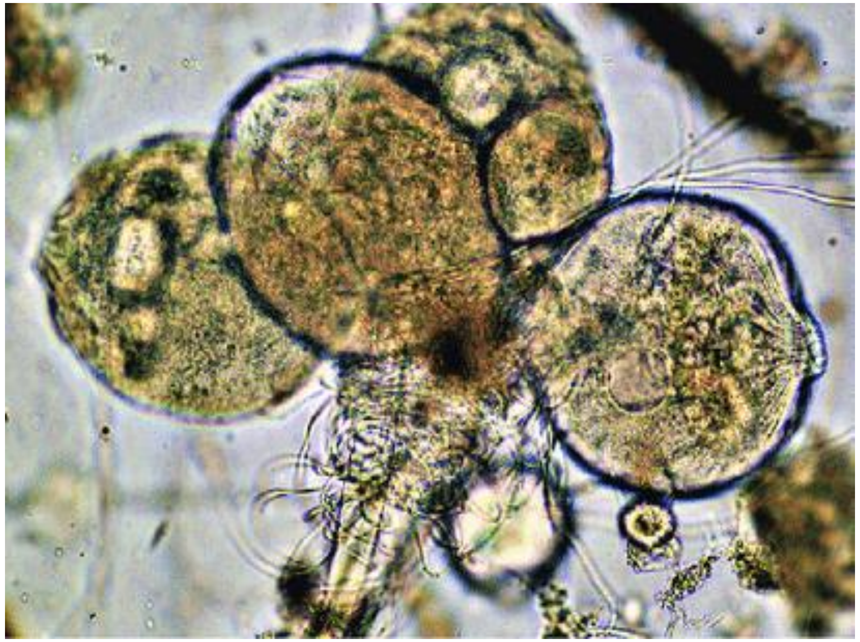
Basic concept



Common microorganisms in aeration basin of activated sludge

- **Bacteria :** organic reduction
- **Protozoa:** remove and digest dispersed bacteria and suspended particles.
- Protozoa Types: Amoebae, Flagellates, Ciliates & free-swimming Ciliates
- **Algae and fungi:** with pH changes/older sludge
- **Metazoa :** longer age systems including lagoons,
- Metazoa Types: Rotifers Nematodes, Tardigrades

