CE 356: Fundamentals of Environmental Engineering

Activated Sludge Design

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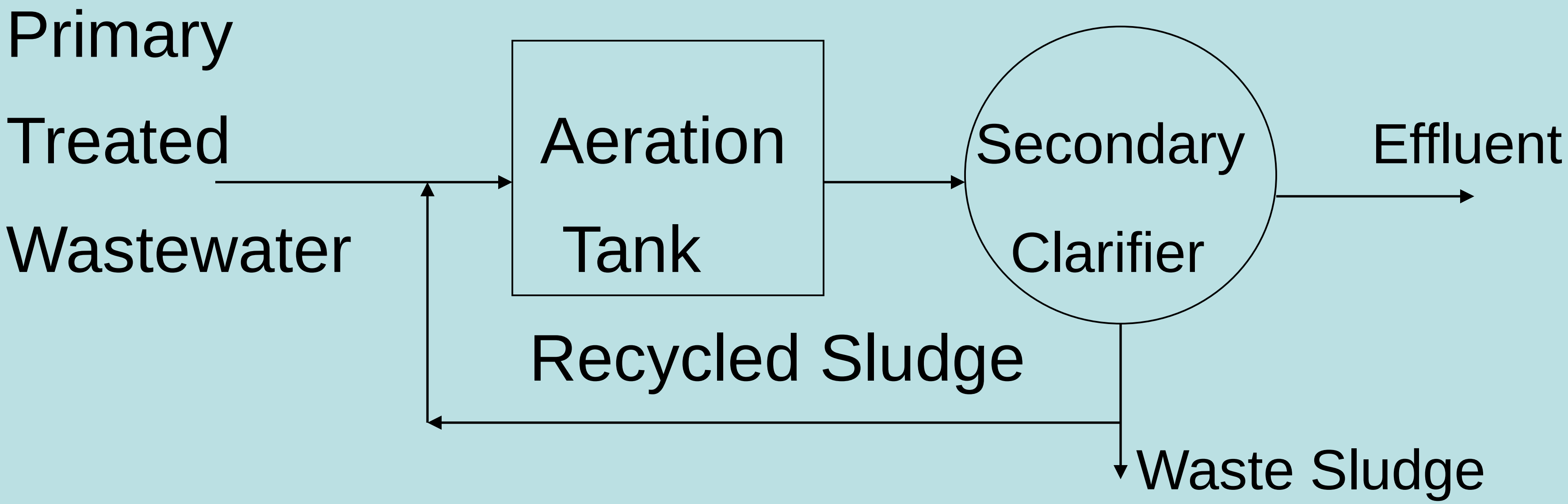
Activated Sludge

- Definition: A process in which wastewater continuously flows into an aerated tank in which a culture of suspended microorganisms biologically flocculate and metabolize colloidal and soluble organic material (BOD).
  - Primary organisms – bacteria, consume soluble and colloidal organics.
  - Secondary organisms – protozoa, consume suspended organics and dispersed bacteria.
  - Aeration provides:
    - Mixing – necessary to keep microorganisms in contact with the organics.
    - Oxygen – for metabolism.

Biological Principles



Aeration Tank – the content of the aeration tank is referred to as the **mixed liquor**. In the aeration tank, the microorganisms come in contact with the waste material. As the organic material is being decomposed synthesis of the microorganisms occurs.

Biological Principles

- Secondary Clarifier – mixed liquor is allowed to separate, the **supernatant** becomes the effluent.
- **Wasted Sludge** – sludge must be wasted to prevent excessive buildup of the microorganisms decreasing the F/M.
- **Recycled Sludge** – sludge is recycled to maintain the F/M ratio. If the sludge is not recycled the microorganism concentration will be diluted.

