Practical applications of biological treatment

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- Major operational issue: settling problems

- Various reactor configurations & operational schemes used for secondary treatment
  - Suspended growth processes for BOD removal & nitrification
  - Suspended growth processes for enhanced N & P removal
  - Attached growth processes
  - Hybrid (attached+suspended) processes

Secondary clarifier settling problems

- In practice, bsCOD removal efficiency at the aeration tank is often not a significant problem
- Failure to meet BOD/COD discharge limit much more often occurs by poor settling
  - (Of course) VSS in the effluent contributes to effluent BOD/COD!
  - May also exceed the SS discharge limit
- Types of settling problems
  - Bulking sludge
  - Nocardioform foam
  - Rising sludge

Bulking sludge

- Sludge blanket not stable; large quantities of MLSS carried along with the clarifier effluent
- Two principal types of sludge bulking
  - **Filamentous bulking**
    - Growth of filamentous organisms
    - Bacteria form filaments of single-cell organisms that attach end-to-end, and the filaments protrude out of the sludge floc
    - Filamentous bacteria are competitive at low DO, low organic conc., low nutrient conc. → need control of these variables!
  - **Viscous bulking**
    - Production of excessive amount of extracellular biopolymer
    - Results in a sludge with a slimy, jellylike consistency
    - Biopolymers are hydrophilic → contains significant amount of water in the floc → low density, poor compaction
    - Found at nutrient-limited systems and at a very high F/M ratio

Nocardioform foam

- "Nocardioform" bacteria have hydrophobic cell surfaces and attach to air bubbles, causing foaming
- Thick foam (0.5~1 m) of brown color forms
- Can occur in diffused aeration systems and also in anaerobic treatment systems
- Major solutions
  - Avoid trapping foam in the aeration tank effluent
  - Surface wasting of activated sludge
  - Avoid the recycle of skimmings

Rising sludge

- Rising of sludge having relatively good settling properties due to gas formation
- Gas commonly produced: N_2
- Gas bubble attaches to the sludge and increases buoyant force
- Solutions
  - Increasing the return activated sludge withdrawal rate from the clarifier (less residence time of sludge in the clarifier)
  - Temporally decreasing the rate of flow of aeration liquor into the clarifier
  - Increasing the speed of the sludge collecting mechanism
  - Decreasing the SRT (prevent nitrification) or add an anoxic reactor (complete nitrification-denitrification)

Suspended growth processes for BOD removal & nitrification

- Conventional activated sludge process
  - Plug flow
  - Complete-mix

- Varieties of activated sludge process
  - Sequential batch reactor
  - Step feed
  - Contact stabilization
  - Oxidation ditch
  - Membrane bioreactor

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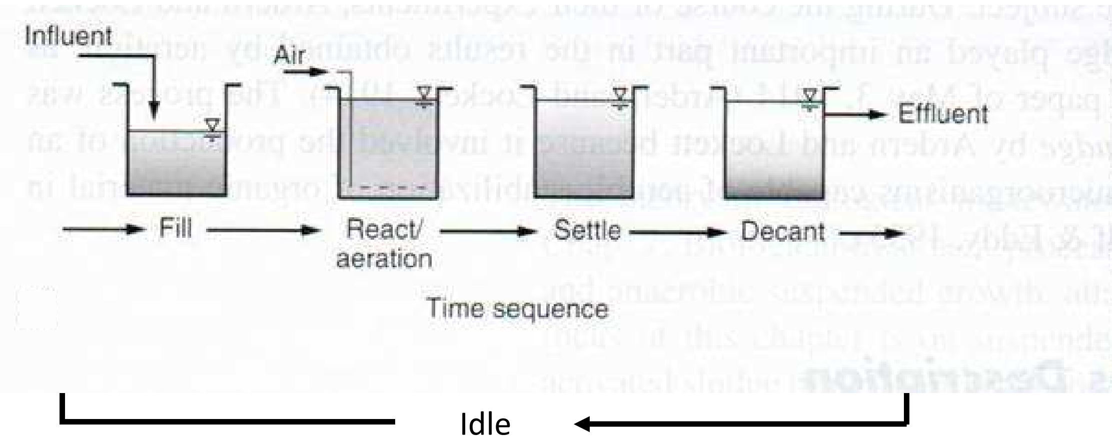
Sequential batch reactor

- Fill-and-draw system, no separate sedimentation tank
- Five stages: Fill – React – Settle – Decant - Idle
- Usually for small communities and industry with intermittent flows
- Increased applications in larger cities these days