Basic concept

Appearance of microorganisms in aeration basin of activated sludge

Individual bacteria

Bacteria in cluster with other microorganisms

Micro-organisms in MLSS as seen in microscope

Basic concept

Activated sludge through microscope

Activated sludge treatment stages

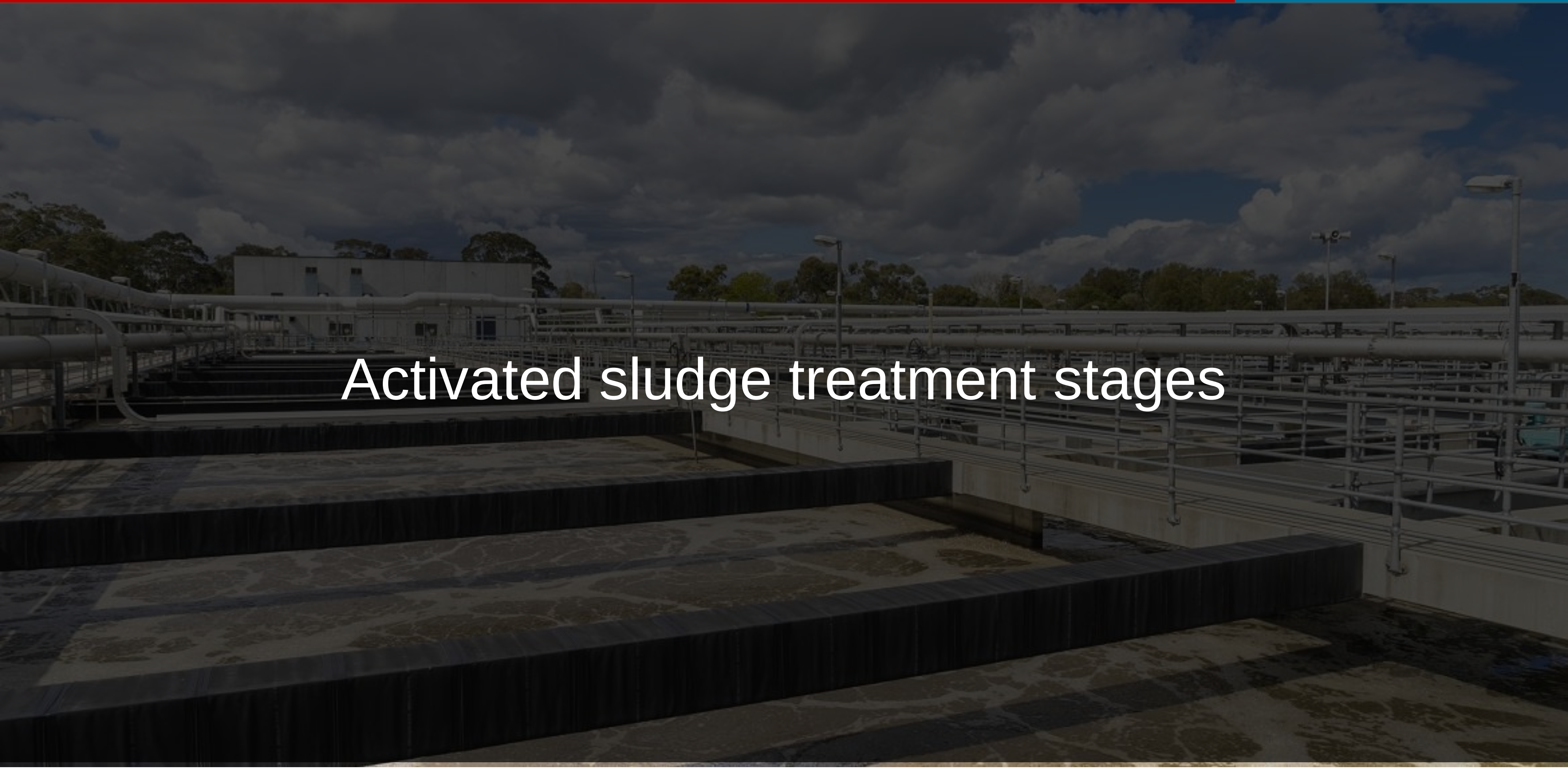


Image: cropaia

Activated sludge treatment stages

Stage 1

- Making food (BOD) in wastewater available to bacteria.
- mixing wastewater thoroughly with bio-sludge, i.e., MLSS
- providing required time for reaction, i.e. retention time

Stage 2

- Converting organic material to carbon dioxide, water and cell matter
- Part of organics directly converted to end products
- some portion remain as intermediate product, i.e. cell mass, becoming MLSS

Stage 3

- Bio-flocculation, when MLSS settling as a block trapping organic materials.
- pumped back to aeration tank as return activated sludge (RAS) and further treated

Activated sludge treatment stages

Differentiation based on **retention time** (HRT) and/or **organic loading rate, activated sludge systems**

- **Conventional** activated sludge systems
  - ✓ F/M ratio of about 0.2-0.4 retention time 8-12 hours.
- **Extended aeration** activated sludge systems
  - ✓ F/M ratio about 0.08 -0.15 and 16-24 hours HRT.
- **High rate** activated sludge systems:
  - ✓ F/M ratio of about 1-2 and HRT as 3-4 hours.

Activated sludge treatment stages

Differentiation by **solid separation**

- **Conventional aeration** systems with **external settling tanks**
- In-situ **settling systems** such as **sequential batch reactors**
- **Membrane bio-reactors** using filtration for bio-solids separation instead of clarifiers.
- **Hybrid reactors** including MBBR, IFAS, FAB
  - ✓ not considered as pure activated sludge systems

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Activated sludge parameters

Image: cropaia

QUIZ

What you mean by the terms MLSS and F/M?

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Activated sludge parameters

MLSS and MLVSS

- **Mixed Liquor Suspended Solids** (MLSS) referring to suspended solids in aeration tank.
- **Mixed Liquor Volatile Suspended Solids** (MLVSS) referring to volatile portion of activated sludge
  - ✓ loss in weight determined by heating MLSS at above 500 degree C with organic portion evaporated
  - ✓ required for calculating F/M ratio as key operational parameter
  - ✓ If MLVSS value not available, MLSS value used for calculating F/M ratio e.g. in case of steady operating plant

