CE 356: Fundamentals of Environmental Engineering

Microbiology and Activated Sludge Design

Ricardo B. Jacquez

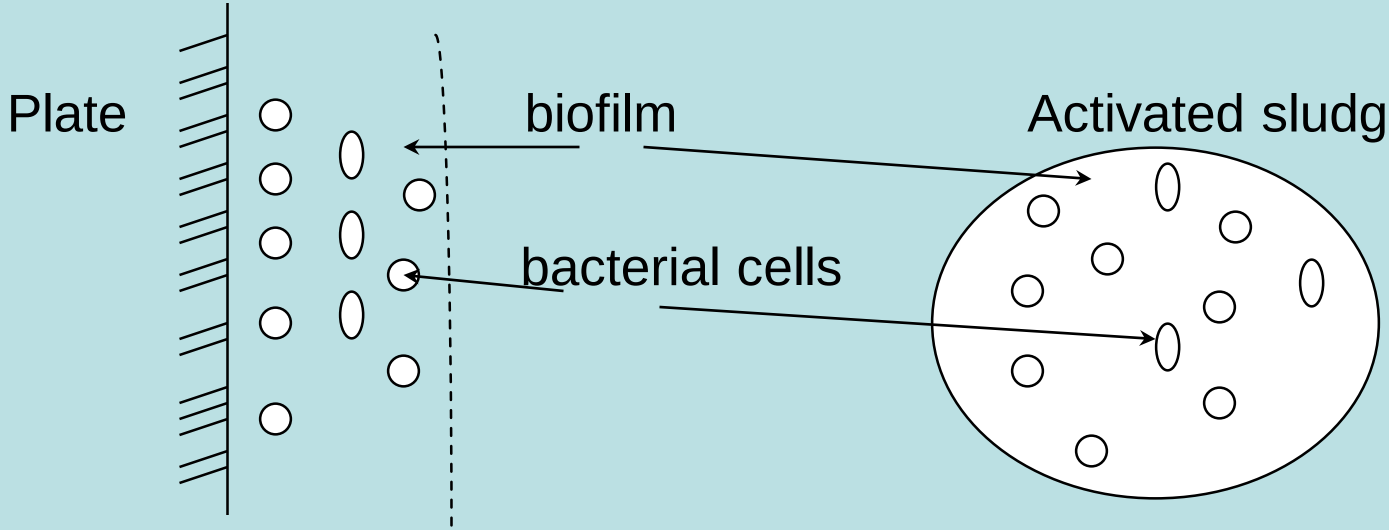
Professor, CAGE Department

New Mexico State University

Teaching Assistant: M. T. Myint

Significant Microorganisms

- Bacteria – single cell microorganisms that reproduce by binary fission.
- Fungi – yeasts and molds.
- Protozoa – Single cell animals
  - Bacteria consume soluble (dissolved) BOD (organic substrate) and are aggregated into biofilm and floc to which suspended solids attach.



