TRAINING PROGRAMME FOR ETP OPERATORS IN TEXTILE INDUSTRY

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

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Activate sludge process

GIZ FABRIC – ETP Operator Course

Contents

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Basic concept

Basic concept

- treatment of organics using micro-organisms in biologically ‘activated’ sludge.
  - Suspended solids in ‘mixed liquor’ hosting bacteria and other micro-organisms.
    - Mixed liquor = raw effluent + returned bio-sludge
  - mixed liquor suspended solids, in short MLSS, housing bacteria
- Activated sludge plant (ASP) including four stages:
  (1) aeration
  (2) solids separation
  (3) recycling of activated sludge (RAS)
  (4) wasting of excess activated sludge (WAS)

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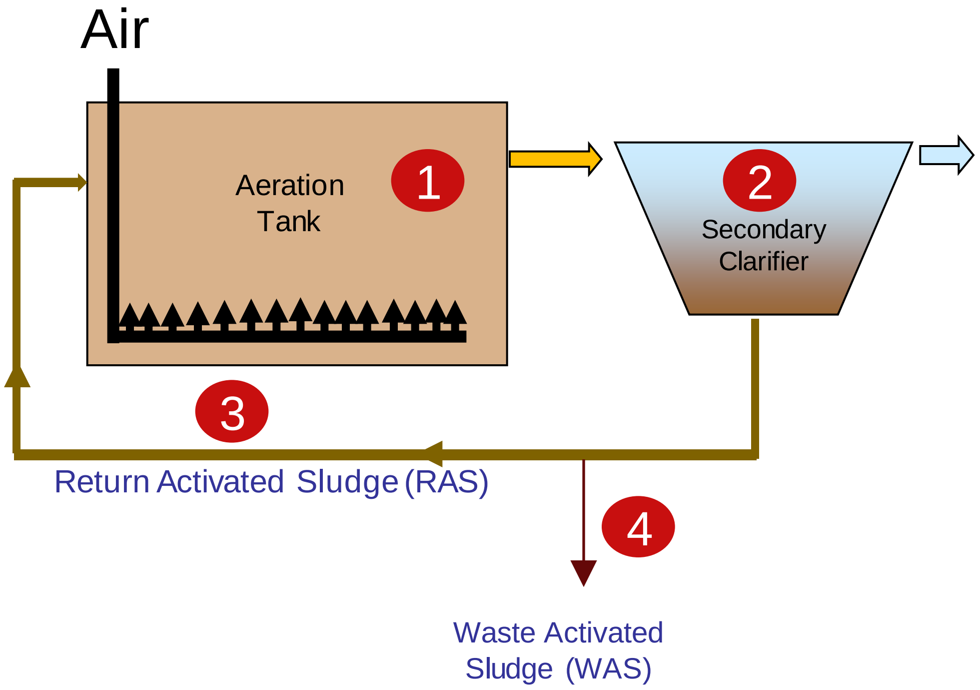
Basic concept

(1) Effluent mixed with activated sludge and aerated for treatment in aeration tank

(2) Bio-sludge separated from clear effluent in secondary clarifier

(3) Separated bio-sludge returned to aeration tank to maintain required quantity of bio-sludge.

(4) Some excess bio-sludge wasted to keep bio-sludge fresh and healthy



Basic concept

Activated sludge

- intermittent product formed during degradation of organics in effluent.
- flocculent culture of organisms developed in aeration tanks under controlled conditions
  - Usually dark brown in color.
  - Depending on micro-organisms health and nature of organics color varying
- Consisting of mixed blend of microorganisms,
  - 95% variety of mostly aerobic bacteria species
  - also population of fungi, protozoa and higher forms of invertebrates.

