Universiti Malaysia PAHANG
Engineering • Technology • Creativity

ENVIRONMENTAL ENGINEERING

Chapter 4 : Waste Water Treatment (Part 2)

Secondary Treatment

by
Siti Hajar Noor
Faculty of Chemical & Natural Resources Engineering
hajarnoor@ump.edu.my

Communitising Technology

Chapter Description

- Topic
  - Secondary treatment

- Expected Outcomes
  - Classify the treatment processes involved in wastewater treatment
  - Interpret the concept in wastewater treatment which consists of primary, secondary, sludge and advance treatment

- References

  - Peavy, H.S., Rowe, D.R. and Tchobanoglous, G., Environmental Engineering, McGraw Hill, 1985.
  - Mackenze, I.D., Introduction to Environmental Engineering, 4th Edition, Davis A. Cornell, Mc Graw Hill, 2008.
  - Sawyer, C.N. Chemistry for Environmental Engineerin. 4th Edition, McGraw Hill, 1994.
  - Martin, T.A. and David, W.H. Fundamental of Environmental Engineering. 2003.
  - Environmental Quality Act 1974 (Subsidiary Legislation), International Law Book, Service June 2002.

Contents

1. Primary Treatment

- Screening
- Comminuting
- Grit removal
- Flow measurement
- Primary sedimentation

2. Secondary Treatment

- Growth & food utilization
- Suspended culture systems
- Activated sludge
- Ponds & lagoons
- Attached culture systems
- Secondary clarification

PART 2

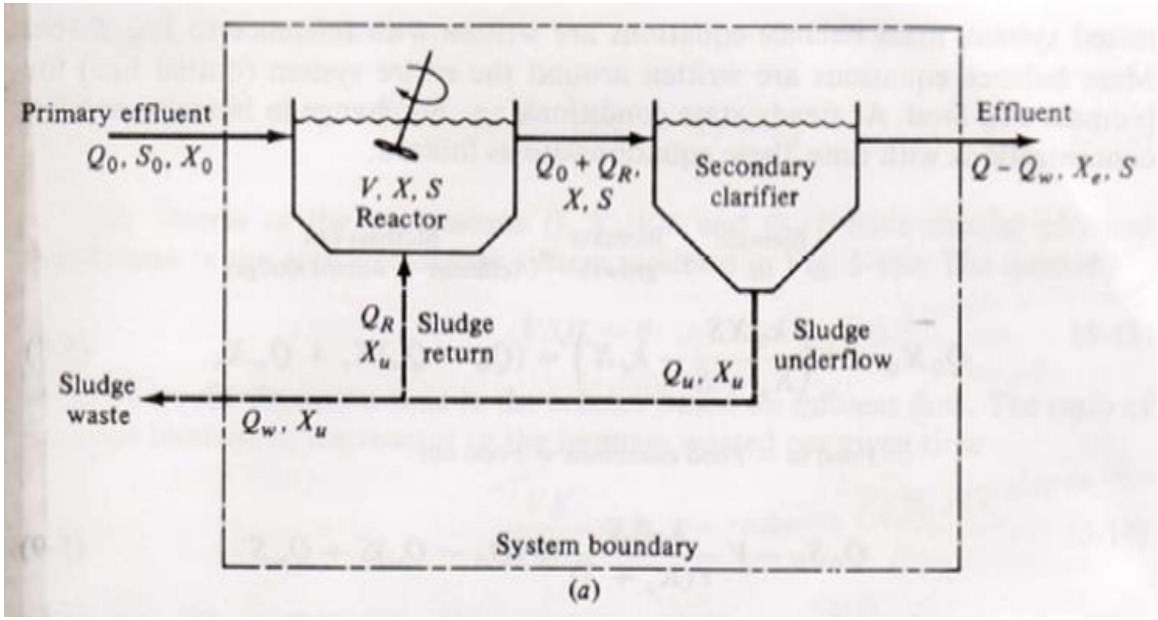
2- Suspended Culture System

- Suspended culture reactors may be of three basic types:
  a) Completely mixed without sludge recycle.
  b) Completely mixed with sludge recycle.
  c) Plug flow with sludge recycle.