Activated sludge parameters

F/M Ratio

= amount of food given to bacteria

- ‘F’ (= food) referring to quantity of organics (e.g. BOD)
- ‘M’ (= micro-organisms) referring to quantity of bio-sludge (i.e. MLSS)
- Bacteria requiring certain food quantity to survive
  - ✓ Ratio of **kilogram BOD per day to the kilogram of MLSS**

Activated sludge parameters

F/M Ratio

depending on type of activated sludge system

Type of activated sludge process	Food to microorganisms	Oxygen to food
	F/M	kg O_2/kg BOD
Extended aeration ASP	**0.1**	**2.0**
Conventional ASP	**0.3**	**1.2**
High rate ASP	**1.0**	**0.8**

0.3 F/M meaning 1 kg BOD needing 3 kg MLSS

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 1

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
MLSSV	70	%
BOD at inlet	500	mg/l

What is the F/M maintained in your ETP?

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 1

ETP flow rate	800	$m^3/d.$
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
MLSSV	70	%
BOD at inlet	500	mg/l

Step 1:

Calculate kg BOD load to aeration tank.
BOD = 500 mg/l, flow = 800 m^3/d.

500 milligrams/litre = 0.5 grams/litre

= 0.5 kg/1000 litres = 0.5 kg/m^3

Total BOD load for 800 m^3 = 800 x 0.5

= 400 kg.

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Activated sludge parameters

Calculating F/M Ratio for ETP

Example 1

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
MLSSV	70	%
BOD at inlet	500	mg/l

Step 2:

Calculate kg MLVSS in aeration tank. MLSS is 3000 mg/l, aeration tank volume 600 m3 and MLVSS is 70%.

MLSS quantity = 3000 milligrams/litre = 3 grams/litre = 3 kg/1000 litres = 3 kg/m3

Total MLSS for 600 m3 = 600 x 3 = 1800 kg, MLVSS = 70% of 1800 kg = 1260 kg

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 1

ETP flow rate	800	$m^3/d.$
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
MLSSV	70	%
BOD at inlet	500	mg/l

Step 3:

Calculating F/M

F/M based on MLSS = kg BOD/kg MLSS

F/M based on MLSS = 400 kg/1800 kg = 0.22

F/M based on MLVSS = kg BOD/kg MLVSS

F/M based on MLVSS = 400 kg/1260 kg = 0.32

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 2

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
MLSSV	70	%
F/M as per design	0.2	MLSS

Step 2:

Calculate the kg BOD needed @ F/M 0.2 based on MLSS, flow is 800 m3/d

F/M = 0.2, Food (F) = M x 0.2, F (kg) = 0.2 x 1800 kg = 360 kg

mg/l BOD = kg BOD/flow m3 = 360/800 = 0.45 kg/m3 = 450 g/m3 = 450 g/1000 litres = 450 mg/l

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 2 **(Calculating MLSS needed to maintain good operation.)**

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
MLSSV	70	%
F/M as per design	0.2	MLSS

How much MLSS needed in the aeration tank?

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 3 **(Calculating MLSS needed to maintain good operation.)**

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
F/M	0.2	MLSS
BOD at inlet	500	mg/l
ETP flow rate	800	m^3/d.

Step 1:

Calculate BOD load to aeration tank; flowrate 600 m3/d and BOD 500 mg/l.

BOD quantity = 500 milligrams/litre = 0.5 grams/litre = 0.5 kg/1000 litres =0.5 kg/m3

BOD quantity for 800 m3 = 0.5 x 800 = 400 kg

Activated sludge parameters

Calculating F/M Ratio for ETP

Example 3

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
F/M	0.2	MLSS
BOD at inlet	500	mg/l

Step 2:

Calculate kg MLSS needed @ F/M 0.2, tank volume 600 m3

F/M = 0.2, M = F ⁄ 0.2, Food (kg) = 400 kg/0.2 = 2000 kg

Total MLSS = 2000 kg, MLSS kilogram/m3 = 2000/600 = 3.3 kg/m3 = 3.3 g/l = **3300 mg/l**

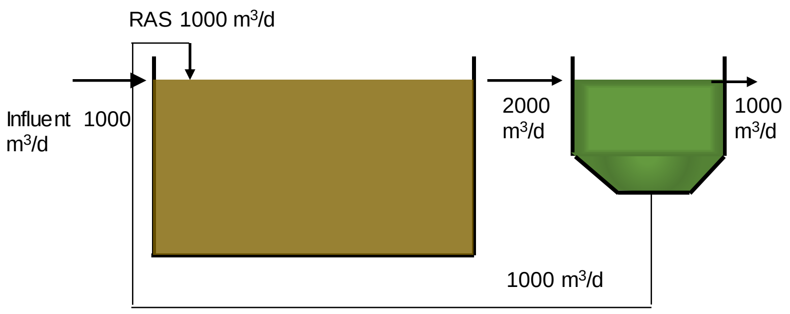
Activated sludge parameters

Return activated sludge (RAS)