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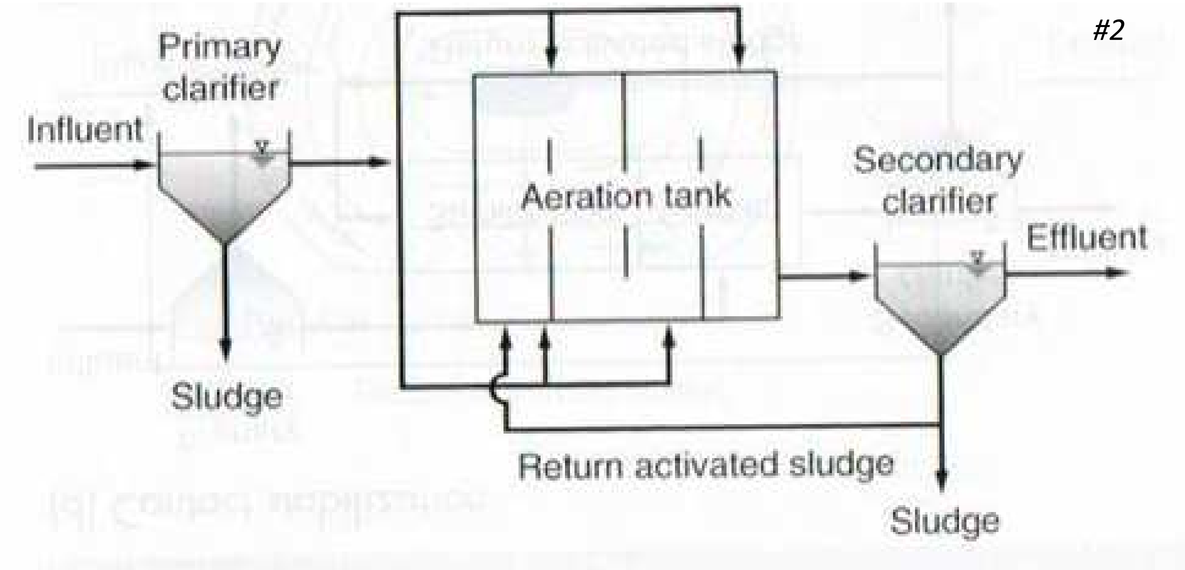
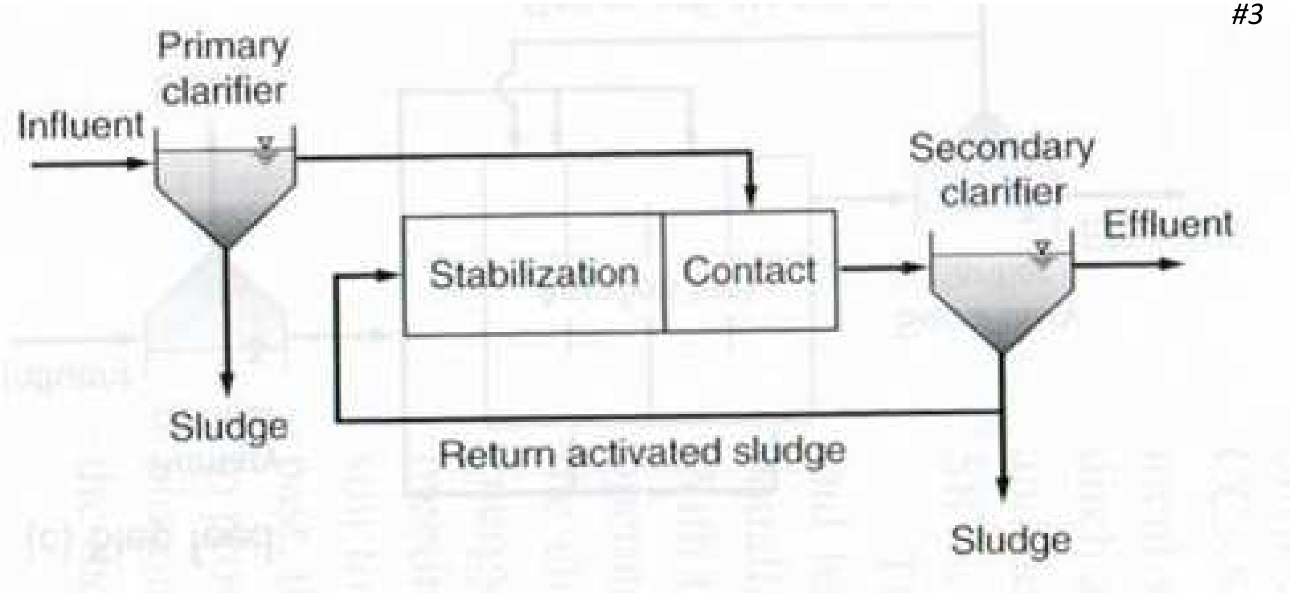
Step feed