Design and Operational Parameter

- Food to Microorganism Ratio (F/M)

$$\frac{F}{M} = \frac{Total\ \ BOD\ \ applied\ \ in\ \ one\ \ day}{Total\ \ mass\ \ of\ \ sludge\ \ in\ \ aeration\ \ tank}$$

$$\frac{F}{M} = \frac{lbs\ \ BOD\ \ applied}{lbs\ \ sludge}$$

- Common range for F/M ratio = 0.05 to 0.6 day^{-1} (0.05 for extended aeration, 1.0 for pure oxygen)

F/M Calculation

Problem: Determine the F/M ratio for an activated sludge process operating under the following conditions: BOD = 200 mg/L, Q = 1MGD, t_d = 4 hrs, MLVSS = 2,550 mg/L

Example: Determine the F/M ratio for an activated sludge process operating under the following conditions: BOD = 200 mg/L, Q = 1MGD, t_d = 4 hrs (0.167day), MLVSS = 2,550 mg/L

M_{BOD} = 1 MGD x 200 mg/L x 8.34 lb/(MG-mg/L)

M_{BOD} = 1,668 lbs/day

V = Q x t_d = 1 MGD x 0.167 day = 0.167 MG

M_{sludge} = 0.167 MG x 2,550 mg/L x 8.34 lb/(MG-mg/L)

M_{sludge} = 3,552 lbs (in aeration tank)

F/M = 1,669 lbs/day / 3,552 lbs = 0.47 day^{-1}

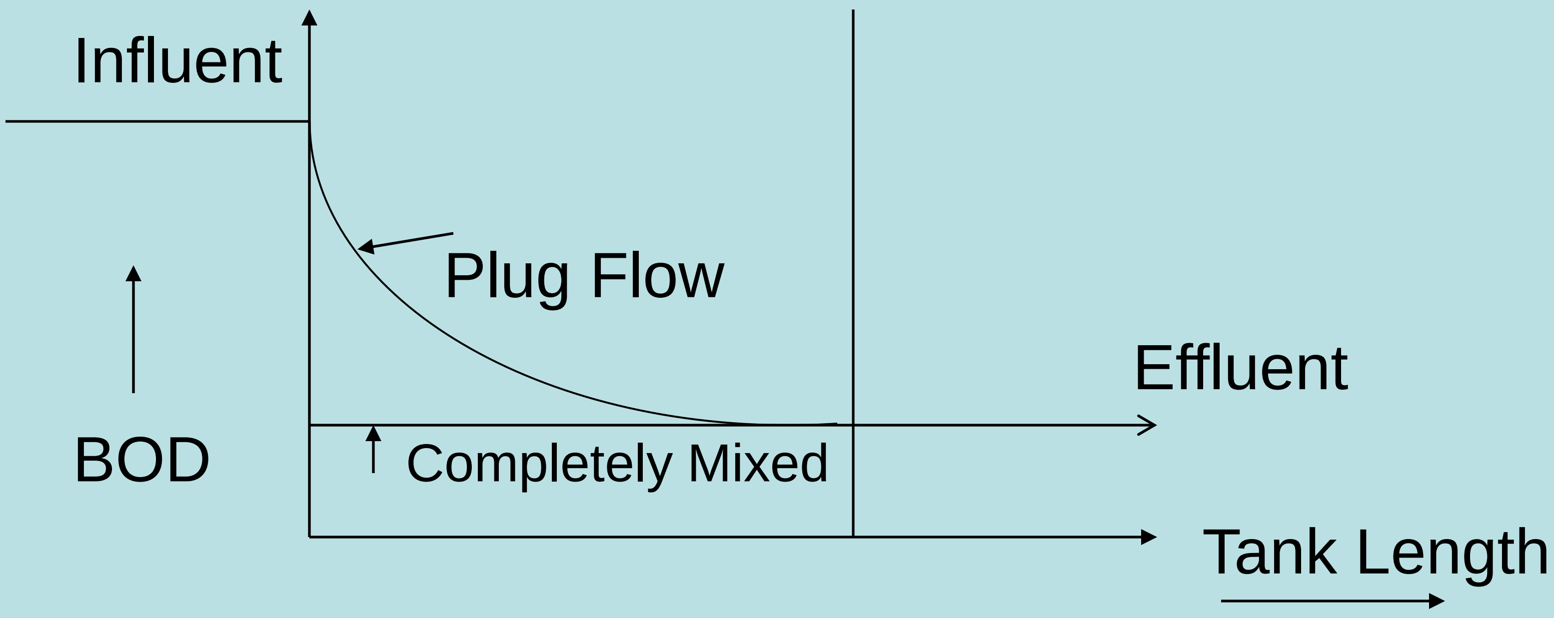
TABLE 15.4 *Design and Operational Parameters for Activated Sludge Treatment of Municipal Wastewaters*