3- Activated Sludge

- Activated sludge – a suspended-culture system that have been used since the early 1900s.
- Settled sludge containing living, or active, microorganisms is returned to the reactor to increase the available biomass and speed up the reactions.
- Process is aerobic, oxygen being supplied by dissolution from entrained air.

(a) Completely Mixed Reactors



At steady state,

- No change in biomass or food concentration with time

Biomass in + biomass growth = Biomass out (effluent + wasted sludge)

$$Q_0 X_0 + V\left(\frac{k_0 XS}{K_s + S}\right) = (Q_0 - Q_w)X_e + Q_w X_u$$

Food in – Food consumed = Food out

$$Q_0 S_0 - V\frac{k_0 S X}{Y(K_s + S)} = (Q_0 - Q_w)S + Q_w S$$

- Where Q_0, Q_w = influent & waste sludge flow rate
- X_0, X, X_e, X_u = biomass concentration in influent, reactor, effluent & clarifier under flow
- S_0, S = soluble food concentration (influent, reactor)
- V = volume
- k_s, k_0, k_d, Y = kinetic constant

- Ratio of total biomass in the reactor per biomass wasted per given time:

$$\frac{VX}{Q_w X_u} = \theta_c$$

- Mean cell residence time, θ_c :

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

- Mixed liquor suspended solids (MLSS), X:

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

- Shortening θ, increase the MLSS

- θ approaches the regeneration time for microorganisms, cells are washed out of the reactor before growth can occur

- X decreases and S approaches S_o, no treatment is occurring

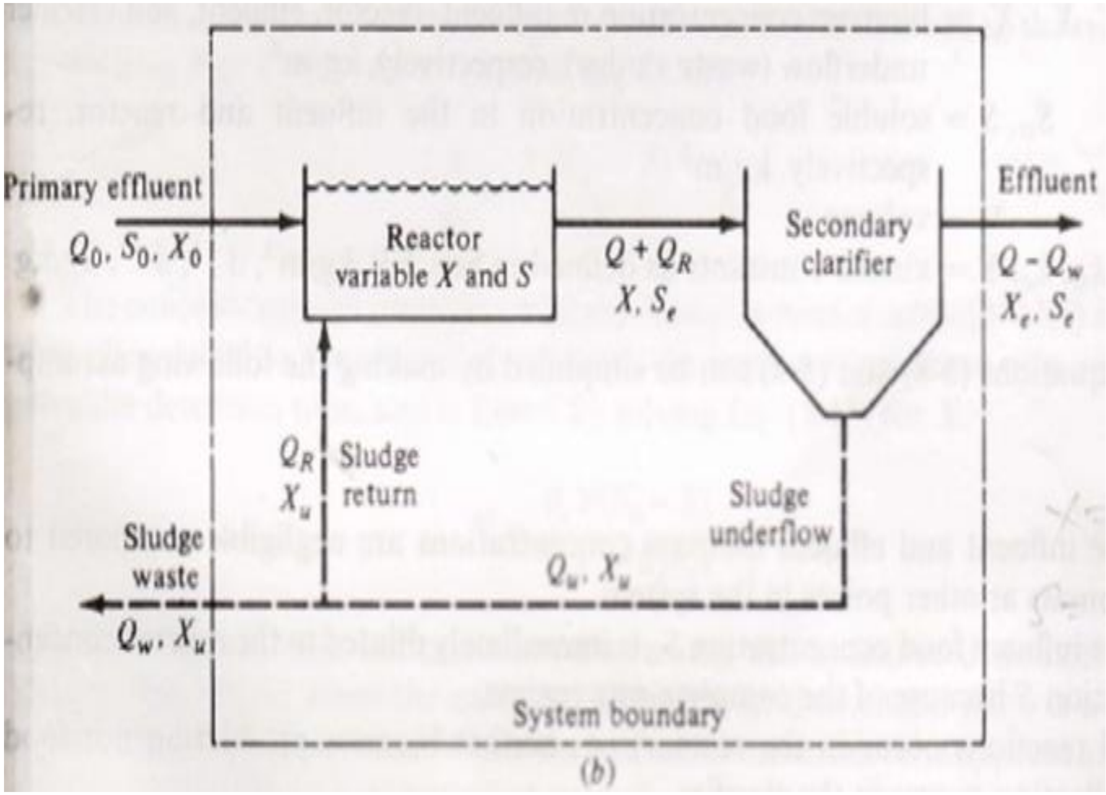
(b) Plug-Flow Reactors

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

$$r_s = \frac{k_0}{Y} \frac{S\overline{X}}{K_s + S}$$

Where X = average biomass concentration in the reactor (mg/L)