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Basic concept

Activated sludge

- developed by seeding aeration tank with bacterial culture during start up
- further developed by controlling
  - feed
  - favorable environmental conditions
  - return of activated sludge after solids separation

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Basic concept

Common microorganisms in aeration basin of activated sludge

(1) Bacteria:

- **aerobic** ones need oxygen removing organic compounds & nutrients
- **anoxic** need very little oxygen
- **anaerobic** survive absence of oxygen

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Basic concept

Common microorganisms in aeration basin of activated sludge

(2) Protozoa

- remove and digest dispersed bacteria and suspended particles
- Types
  - **Amoebae** with little effect on treatment
  - **Flagellates** primarily feeding on nutrients
  - **Ciliates** clarifying water by removing suspended bacteria ciliates
  - free-swimming Ciliates removing dispersed bacteria.

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Basic concept

Common microorganisms in aeration basin of activated sludge

(3) Metazoa

- dominating in longer age systems including lagoons,
- Common types:
  - Rotifers clarifying effluent
  - Nematodes feeding on feed on bacteria, fungi, small protozoa and other nematodes
  - Tardigrades (water bear) surviving environmental extremes and toxic sensitivity

Basic concept

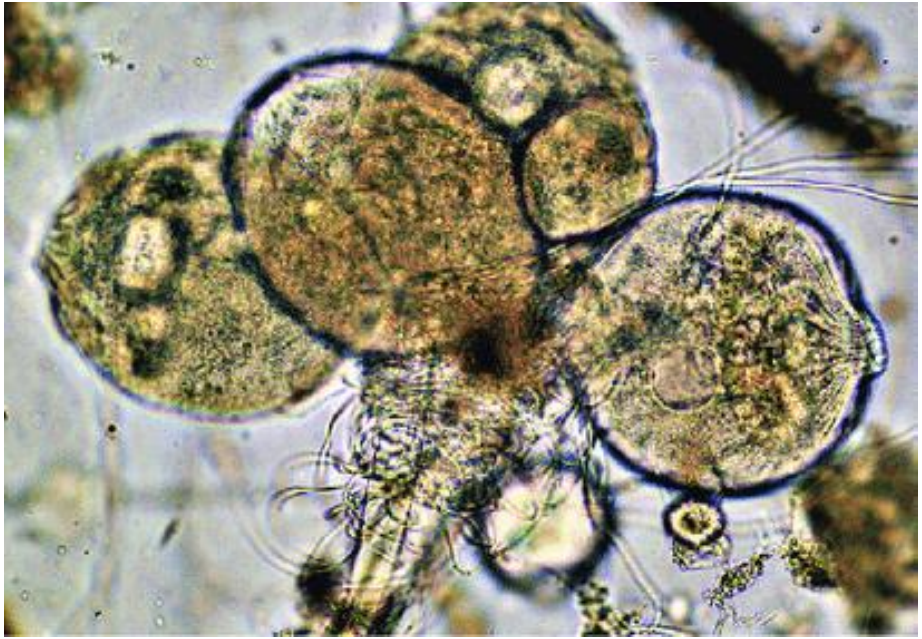
Common microorganisms in aeration basin of activated sludge

(4) Algae and fungi

– Fungi present with pH changes and older sludge

Basic concept

Common microorganisms in aeration basin of activated sludge



A biofloc in MLSS with micro-organisms

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

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 remaining as intermediate product, i.e. cell mass, becoming MLSS
  - Bacteria growing in MLSS particles and distributed throughout tank

Activated sludge treatment stages

Stage 3

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

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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 **feed pattern**

- **Tapered aeration**
  - aeration, i.e., more diffusers provided at inlet side of the tank, where pollution load is high
- **Step aeration**
  - Inlet effluent admitted at different points of tank
- **Contact stabilization**
  - returned sludge re-aerated before admitted to tank.
- **Complete mix tank**
  - single aeration tank without baffles with contents mixed completely

Activated sludge treatment stages

Differentiation by **configuration of aeration basin**

- Conventional aeration tank based systems & step aeration
- Oxidation ditches
- Deep shaft aeration systems

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

Activated sludge parameters

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**

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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?

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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 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.

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**

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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 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

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Activated sludge parameters

Calculating BOD concentration to be maintained for good operation

Example 2

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 allowed BOD for aeration tank?