TYPE OF PROCESS	MEAN CELL RESIDENCE TIME, θ_c, days	FOOD-TO-MICROBE RATIO	SPACE LOADING $\frac{\text{lb BOD}_5}{\text{day-1000 ft}^3}$	SPACE LOADING $\frac{\text{kg BOD}_5}{\text{day-m}^3}$	HYDRAULIC RETENTION TIME IN AERATION BASIN θ, hr	MIXED-LIQUOR SUSPENDED SOLIDS (MLSS), mg/ℓ	RECYCLE RATIO, R/Q	FLOW REGIME[a]	BOD REMOVAL EFFICIENCY, %
Conventional	5–15	0.2–0.4	20–40	0.3–0.6	4–8	1500–3000	0.25–1.0	PF, DPF	85–95
Tapered aeration	5–15	0.2–0.4	20–40	0.3–0.6	4–8	1500–3000	0.25–1.0	PF, DPF	85–95
Completely mixed	5–30	0.1–0.6	50–120	0.8–2.0	3–6	2500–4000	0.25–1.5	CM	85–95
Step aeration	5–15	0.2–0.4	40–60	0.6–1.0	3–5	2000–3500	0.25–0.75	PF, DPF	85–95
Modified aeration	0.2–0.5	1.5–5.0	75–150	1.2–2.4	1.5–3	200–500	0.05–0.15	PF, DPF	60–75
Contact stabilization	5–15	0.2–0.6	60–75	1.0–1.2			0.50–1.5		
Contact basin					0.5–1.0	1000–3000		PF, DPF	80–90
Stabilization basin					3–6	4000–10,000		PF, DPF	
High-rate aeration	5–10	0.4–1.5	100–1000	1.6–16	2–4	4000–10,000	1.0–5.0	CM	75–90
Extended aeration	20–30	0.05–0.15	10–25	0.16–0.4	18–36	3000–6000	0.75–1.50	PF, DPF	75–95
Pure oxygen	8–20	0.25–1.0	100–200	1.6–3.2	1–3	3000–8000	0.25–0.5	CM	85–95

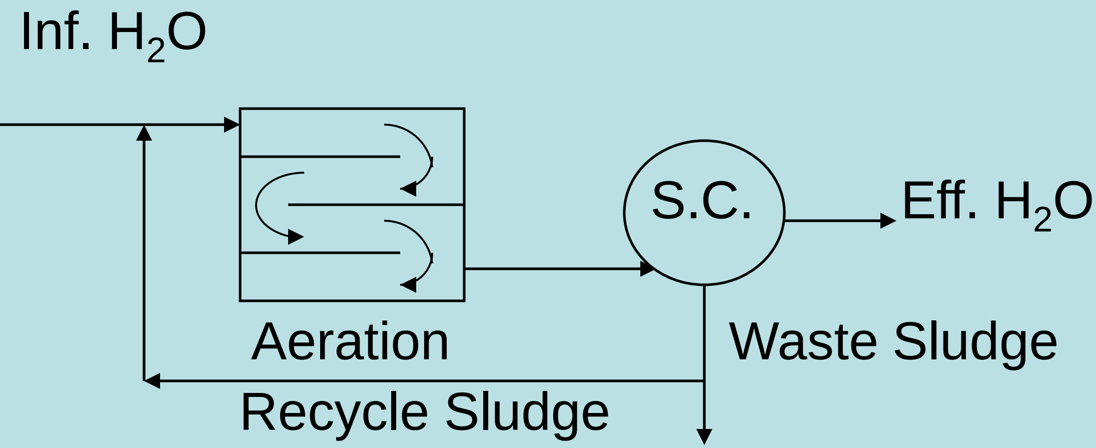
[a] PF = plug flow, DPF = dispersed plug flow, CM = completely mixed.

(from Reynolds/ Richards, 1996)