Only applicable when $\theta_c/\theta \geq 5$



$$\frac{1}{\theta_c} = \frac{k_0(S_0 - S)}{(S_0 - S) + (1-\alpha)(K_s \ln S_i / S)} - k_d$$

Where

α = recycle factor, Q/Qr

Si= concentration of substrate after mixing with recycled sludge, mg/L.

$$S_i = \frac{S_0 + \alpha S}{1 + \alpha}$$

(c) Design considerations

- Design variable
  - Volumetric loading rates, V_L
  - Food to mass ratios, F/M
  - Mean cell residence time, θ_c
- Complete mixed reactors – wide fluctuations of flow rate occur.
- Plug flow reactor – produce more mature sludge + excellent settling char.

$$V_L = \frac{QS_0}{V}$$

- V_L = mass of BOD in the influent / volume of the reactor, kg BOD/m^3.d

$$F/M = \frac{Q(S_0 - S)}{VX}$$

- F/M is the mass of BOD removed / biomass in the reactor (MLSS), kg BOD/kg MLSS.d

F/M parameter

- Low F/M (low rate of wasting)
  - Starved organisms
  - More complete degradation
  - Larger, more costly aeration tanks
  - More O_2 required
  - Higher power costs (to supply O_2)
  - Less sludge to handle
- High F/M (high rate of wasting)
  - Organisms are saturated with food
  - Low treatment efficiency

(d) Aeration of activated sludge

- Air diffusers – inject compressed air into the biological reactor.
- Mechanical aerators – mechanical mixers to stir the contents violently enough to entrain and distribute air through the liquid.

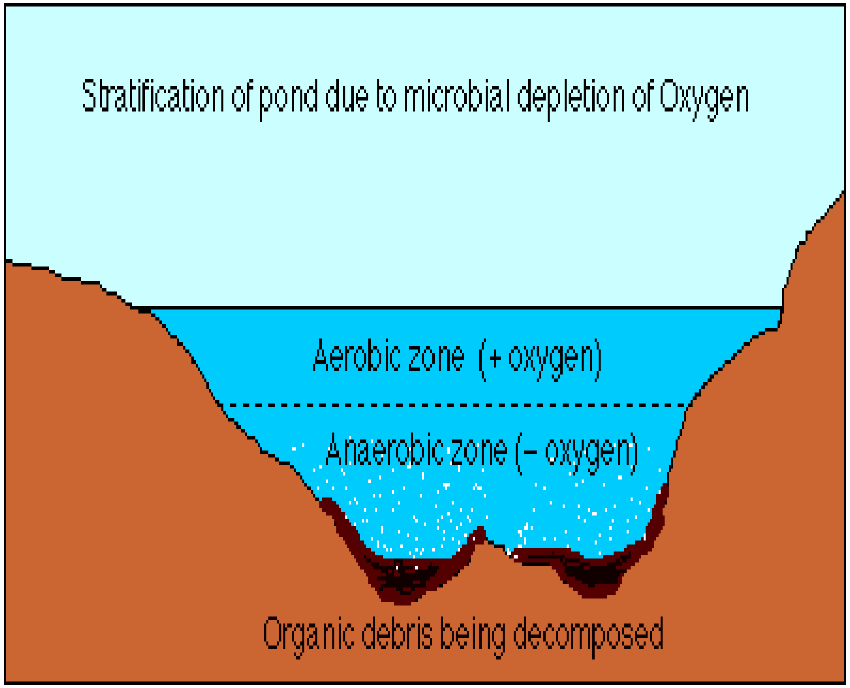
4- Ponds & Lagoons

- **Oxidation Ponds:** an open, flow through a large basin of controlled shape specially design and constructed to treat sewage and bio-degradable industrial waste by natural processes involving bacteria and algae.
- Oxygen is provided by diffusion from the air and photosynthesis.
- **Lagoons:** oxygen is provided by artificial aeration (*e.g.* mechanical aerators).