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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 1:

Calculate kg MLSS in the aeration tank. The tank volume is 600 m3/d and MLSS is 3000 mg/l.

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

Total MLSS for 600 m3 = 600 x 3 = 1800 kg

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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**

Allowed BOD at inlet of aeration tank = 450 mg/l

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Activated sludge parameters

Calculating MLSS needed to maintain good operation.

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

How much MLSS needed in the aeration tank?

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Activated sludge parameters

Calculating MLSS needed to maintain good operation.

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 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 MLSS needed to maintain good operation.

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**

Need to maintain MLSS concentration of 3300 mg/l in aeration tank to treat 800 m3/d effluent with 500 mg/l BOD.

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

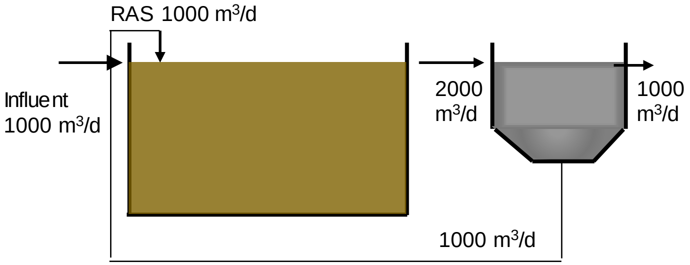
Return activated sludge (RAS)

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.

Activated sludge parameters

Return activated sludge (RAS)

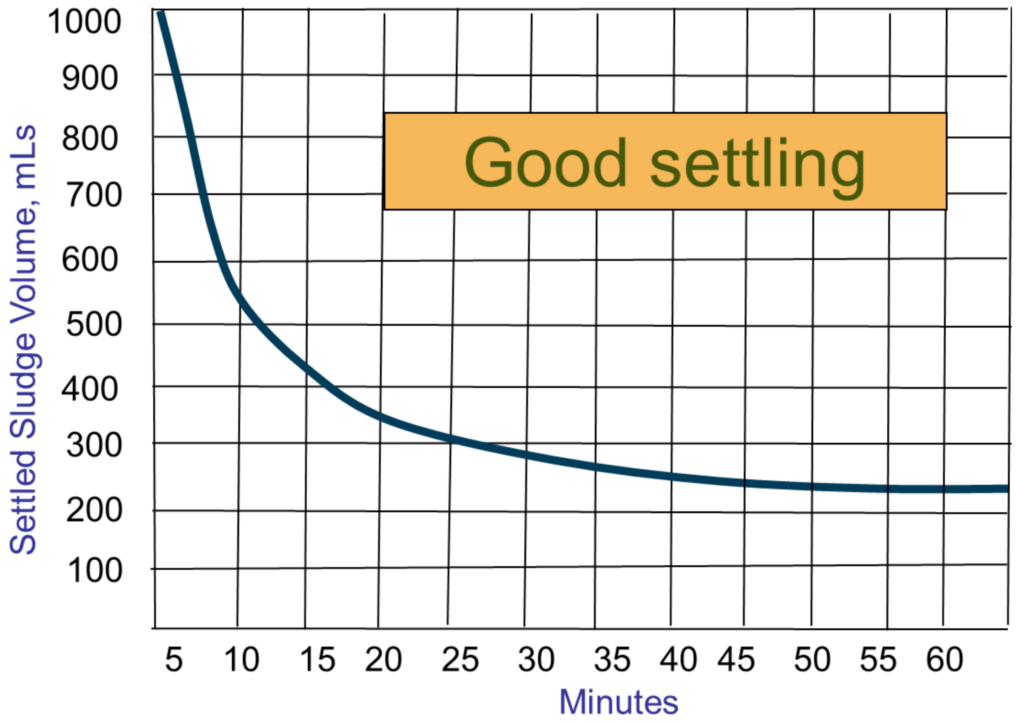
- Need to **observe settleability of bio-sludge**
  - Take aeration tank MLSS in 1000 ml beaker and allowed to settle for some time
  - Good MLSS settling to about 30-40% in 30 minutes
- Good settling process gradual and smooth
  - **Too fast** settling resulting in **insufficient bio-flocculation**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