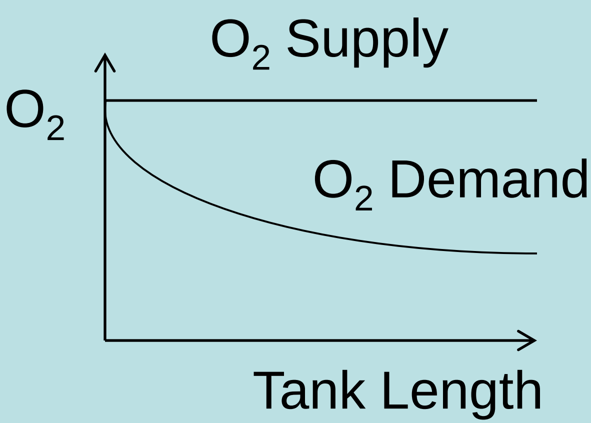
Completely Mixed vs Plug Flow



Conventional Treatment

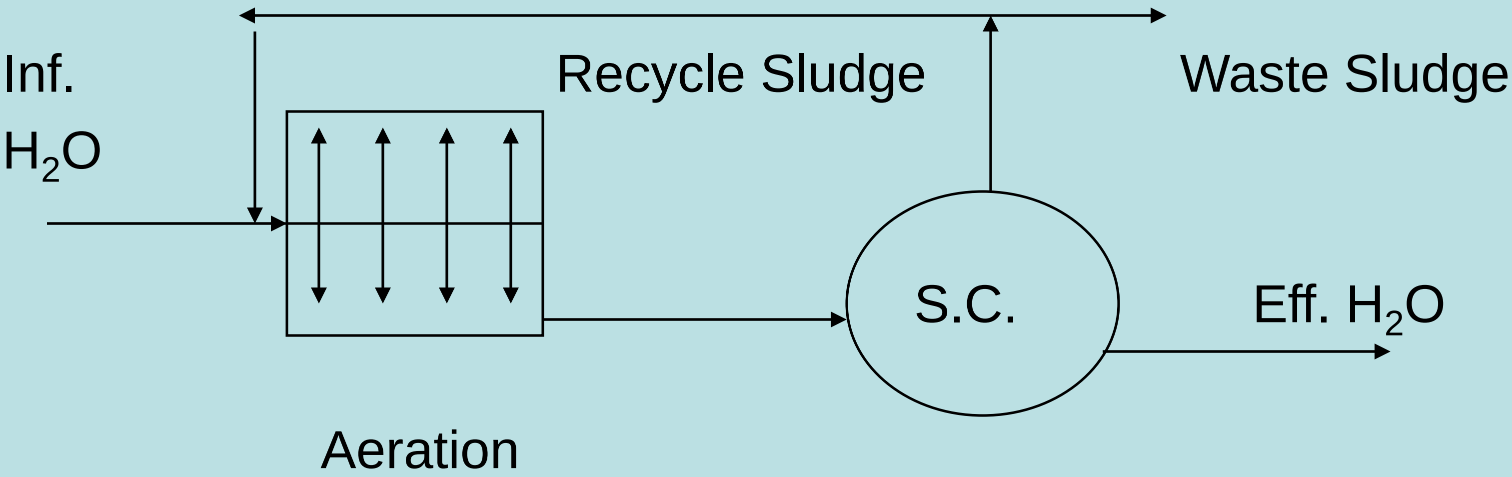


- F /M = 0.2 to 0.4
- MLSS = 1,500 to 3,000 mg/L
- td = 4 to 8 hrs
- F/M is decreasing across the length of the tank.