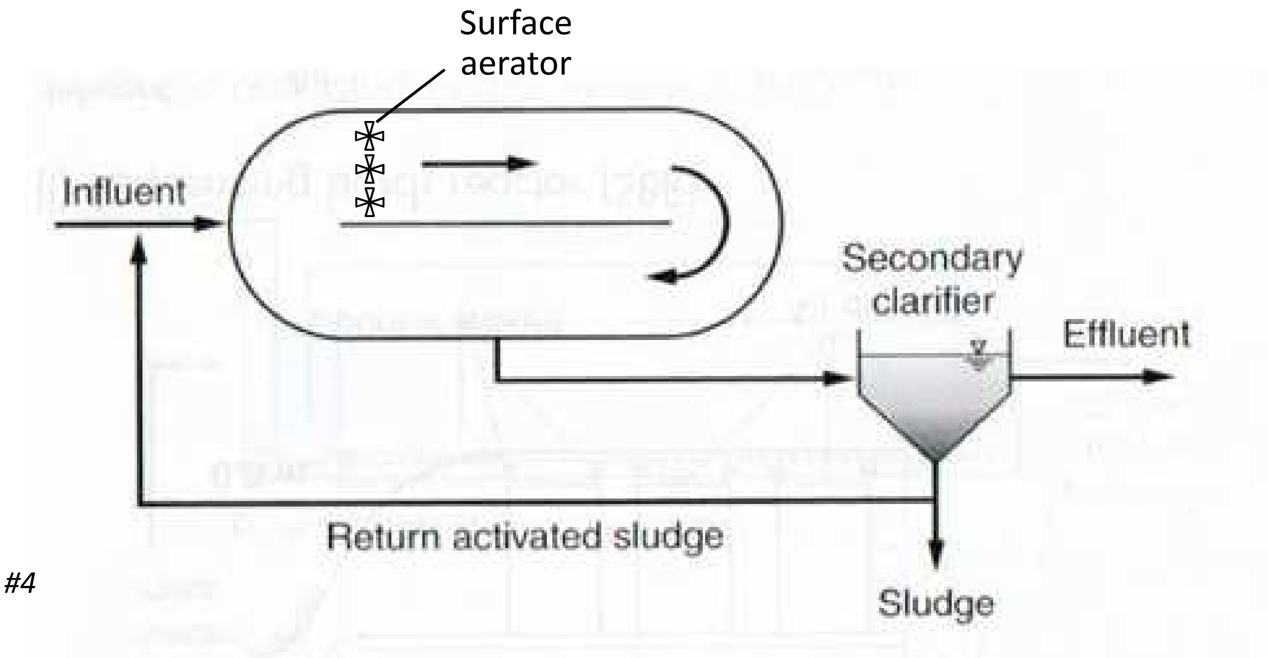
- Modification of conventional plug-flow type activated sludge process
- Primary effluent is introduced at 3-4 feed points in the aeration tank
- Advantages (compared to plug-flow with single point of inflow)
  - Lowered peak oxygen demand: oxygen is consumed more evenly throughout the tank
  - Flexibility of operation: feed apportionment can be changed to suit operating conditions
  - Can achieve higher SRT

Contact stabilization



- Two separate compartments: contact zone (HRT 30-60 min) & stabilization zone (HRT 1-2 hr)
  - Contact zone: HRT 0.5-1 hr, low-moderate MLSS concentration, bsCOD removal
  - Stabilization zone: HRT 1-2 hr, very high MLSS concentration, particulate COD removal
- Advantage: Less aeration requirement than conventional activated sludge process

Oxidation ditch



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- A racetrack-shaped channel equipped with mechanical aeration devices
- Generally pretreated wastewater is introduced (skips primary clarifier)
- Mixing is achieved by surface aeration + channel flow
- Relatively long HRT
- Denitrification may occur far downstream from the aeration zone