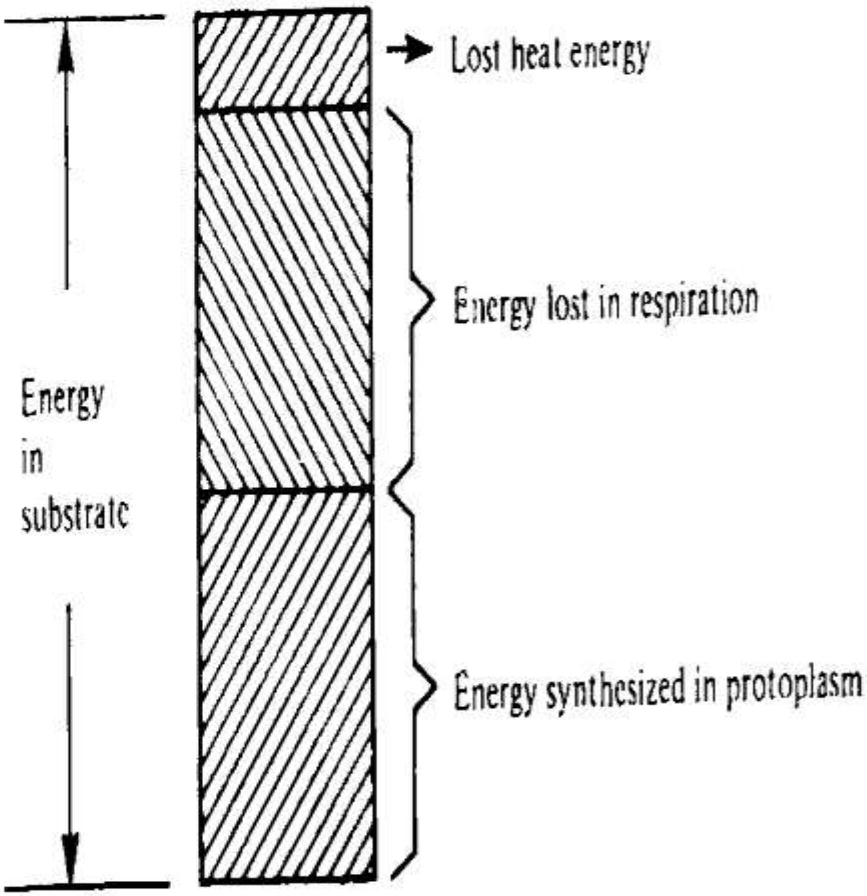


Figure 12.3 Energy conversions in aerobic metabolism.

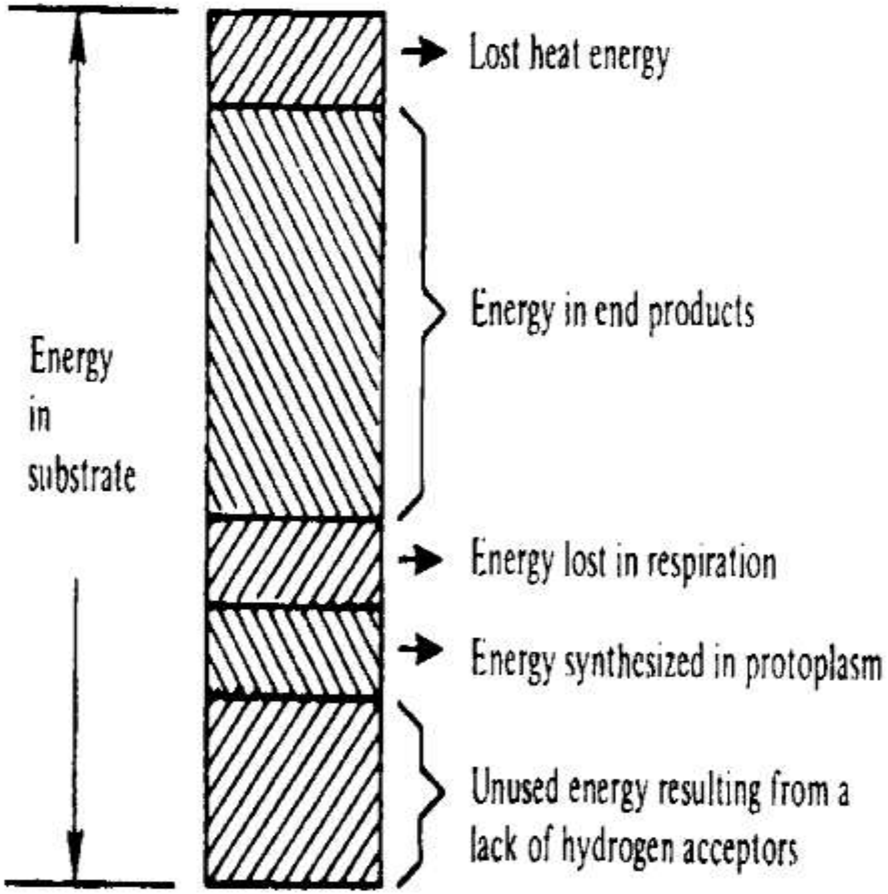


Figure 12.2 Energy conversions in anaerobic metabolism.