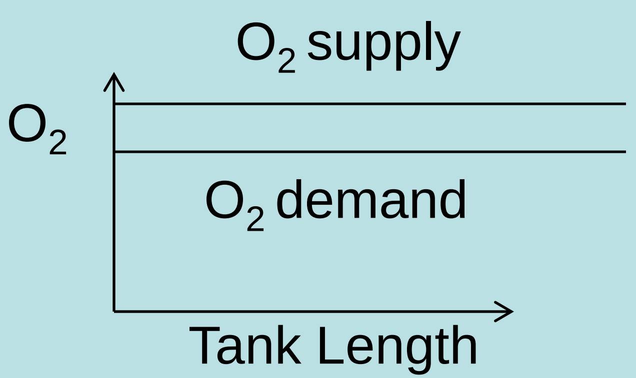


S.C.= secondary clarifier

Completely Mixed



- F/M = 0.2 to 0.6
- MLSS = 3,000 – 6,000 mg/L
- td = 3 – 5 hrs



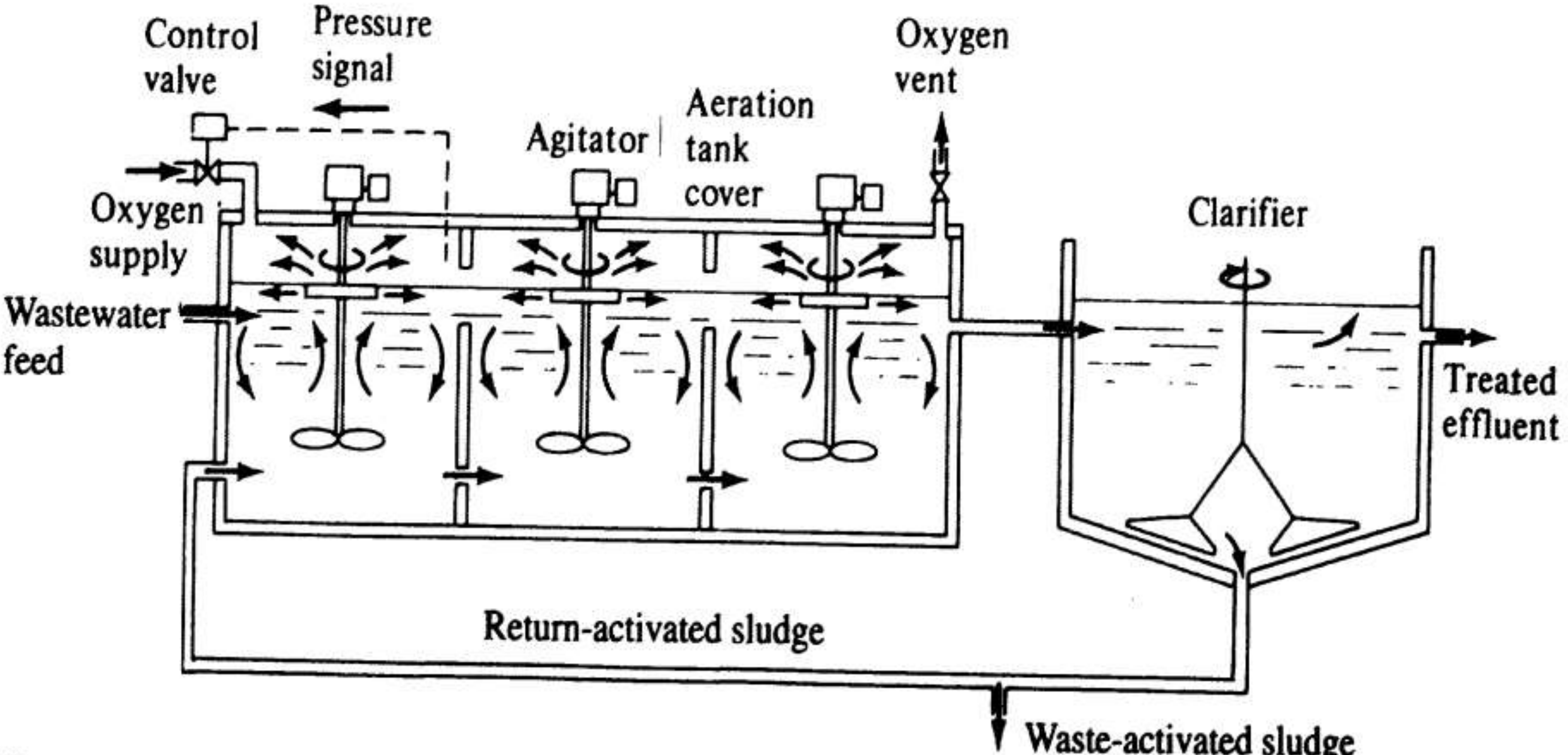


Figure 12.39 Schematic diagram of a high-purity-oxygen activated-sludge process with surface aerators in three stages. (Courtesy of UNOX System, Lotepro Corp.)

(from Viessman, Jr. and Hammer, 1998)

Field Data

- Aeration Tank Volume – 120,000 ft^3
- Influent Flow – 3.67 MGD
- Return Sludge Flow – 1.27 MGD
- Waste Sludge Flow – 18,900 gpd
- MLSS – 2,350 mg/L
- Sludge Underflow – 11,000 mg/L
- Influent BOD – 128 mg/L
- Effluent BOD – 22 mg/L
- Effluent SS – 26 mg/L

Evaluate:

- F/M Ratio, day^{-1}
- Volumetric BOD Loading, lb BOD/1,000 ft^3/day
- Sludge Age, days
- Aeration Detention Time, hr
- Return Sludge Rate, %
- BOD Efficiency, %
- Sludge Yield, lb SS/lb BOD Applied

Solution

- See pgs 576 – 577
- Example 12.9