= quantity of settled bio-sludge returned to aeration tank from secondary settling tank;

- important to maintain bacterial population and health of aeration tank.
  - ✓ Generally about 85-90% of bio-solids entering settling tank returned as RAS
  - ✓ 5% overflows as suspended solids in treated effluent and 5-10% wasted as excess sludge.
- RAS quantity about 100% of inlet (range 80% -125%)

Activated sludge parameters



Return activated sludge (RAS)

Example:

- 1000 m3/d inflow to aeration tank = RAS 1000 m3/d.

Explanation

- 1000 m3/d RAS pumped back
- Actual inflow increasing to 2000 m3/d (1000 m3 of inlet + 1000 m3/d RAS)

Activated sludge parameters

Return activated sludge (RAS)

- **Maintain proper RAS level**
  - ✓ **Too much** RAS **thinning bio-sludge** and **increasing hydraulic load** with effect on settling process.
  - ✓ **Too low** RAS leading to **insufficient return of bio-solids** and **bio-solids overflow** out of secondary clarifier, spoiling treated effluent quality and loss of bio-sludge.

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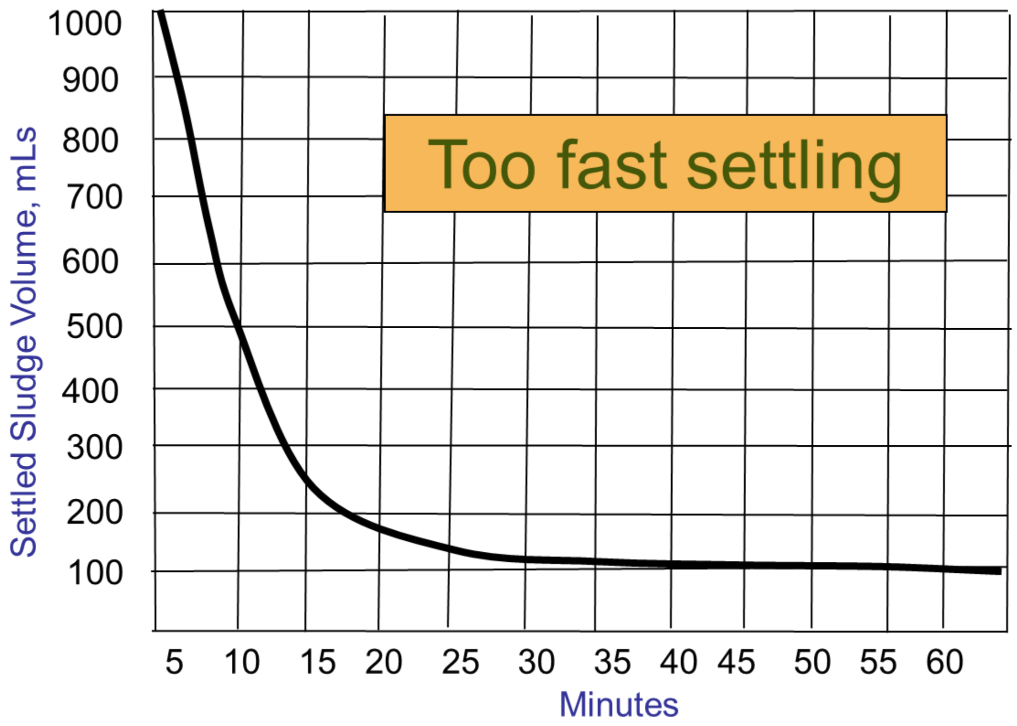
Activated sludge parameters

Return activated sludge (RAS)

- Need to **observe settleability of bio-sludge**
  - ✓ Take aeration tank MLSS in 1000 ml beaker and allowed to settle for some time
  - ✓ Good MLSS settling to about 30-40% in 30 minutes
- Good settling process gradual and smooth
  - ✓ **Too fast** settling resulting in **insufficient bio-flocculation** in secondary settling tank
  - ✓ **Too slow** settling resulting in **loss of bio-solids** through overflow in treated effluent.