Ponds & Lagoon System biology

- **Anaerobic zone** – at the bottom, anaerobic bacteria, produce organic acids & gases as soluble food for aerobic zone

- **Aerobic zone** – biological solid produced settle to the bottom, providing food for anaerobic bacteria

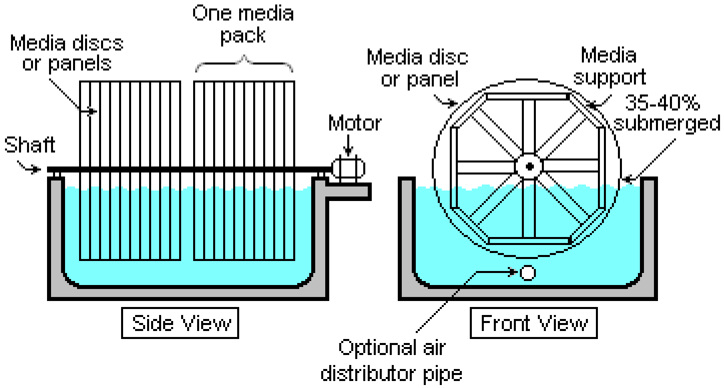


- Facultative zone – organism

Source:https://upload.wikimedia.org/wikipedia/commons/a/a9/Benfleet_Sewage_Treatment_Plant%2C_Filter_Bed_-_geograph.org.uk_-_1450096.jpg

5- Attached Culture System

1. Trickling filter – randomly packed solid medium



2. Bio-tower – advent of modular synthetic media of high porosity and low weight enables a vertical arrangement of medium several meters high

