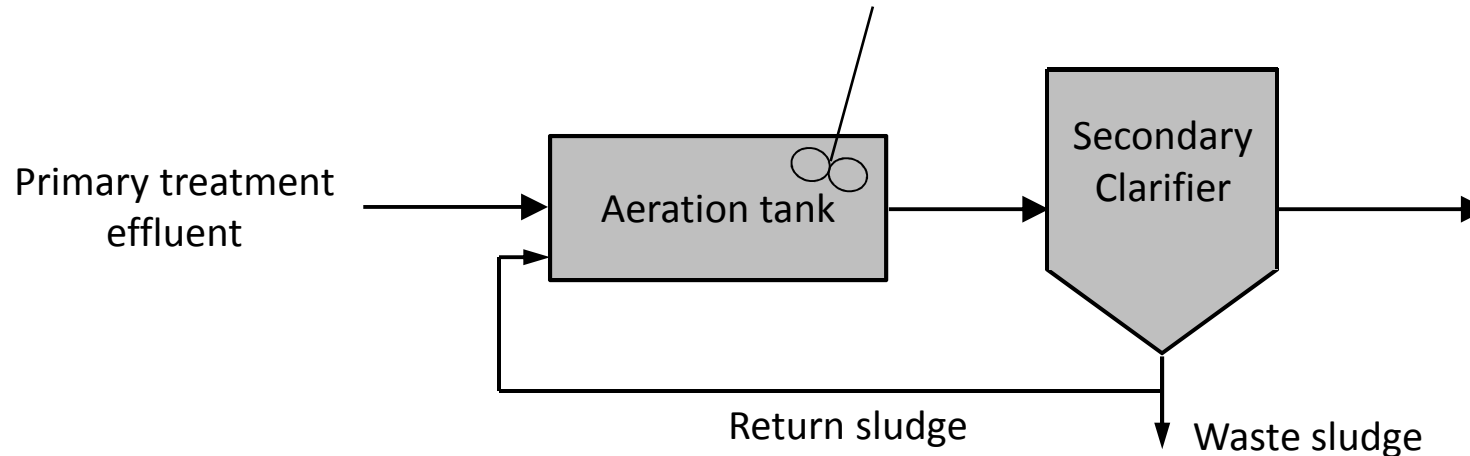


Wastewater treatment II

Wastewater treatment II

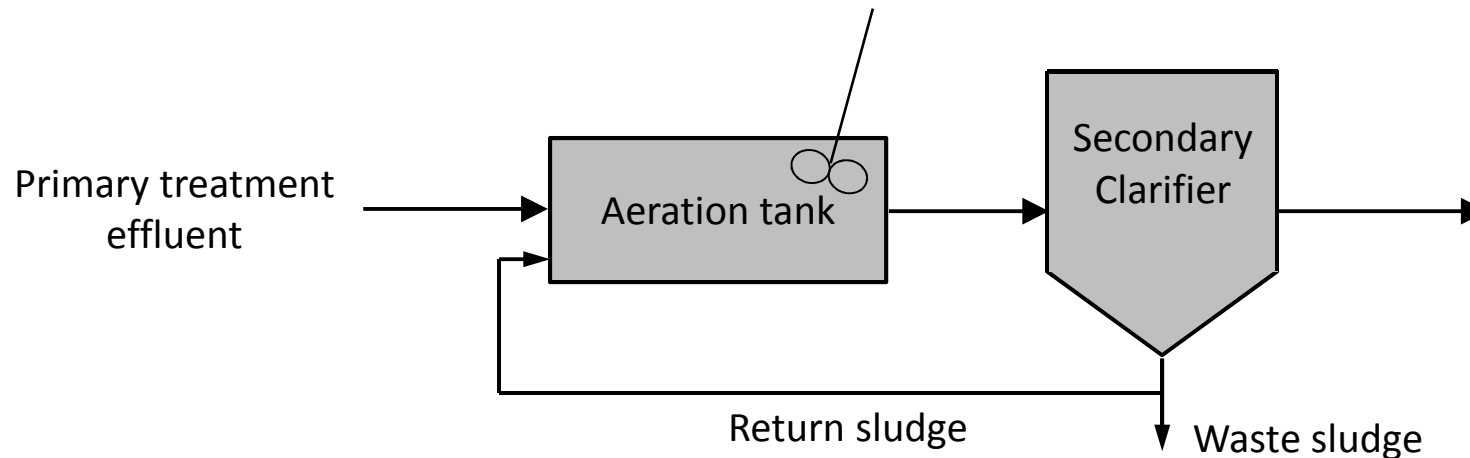
- Wastewater treatment processes
 - Secondary treatment – activated sludge; concept & analysis
 - Tertiary treatment
 - Sludge treatment and disposal
- Wastewater as a resource