Membrane bioreactor (MBR)

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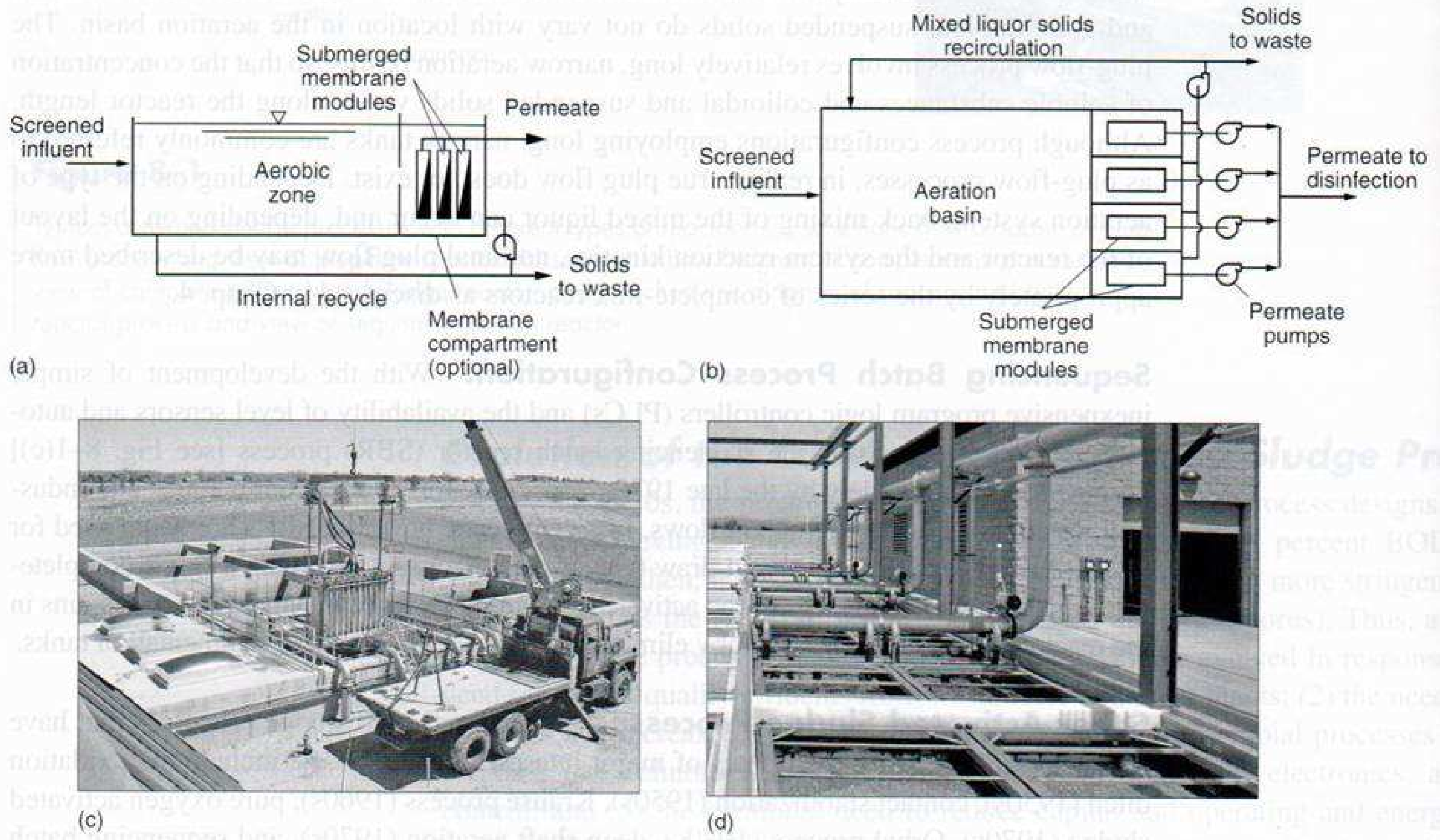

Figure 8-2

Membrane bioreactor (MBR). A multi-staged activated sludge system with membranes for liquid-solids separation: (a) section through MBR with separate compartment for the membranes, (b) plan view of MBR, (c) view of membrane cassettes being placed in separate compartment, and (d) view of separate membrane compartment.

MBR: features

- Use membrane for solid/liquid separation
- Microfiltration or ultrafiltration membrane immersed directly into the reactor
- Membrane fouling a major concern: became feasible with advances in membrane manufacturing & configuration technique

MBR process: adv. & disadv.