3 (RBC) – rotating disks partially submerged in wastewater

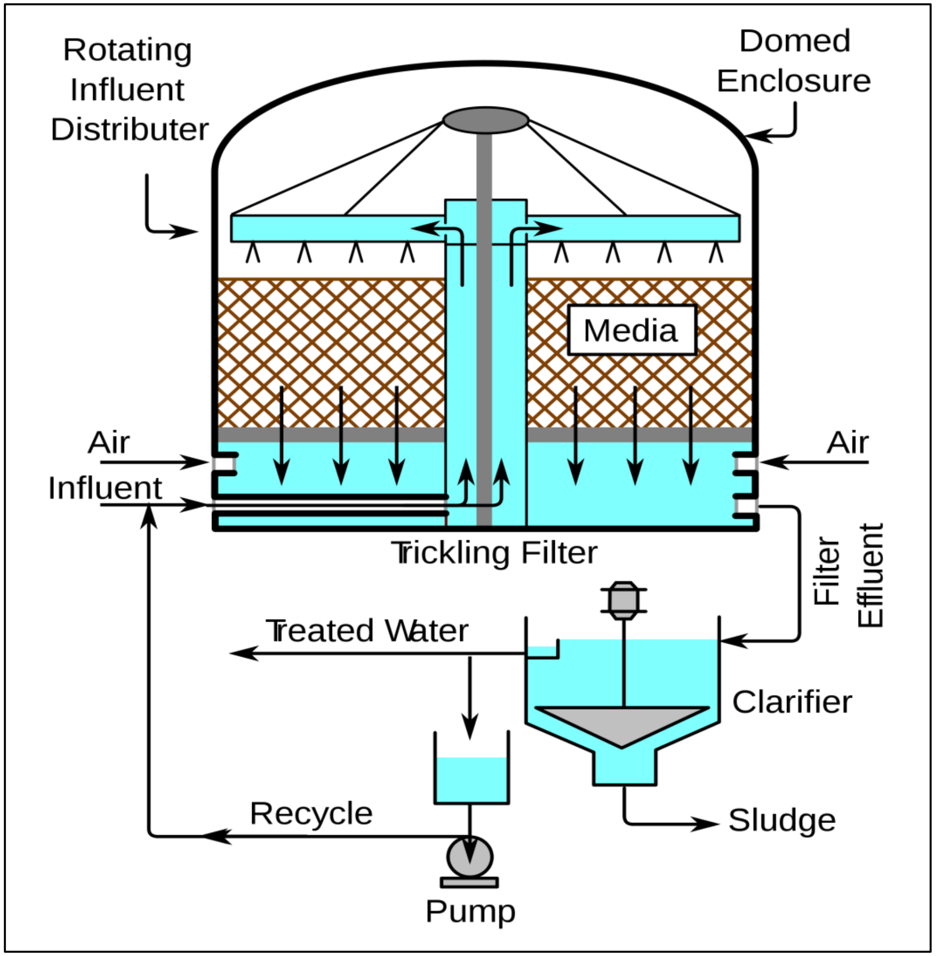
5- Attached Culture System

(a) Attached-culture system biology

- Solid medium
- Biofilm – organisms attach to medium, grow into dense films.
- Food for organisms – dissolved organics, suspended particles, colloids, oxygen.
- Films grow thicker, create anaerobic site, attachment mechanisms weakened, biofilm washed away from medium (sloughing).

(b) Trickling filters

- Rotating distribution arm sprays primary effluent over circular bed of rock or other coarse media.
- Air circulates in pores between rocks.
- 'Biofilm' develops on rocks and microorganisms degrade waste materials as they flow past.
- Organisms slough off in clumps when film gets too thick.



Source:https://upload.wikimedia.org/wikipedia/commons/thumb/e/e0/Trickle_Filter.svg/2000px-Trickle_Filter.svg.png

Trickling filters

- Not a true filtering or sieving process.
- Material only provides surface on which bacteria to grow.
- Can use plastic media:
  - Lighter – can get deeper beds (up to 12 m).
  - Reduced space requirement.
  - Larger surface area for growth.
  - Greater void ratios (better air flow).
  - Less prone to plugging by accumulating slime.

Source:https://upload.wikimedia.org/wikipedia/commons/a/a9/Benfleet_Sewage_Treatment_Plant%2C_Filter_Bed_-_geograph.org.uk_-_1450096.jpg

(c) Bio towers

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

- Essentially deep trickling filters
- Lightweight, flat polyvinyl chloride sheets together.
- Can overcome the head loss problem.
- Operated in similar to high-rate trickling filters.
- Advantages:

  a) Porosity and nature of the packing eliminate plugging problems.

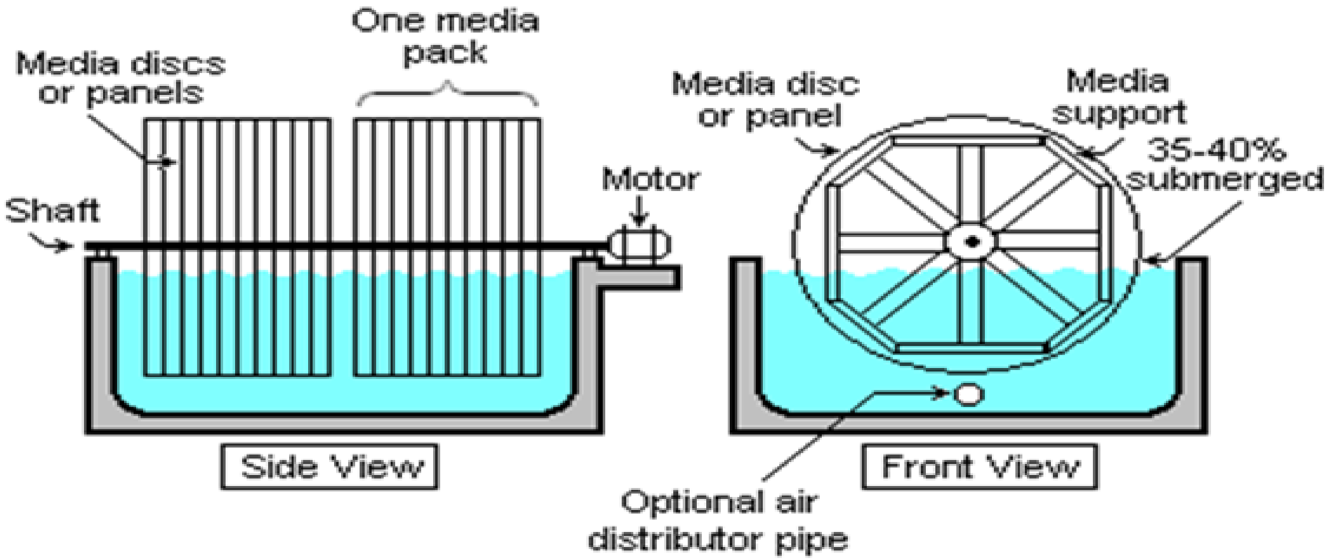
  b) Increased ventilation minimize odor problems.

  c) Economical housing.