Activated sludge process – concept



- A biological wastewater treatment technique using suspended microorganisms (dispersed growth)
- Aeration tank: a mixture of wastewater and microorganisms is agitated and aerated
- Wastewater BOD is removed by active microorganisms

Activated sludge process – concept

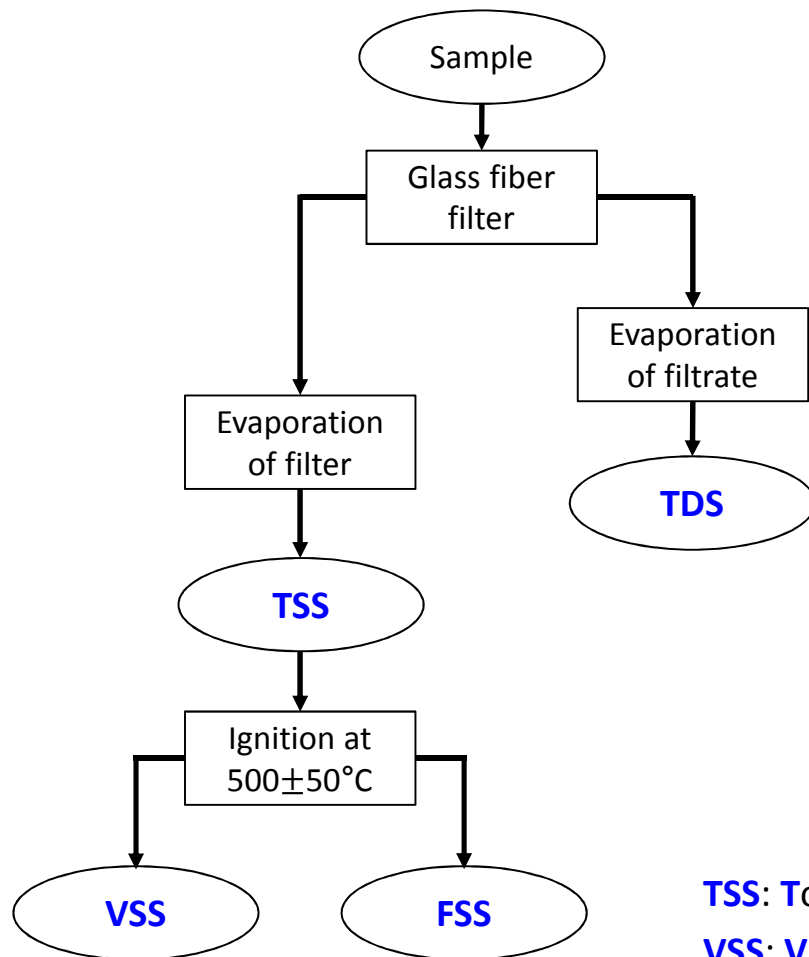


- Secondary clarifier: the microorganisms (also called biosolids or sludge) are separated from water by gravity
- Most of the settled sludge is returned to the aeration tank (Why? - We need a high population of microorganisms)
- A fraction of the settled sludge is wasted (Why? – microorganisms grow!)