(from Viessman, Jr. and Hammer, 1998, pp. 521-522)

Biomass General Formulas

- $C_{60}H_{87}O_{23}N_{12}P$
- $C_5H_7O_2N_2$

C = 50%
O = 20%
N = 14%
H = 8%
P = 3%

Total = 95%

How does this information relate to the characteristics of wastewater?

Growth of Heterotrophic Cultures

- Cultures:

  - Continuous Growth: substrate (BOD) fed continuously

  - Batch Growth:
    - ➢ Single dose of substrate (BOD)
    - ➢ Single inoculation of biomass (mixed liquor suspended solids, MLSS)
    - ➢ Growth not limited by O_2, N, or P
    - ➢ Monitor change of substrate level (COD or BOD) and MLSS with time

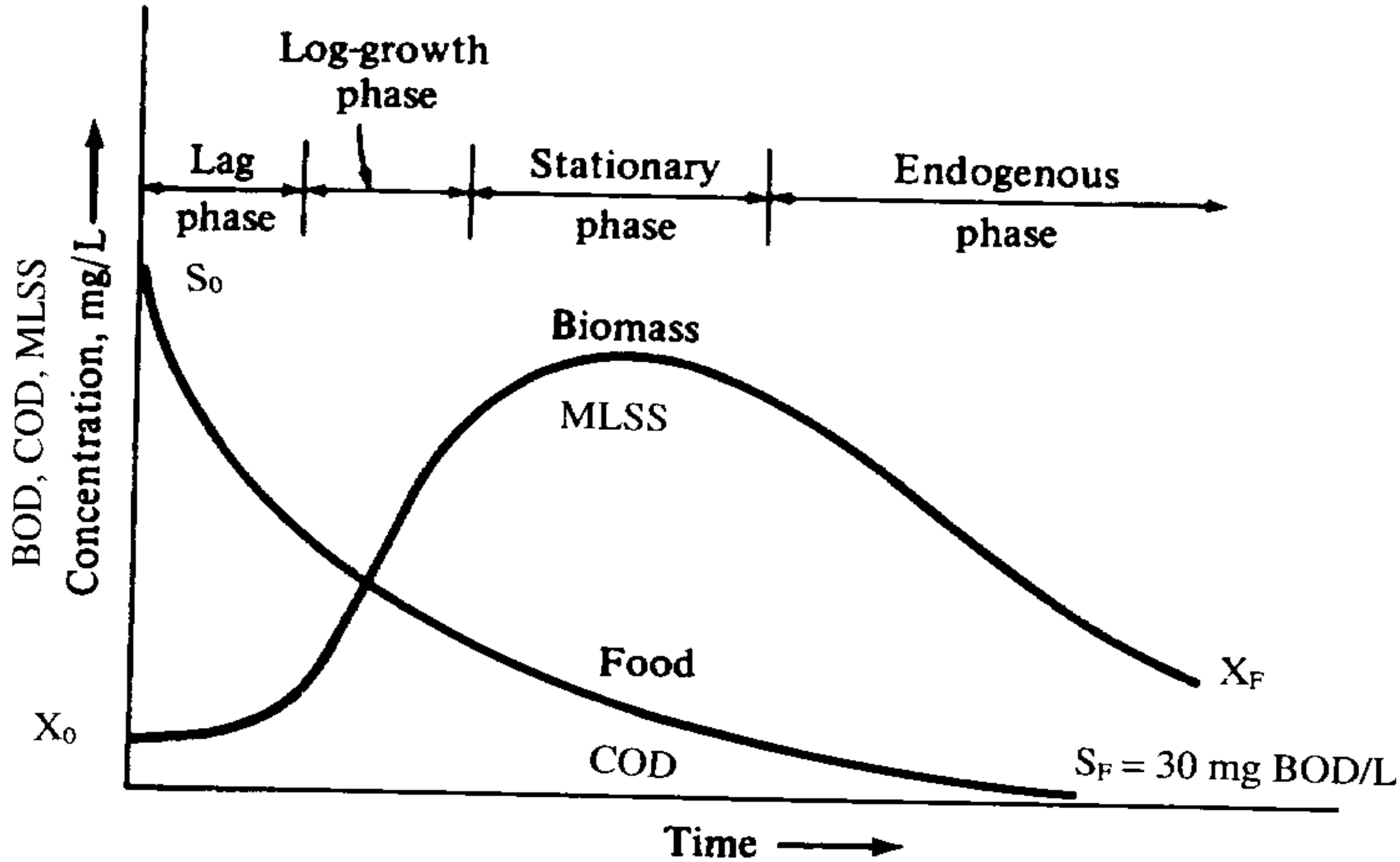


Figure 5-14 Biomass growth and food utilization.

$$X_F - X_O = Sludge\ Production$$

$$S_0 - S_F = Substrate\ removal\ (BOD\ reduction)$$

(from Peavy, Rowe, and Tchobanoglous, 1985, p.231)

Growth of Heterotrophic Cultures

- Lag phase: acclimation to new substrate, could be short lived