Activated sludge parameters

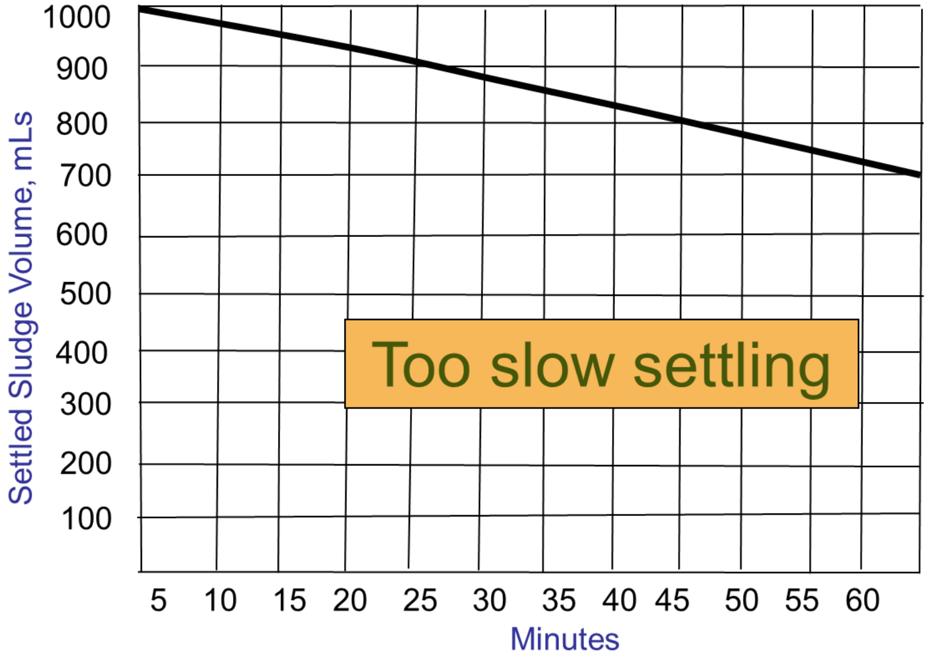


Return activated sludge (RAS)

Example of bad settling

- Settling rate too fast.
- Within 15 mins sludge settled to about 250 ml.
- Sludge not settling as a block in settling tank.
- Results in poor BOD removal.

Activated sludge parameters

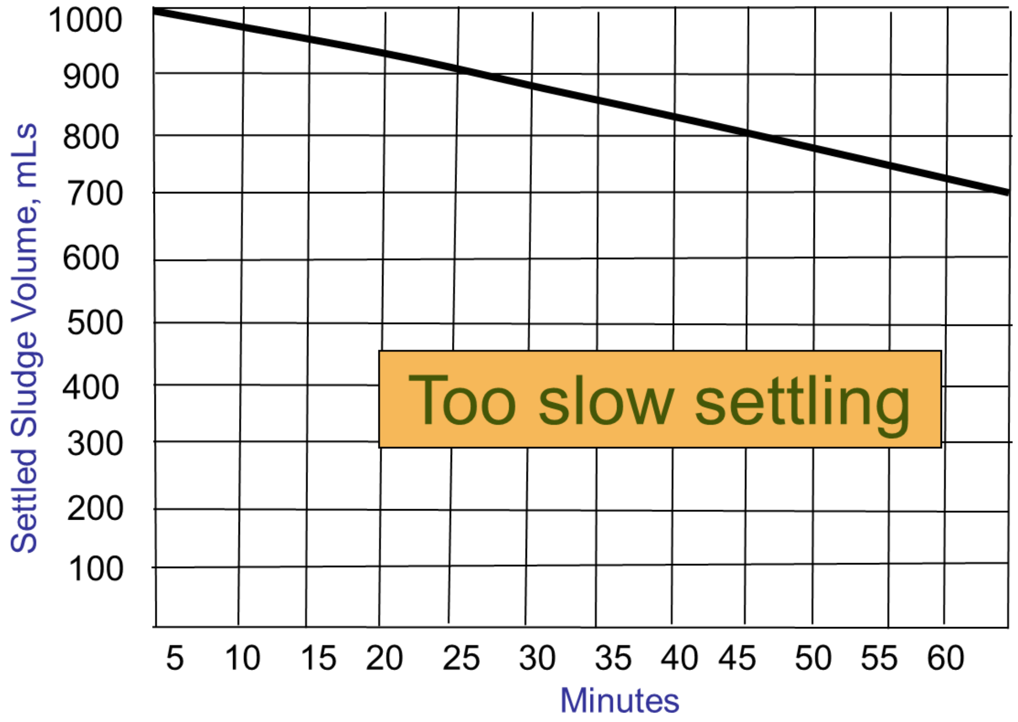


Return activated sludge (RAS)