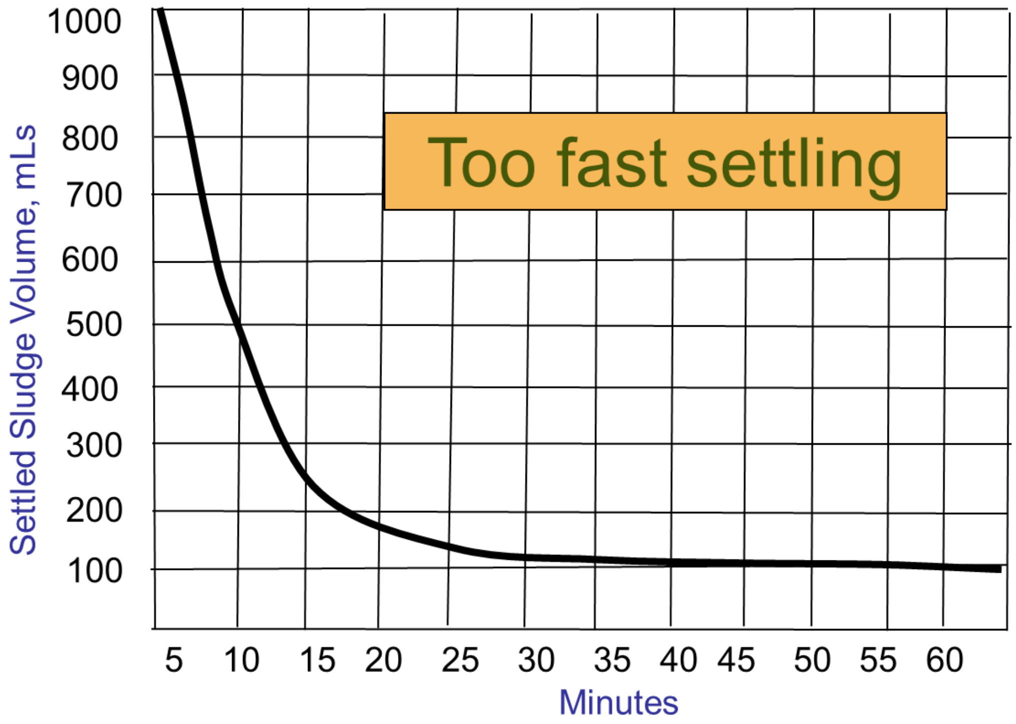


Activated sludge parameters

Return activated sludge (RAS)