Solids retention time (SRT)

- Recall hydraulic retention time
 $t_o =$ the time that fluid elements stay in the system
 $= V/Q$
- Solids retention time (or mean cell residence time)
 $\theta_c =$ the time that microorganisms stay in the system
- $t_o \neq \theta_c$ if sludge is returned to the aeration tank
(Why??)

Suspended solids in AS process



TSS: Total **S**uspended **S**olids

VSS: **V**olatile **S**uspended **S**olids

FSS: **F**ixed **S**uspended **S**olids

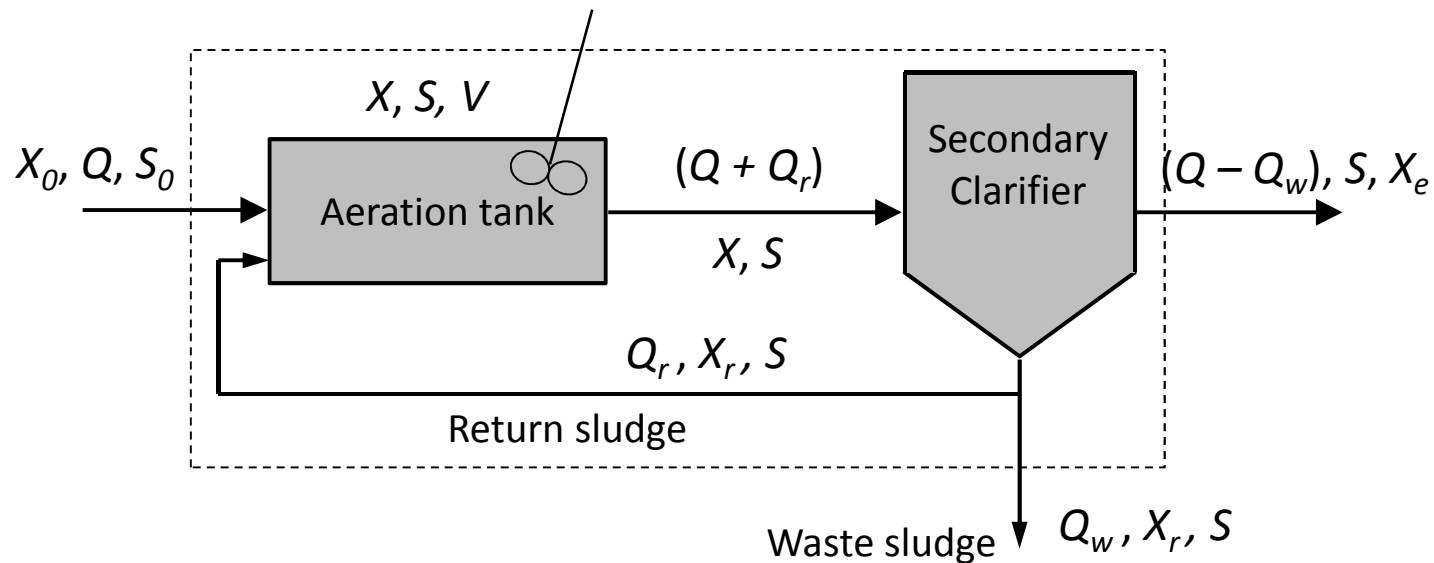
TDS: Total **D**issolved **S**olids

- **TSS**
 - A measure of the amount of all suspended solids
- **VSS**
 - For activated sludge process, a measure of the amount of microorganisms
 - Microorganisms are suspended solids which volatilize at 500°C

Analyzing activated sludge process

- Let's analyze the activated sludge process using two basic knowledge:
 - Monod kinetics (the reaction)
 - The system configuration (mass balance)
- We have two substances to analyze:
 - BOD (=substrate=food): the performance of the activated sludge process to treat wastewater
 - Microorganisms (measured as VSS): those that consume BOD; also related to sludge production