- Log Growth: active reproduction by binary fission
- Stationary: Growth = Death
- Endogenous: Death > Growth
- In lag and log growth phases sufficient substrate is available
- In stationary and endogenous phases substrate is limited

$$\frac{X_F - X_0}{S_0 - S_e} = Y = biomass\ \ yield = \frac{mg\ \ MLSS\ \ produced}{mg\ \ BOD\ or\ COD\ removed}$$

Design Equation: Identify, define (units), and describe the "design parameters" vs "typical known" conditions. Which parameter(s) does the design engineer control?

$$\frac{1}{\theta_c} = Y\frac{(S_0 - S_e)Q}{XV} - k_d$$

Sludge Age

- Sludge age is the length of time (days) the sludge (bacteria) is retained within the secondary treatment process.
  - Activated sludge: 10 days $Y_{net} = 0.4 - 0.6$
  - Trickling filter: 100 days $Y_{net} = 0.1 - 0.3$

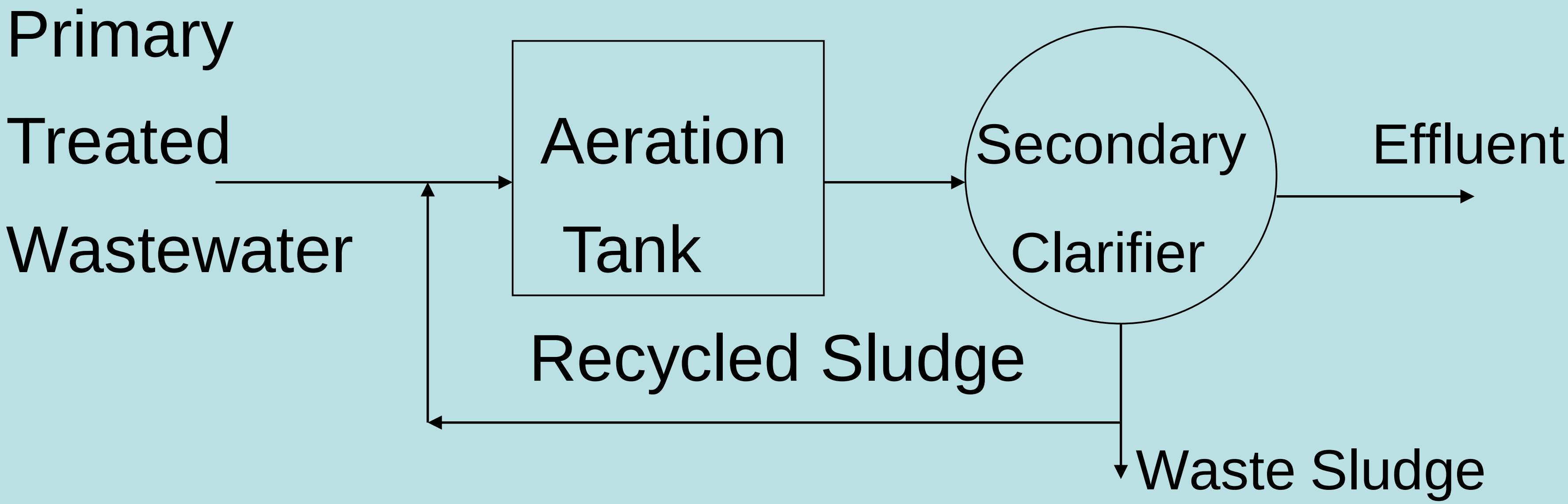
$$Y_{net} = \frac{lb\ sludge\ produced}{lb\ BOD\ removed}$$