Example of good settling

- Settling rate too slow.
- Even after one hour, sludge occupying 700 ml of beaker volume.
- Bio-solids overflowing in secondary clarifier and loss of MLSS.

Activated sludge parameters



Return activated sludge (RAS)

Example of good settling

- Settling rate even and smooth.
- Within 30 min. sludge settled to about 300 ml (i.e, about 30% of total volume).
- This shows good compaction

Activated sludge parameters

Sludge volume index (SVI)

= volume (in milliliters) occupied by one gram of activated sludge settled for 30 min in ml/g

To calculate SVI

1. keep bio-sludge inbeaker of 1 litre and settle same for 30 mins
2. Check MLSS (mg/l) in laboratory and calculate concentration as grams per litre
   - ✓ 3000 mg/MLSS = 3 grams per litre
3. Calculate SVI as ml of settled bio-sludge divided by grams per litre of MLSS
   - ✓ General SVI range 75 -150 ml/g, for textile ETP around 90 - 110 ml/g.

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Activated sludge parameters

Calculating SVI for ETP operation

Example 3

MLSS concentration	3500	mg/l
Sludge volume settling after 30 min in 1 litre beaker	325	ml

What is the SVI?

Activated sludge parameters

Calculating SVI for ETP operation

Example 3

MLSS concentration	3500	mg/l
Sludge volume settling after 30 min in 1 litre beaker	325	ml

Step 1

Calculate MLSS as grams per litre

MLSS = 3500 milligrams/litre = 3.5 grams/litre

Activated sludge parameters

Calculating SVI for ETP operation

Example 3

MLSS concentration	3500	mg/l
Sludge volume settling after 30 min in 1 litre beaker	325	ml

Range of SVI needed for ETP =93

ETP appears to be in a good operational level (between 90 - 110 ml/g)

Step 2

Verify the settleability of bio-sludge in milli litres in a one litre beaker after settling for 30 minutes. Sludge settled in 30 minutes = 325 millilitre

SVI = Sludge volume settling (ml)/MLSS (gr/l)

SVI = 325/3.5 = 92.8 = say **93**

Activated sludge parameters

Sludge volume index (SVI)

Effects of different SVI in settling of bio-sludge

SVI ml/g	Effect on settling & quality of treated effluent
< 60	Too low, bio-sludge not settling as block since not enough filaments, possibility of fine suspended solids in treated effluent
60-120	Good settling of bio-sludge, clear treated effluent, compact sludge blanket formation.
120-180	Fair settleability, clear treated effluent
180-250	Poor settleability, reasonably clear treated effluent
>250	Very poor settleability, sludge bulking, turbid effluent with intermittent sludge overflow.

Activated sludge parameters

Sludge volume index (SVI)

Effects of different SVI in settling of bio-sludge

SVI ml/g	Effect on settling & quality of treated effluent
< 60	Too low, bio-sludge not settling as block since not enough filaments, possibility of fine suspended solids in treated effluent
60-120	Good settling of bio-sludge, clear treated effluent, compact sludge blanket formation.
120-180	Fair settleability, clear treated effluent
180-250	Poor settleability, reasonably clear treated effluent
>250	Very poor settleability, sludge bulking, turbid effluent with intermittent sludge overflow.

Conclusion

- Anaerobic systems for organic rich effluents (distillery, brewery, and UASBs in sewage)
- Aerobic for small medium organics, most common : Activated sludge process (ASP)
- System to be selected on consideration of cost (capital, O&M) and local factors (e.g. availability of land, power supply, operator skills)
- ASP Stages including aeration, bio-sludge separation, return of bio-sludge to aeration tank and sludge wasting

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Conclusion

- ASP efficiency depending on bacterial population, usually by MLSS parameter
- Maintain F/M at designed level to ensure right quantity of food for bacteria
- Control system effectively by calculating process parameters like SVI as well as maintaining optimum SVI and SRT

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