Control volume and assumptions



Assumptions:

X, X_e, X_r : microorganism concentrations in aeration tank, effluent, and return sludge (measured as VSS)

- i) Steady-state
- ii) The aeration tank is a CMFR
- iii) All reactions occur in the aeration tank

Mass balances

- Mass balance for substrate:

$$QS_0 - V \frac{\mu_m SX}{Y(K_s + S)} = (Q - Q_w)S + Q_w S \quad (\text{A})$$

- Mass balance for microorganisms:


$$QX_0 + V \left(\frac{\mu_m SX}{K_s + S} - k_d X \right) = (Q - Q_w)X_e + Q_w X_r$$

Solving the mass balance equations

Additional assumption: The influent and effluent VSS is negligible

- Mass balance for microorganisms

$$QX_0 + V \left(\frac{\mu_m SX}{K_s + S} - k_d X \right) = (Q - Q_w)X_e + Q_w X_r$$


$$\frac{\mu_m S}{K_s + S} = \frac{Q_w X_r}{VX} + k_d$$

(B)

Representation of SRT

When the effluent VSS is negligible, we find:

$$\theta_c = \frac{\text{VSS in the aeration tank}}{\text{VSS mass flow out of the system}} = \frac{VX}{Q_w X_r}$$

$$(B): \quad \frac{\mu_m S}{K_s + S} = \frac{1}{\theta_c} + k_d$$

$$(A): \quad \frac{\mu_m S}{K_s + S} = \frac{QY}{VX} (S_0 - S) \quad \rightarrow \quad \frac{1}{\theta_c} + k_d = \frac{Y}{t_0 X} (S_0 - S)$$

Solutions

Effluent substrate concentration

$$S = \frac{K_s(1 + k_d\theta_c)}{\theta_c(\mu_m - k_d) - 1}$$

Aeration tank VSS concentration

$$X = \frac{\theta_c Y (S_0 - S)}{t_0(1 + k_d\theta_c)}$$

- SRT (θ_c) is a key design and operation parameter
- The effluent substrate concentration, S , is independent of the influent substrate concentration, S_0
- Higher $S_0 \rightarrow$ higher VSS in the aeration tank \rightarrow more substrate biodegradation \rightarrow same S

Analyzing activated sludge process

Q1: A completely mixed activated sludge process receives a primary effluent at a flowrate of $0.150 \text{ m}^3/\text{s}$ with a BOD_5 of 84.0 mg/L . Calculate the solids retention time required to meet a secondary effluent standard of 10.0 mg/L BOD_5 .

Following microbial growth parameters apply:

$$K_s = 100 \text{ mg/L BOD}_5$$

$$\mu_m = 2.5 \text{ day}^{-1}$$

$$k_d = 0.050 \text{ day}^{-1}$$

$$Y = 0.50 \text{ mg VSS/mg BOD}_5$$

Analyzing activated sludge process

Q2: For the given activated sludge process, calculate the volume of the aeration tank to maintain VSS concentration of 2000 mg/L in the aeration tank.

Tertiary (advanced) treatment

- Goal: to improve the quality of the secondary treatment effluent
- Many of the Korean wastewater treatment plants now have advanced treatment process
- Further BOD and SS removal, nutrient removal, TDS removal, or the removal of refractory organic compounds
- Different processes can be used depending on the major target

Tertiary (advanced) treatment

- Available advanced treatment processes
 - **Granular filtration**
 - Additional removal of SS (including microorganisms)
 - Similar to water treatment
 - **Membrane filtration**
 - Additional removal of SS
 - Microfiltration is mostly commonly used for advanced treatment of wastewater
 - **Carbon adsorption**
 - Removal of non-biodegradable organic compounds (contributes to COD, but not to BOD)
 - Activated carbon is most commonly used as an adsorbent