- Trickling filters also produce a more dense (thicker) sludge:
  - TF = 1.5% solids
  - AS= 0.8% solids

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)

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}

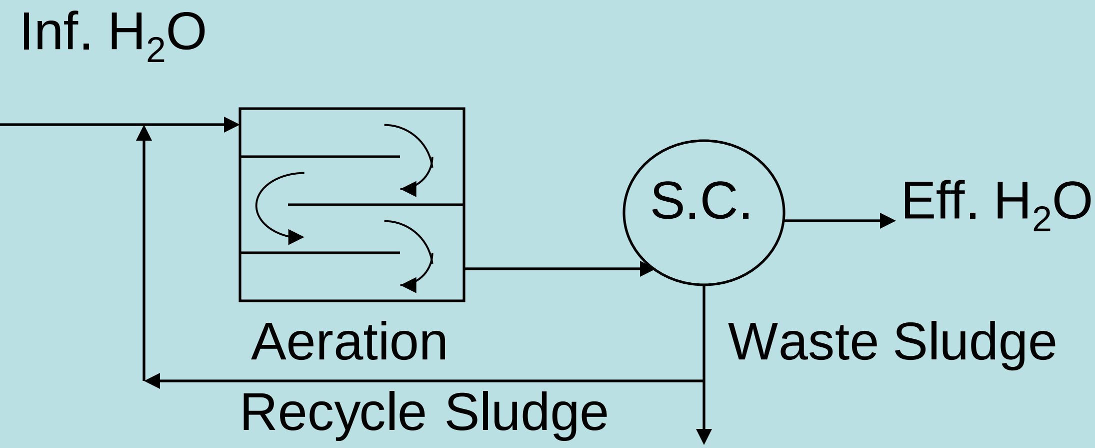
TABLE 15.4 *Design and Operational Parameters for Activated Sludge Treatment of Municipal Wastewaters*

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

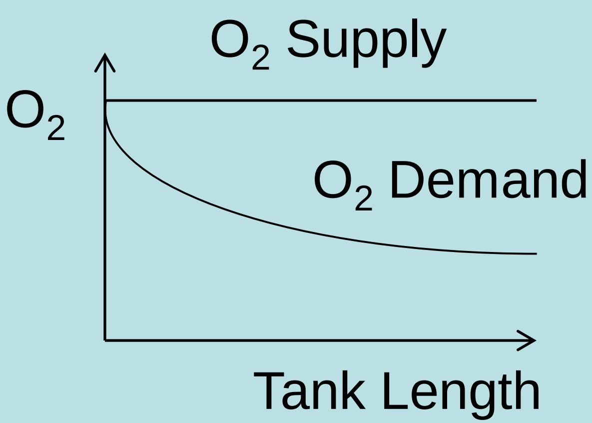
[a] PF = plug flow, DPF = dispersed plug flow, CM = completely mixed.