Example of good settling

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

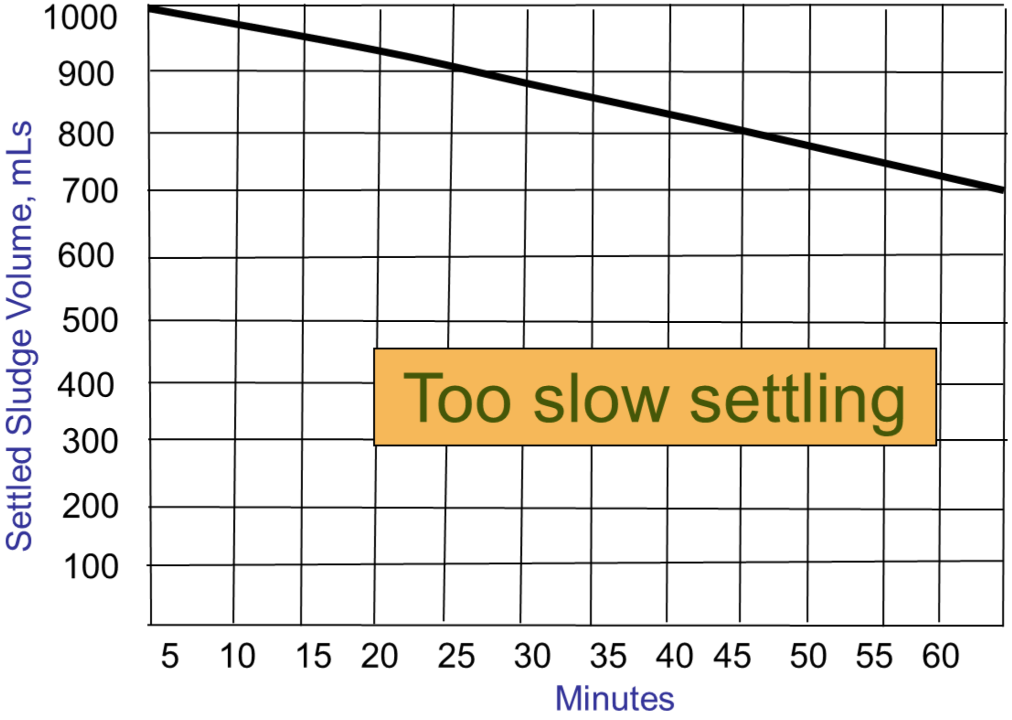


Activated sludge parameters

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.



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Activated sludge parameters

Solid retention time (SRT)

indicating how long bio-solids actually remaining in system also cell retention time (CRT) or sludge age

- mean cell retention time (MCRT) = retention time of volatile suspended solids.
- calculated by dividing total amount of solids in system by quantity leaving system
  - Suspended solids leaving system by
    - wasting
    - overflow in treated effluent

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Activated sludge parameters

Solid retention time (SRT)

- Longer SRT (upto some level) => system with more stabilized bacteria and better performance
- Usual SRT for conventional aeration tank treating textile effluents 10-20 days
  - Systems like MBR with much longer SRT
  - Too low SRT => low efficiency and too much sludge for disposal
  - Too high SRT wasting power for aeration and sludge settling problems (since promoting filamentous organics)
- SRT important variable to control by operator

Activated sludge parameters

Calculating SRT for ETP operation

Example 3

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
TSS in treated effluent	60	mg/l
Sludge wastage @ 6000 mg/l TSS	10	m3/d

What is the SRT?

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Activated sludge parameters

Calculating SRT for ETP operation

Example 1

ETP flow rate	800	$m^3/d.$
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
TSS in treated effluent	60	mg/l
Sludge wastage @ 6000 mg/l TSS	10	m3/d

Step 1

Calculate the quantity of MLSS in kilograms

MLSS = 3000 milligrams/litre = 3 kg/m3, for 600 m3,

Total MLSS quantity is = 3 x 600 = 1800 kg.

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Activated sludge parameters

Calculating SRT for ETP operation

Example 1

ETP flow rate	800	$m^3/d.$
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
TSS in treated effluent	60	mg/l
Sludge wastage @ 6000 mg/l TSS	10	m3/d

Step 2

Calculate quantity of solids leaving system.

Solids leaving via treated effluent = 60 mg/l = 0.06 g/l = 0.06 kg/m3, for 800 m3/d = 0.06 x 800 = 48 kg

Solids lost through sludge wasting = 10 m3 @ 6g/m3, Total quantity = 10 x 6 = 60 kg

Total solids lost = 48 + 60 = 108 kg

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Activated sludge parameters

Calculating SRT for ETP operation

Example 1

ETP flow rate	800	m^3/d.
Aeration tank size	600	m^3
MLSS concentration	3000	mg/l
TSS in treated effluent	60	mg/l
Sludge wastage @ 6000 mg/l TSS	10	m3/d

Step 3

Calculate SRT.

SRT = MLSS/total solids lost

SRT = 1800kg/108kg = 14.8 = say **15 days**

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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 4

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

What is the SVI?

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Activated sludge parameters

Calculating SVI for ETP operation

Example 4

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 4

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**

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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.

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Conclusion

- Activated sludge process (ASP) = aerobic process and **most common biological treatment**
- Stages including **aeration**, **bio-sludge separation**, **return of bio-sludge** to aeration tank and **sludge wasting**
- ASP efficiency depending on bacterial population, usually controlled through **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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