Tertiary (advanced) treatment

- Available advanced treatment processes
 - **Chemical phosphorus removal**
 - Use chemical precipitants such as ferric chloride (FeCl_3), alum ($\text{Al}_2(\text{SO}_4)_3$), lime ($\text{Ca}(\text{OH})_2$)
 - **Chlorine disinfection**
 - Removal of pathogens
 - Required process in the U.S. → considered as a conventional process, but often categorized as tertiary treatment

Sludge treatment

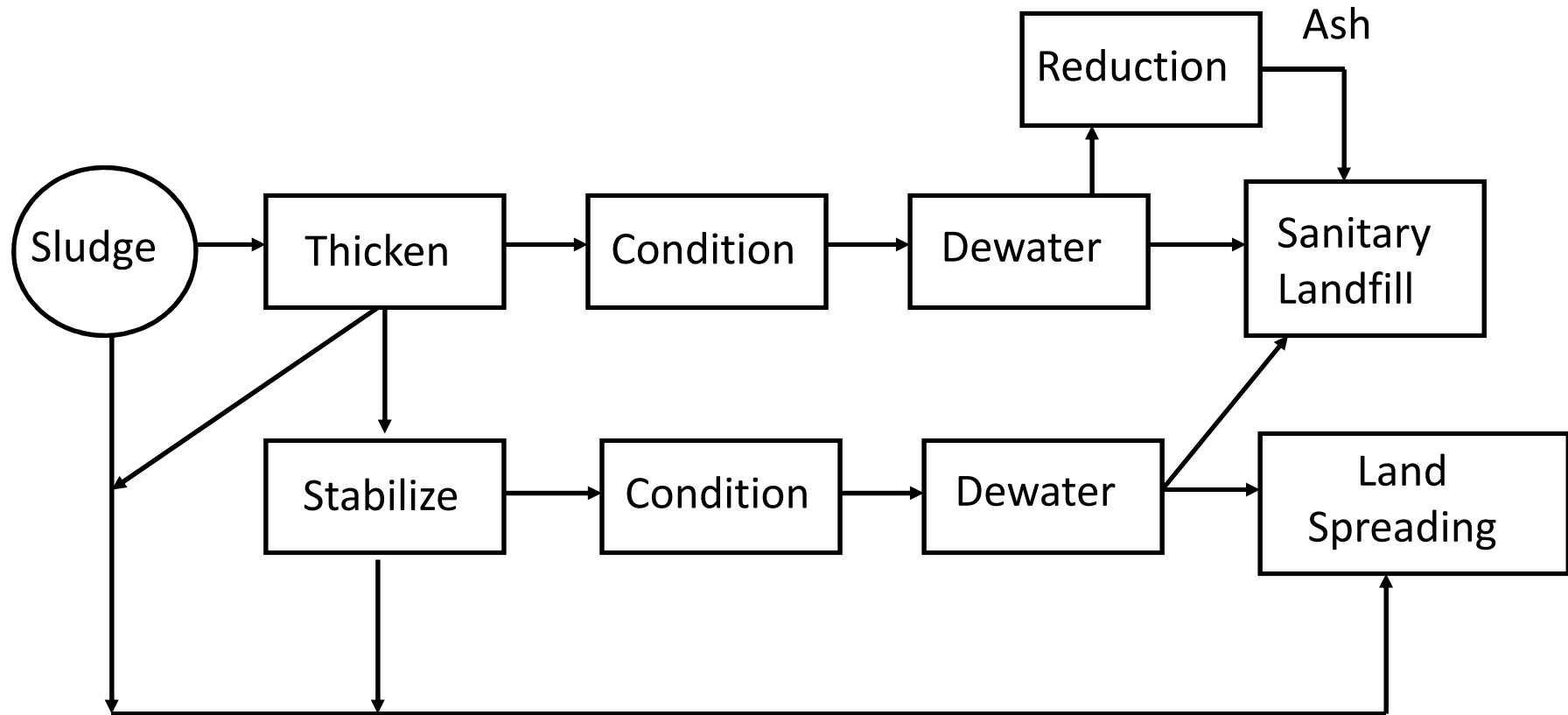
- Sources of solid waste from wastewater treatment
 - Bar racks & grit chamber
 - Inert, water can be easily removed
 - Generally not called as “sludge”
 - Truck directly to landfill after water removal
 - Primary and secondary treatment
 - Produces waste called “sludge”
 - High organic content → rapidly becomes anaerobic and putrefies
 - 3-8% solids for primary sludge & 0.5-2% solids for secondary sludge
 - Tertiary treatment: variable characteristics