(from Reynolds/ Richards, 1996)

Conventional Treatment

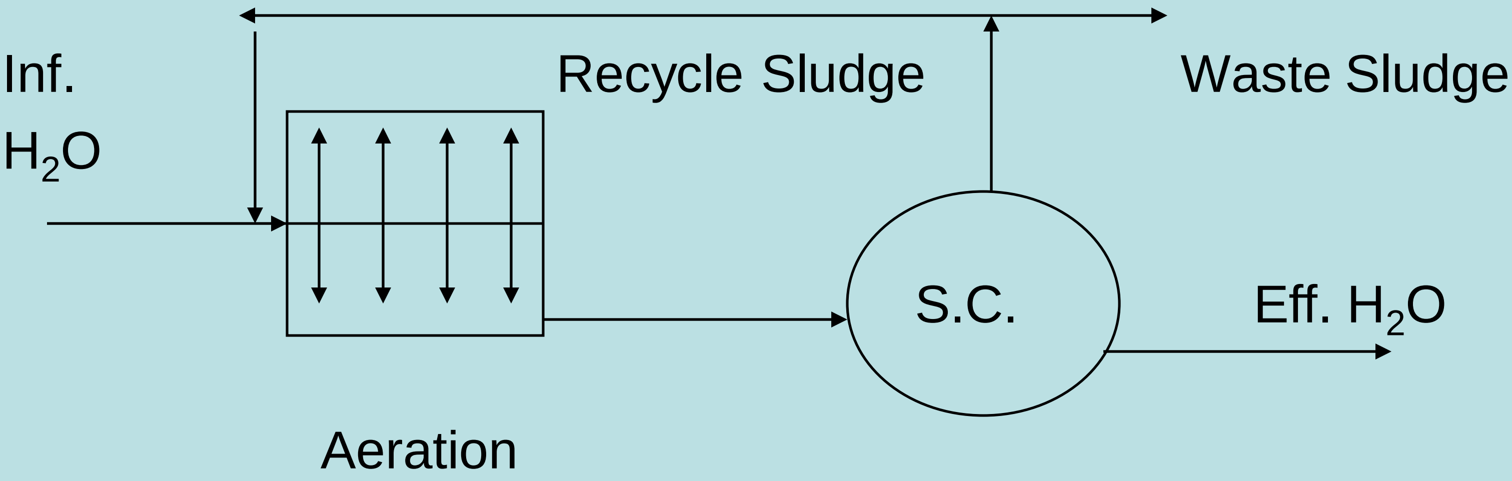


- F /M = 0.2 to 0.4
- MLSS = 1,500 to 3,000 mg/L
- td = 4 to 8 hrs
- F/M is decreasing across the length of the tank.

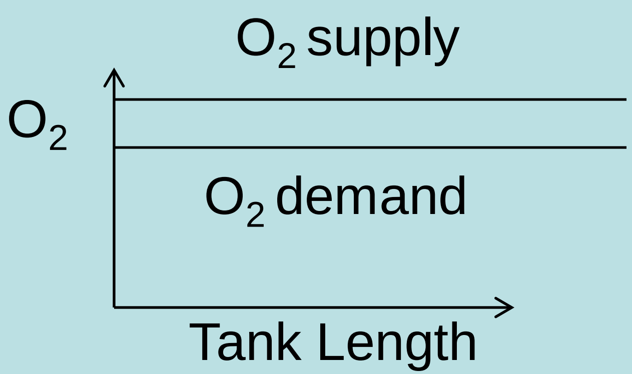


S.C.= secondary clarifier

Completely Mixed



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



Example for Review

- See pgs 576 – 577
- Example 12.9