(d) Rotating Biological Contactors

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

- Called RBCs
- Consists of series of closely spaced discs mounted on a horizontal shaft and rotated while ~40% of each disc is submerged in wastewater.
- Discs : light weight plastic.
- Slime is 1-3 mm in thickness on disc.



Source:https://upload.wikimedia.org/wikipedia/commons/3/3c/Rotating_Biological_Contactor.png

6- Secondary clarification

- Activated sludge and attached-culture systems, solids are removed in secondary clarifiers.
- Ponds and lagoons, removal accomplished by settling within the reactor
- Design of secondary clarifiers for attached-culture systems similar to that for primary clarifiers

Source:https://upload.wikimedia.org/wikipedia/commons/1/18/Siloam_Springs_WWTP_003.jpg

Activated-sludge clarifiers

- Two objectives:
  - Must produce an effluent sufficiently clarified to meet discharge standards.
  - Must concentrate the biological solids to minimize the quantity of sludge that must be handled.

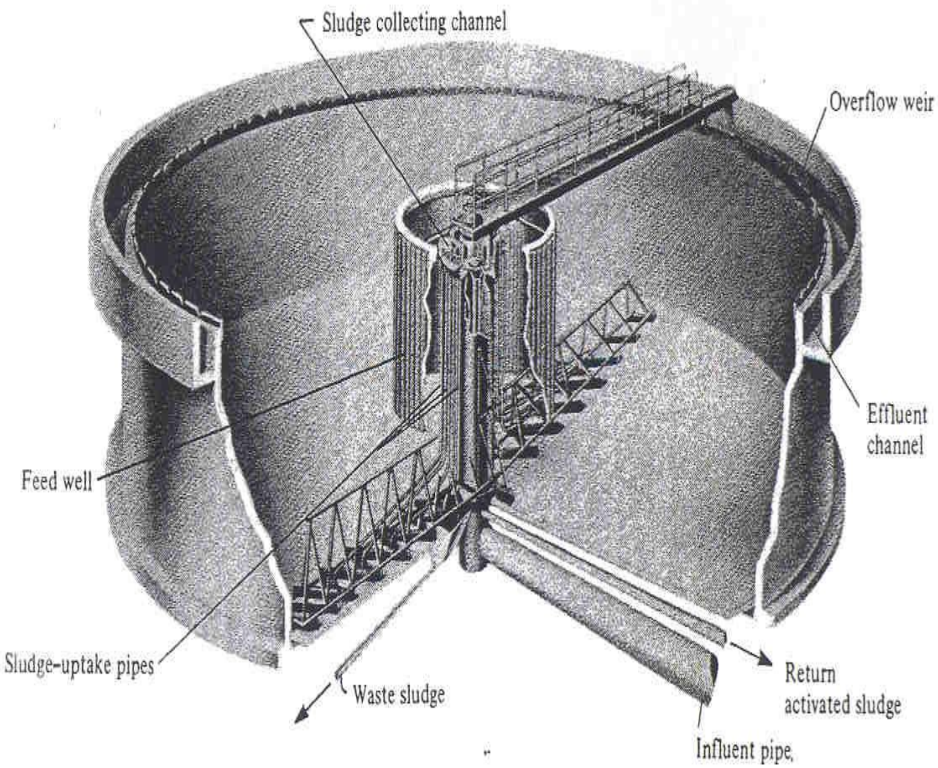


Figure 10.26 Final clarifier for an activated-sludge secondary with rapid-sludge-removal apparatus. (Courtesy of Dorr-Oliver, Inc.)

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

To be continued….

Author Information

Credit to the author: Dr Norhanimah Hamidi