Sludge treatment processes

- **Thickening:** separating as much as water possible from the raw sludge by gravity or flotation
- **Stabilization:** converting the organic solids to more inert forms
- **Conditioning:** treating the sludge with chemicals or heat so that the water can be readily separated
- **Dewatering:** separating water by vacuum, pressure, or drying
- **Reduction:** further reducing the solids and water when needed (ex: incineration)

Sludge treatment processes

- Organize the processes as needed



Sludge disposal

- **Land spreading:** can use nutrients and water in the sludge, but pathogen & heavy metal problem
- **Ocean disposal:** simple & easy, but not environmentally-friendly, now prohibited in Korea
- **Landfilling:** simple & easy, but takes a lot of landfill space
- **Composting:** use sludge as a valuable resource – but not well accepted by consumers

Wastewater as a resource

- A new paradigm: wastewater is not a WASTE, but a valuable RESOURCE
- Wastewater = water + nutrients + carbon (energy)
- Water reuse
 - Non-potable reuse: cooling water, irrigation, recreational use
 - Potable reuse: direct/indirect; can produce effluent with drinking water quality by reverse osmosis + UV disinfection
- Wastewater as a nutrient source
 - Irrigation of primary effluent
 - Use processed sludge as soil amendment
 - Precipitate nutrients to produce fertilizers

Wastewater as a resource

- Wastewater as an energy source
 - Wastewater treatment is a high energy process: accounts for 2-5% of the national energy consumption
 - Make the process “energy positive” → lots of energy savings!
 - Several ways to use energy in wastewater
 - CH₄ gas production from wastewater → heat / electricity generation
 - Electricity generation directly from wastewater (microbial fuel cells)
 - Using heat value of wastewater

Reading assignment

Textbook Ch 11 p. 538-571

Analyzing activated sludge process

Slide#13 solution)

$$S = \frac{K_s(1+k_d\theta_c)}{\theta_c(\mu_m-k_d)-1}$$

$$10.0 \text{ mg/L} = \frac{100 \text{ mg/L} \times (1+0.050 \text{ day}^{-1} \times \theta_c)}{\theta_c(2.5-0.050) \text{ day}^{-1}-1}$$

$$10.0 \text{ mg/L} \times 2.45 \text{ day}^{-1} \times \theta_c - 10 \text{ mg/L} = 100 \text{ mg/L} + 100 \text{ mg/L} \times 0.050 \text{ day}^{-1} \times \theta_c$$

$$19.5 \text{ mg/L} - \text{day} \times \theta_c = 110 \text{ mg/L}$$

$$\theta_c = 5.6 \text{ days}$$

Analyzing activated sludge process

Slide#14 solution)

$$X = \frac{\theta_c Y (S_0 - S)}{t_0 (1 + k_d \theta_c)}$$

$$t_0 = \frac{\theta_c Y (S_0 - S)}{X (1 + k_d \theta_c)} = \frac{5.6 \text{ days} \times 0.50 \times (84 - 10) \text{ mg/L}}{2000 \text{ mg/L} \times (1 + 0.050 \text{ day}^{-1} \times 5.6 \text{ days})} = 0.081 \text{ day}$$

$$t_0 = \frac{Q}{V}, \quad V = Qt_0 = 0.150 \text{ m}^3/\text{s} \times 86400 \text{ s/day} \times 0.081 \text{ day} = \mathbf{1050 \text{ m}^3}$$