- **Advantage**
  - Can maintain high biomass concentration → much higher volumetric organic loading rate → much smaller reactor size requirement
  - No need for separate clarifier → additional area saving
  - Simpler process operation with no concerns about activated sludge settling properties
  - Better effluent quality through membrane separation
  - Lower disinfectant dose requirement for the following disinfection unit because of low turbidity effluent

- **Disadvantage**
  - Energy cost for membrane filtration
  - Need for membrane replacement
  - Operational demands for fouling control

Suspended growth process for N & P removal

- **For improved N removal**
  - Modified Ludzack-Ettinger (MLE)

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- **For improved P removal**
  - Anaerobic/aerobic (A/O) process

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- **For improved N & P removal**
  - Anaerobic/anoxic/aerobic (A^2O) process
  - Modified Bardenpho process
  - University of Capetown (UCT) process

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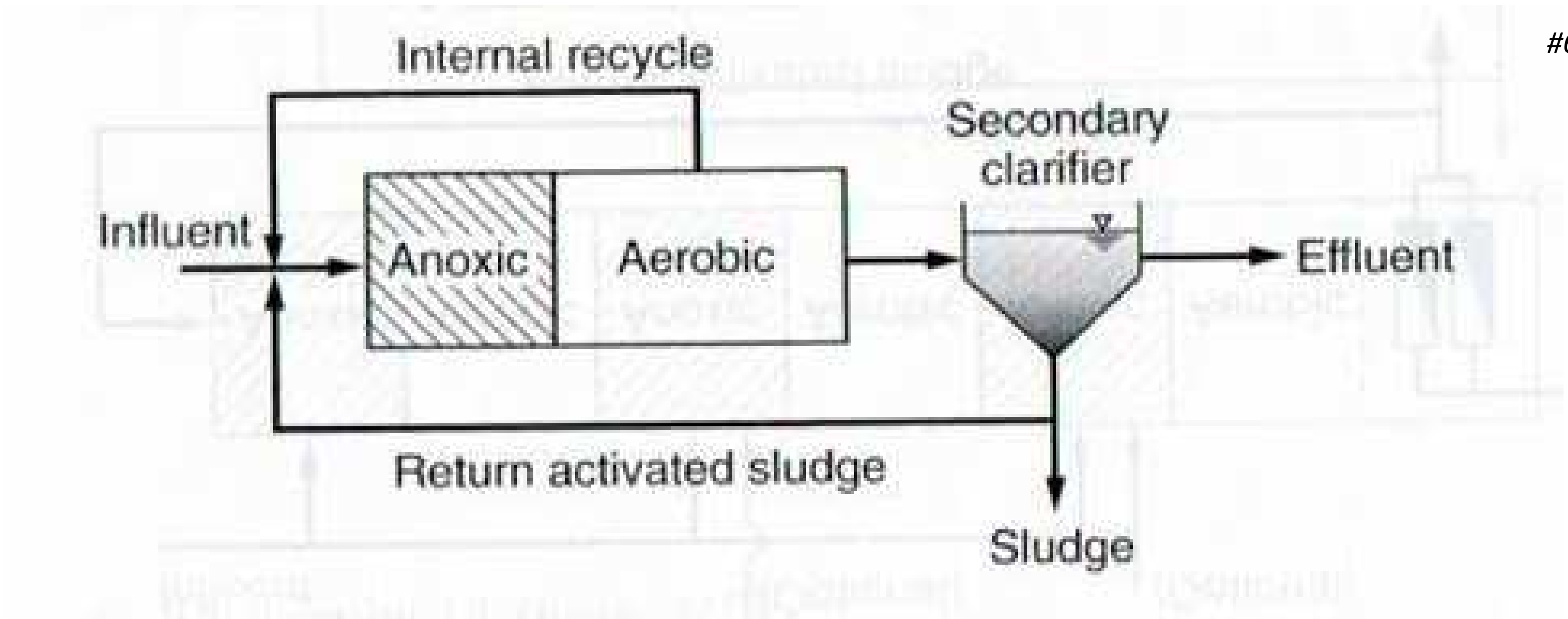
Modified Ludzak-Ettinger (MLE)



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- Typical value of (internal recycle flowrate) / (influent flowrate) = 2-4
- Very adaptable to existing activated sludge facilities

Anaerobic/aerobic (A/O) process

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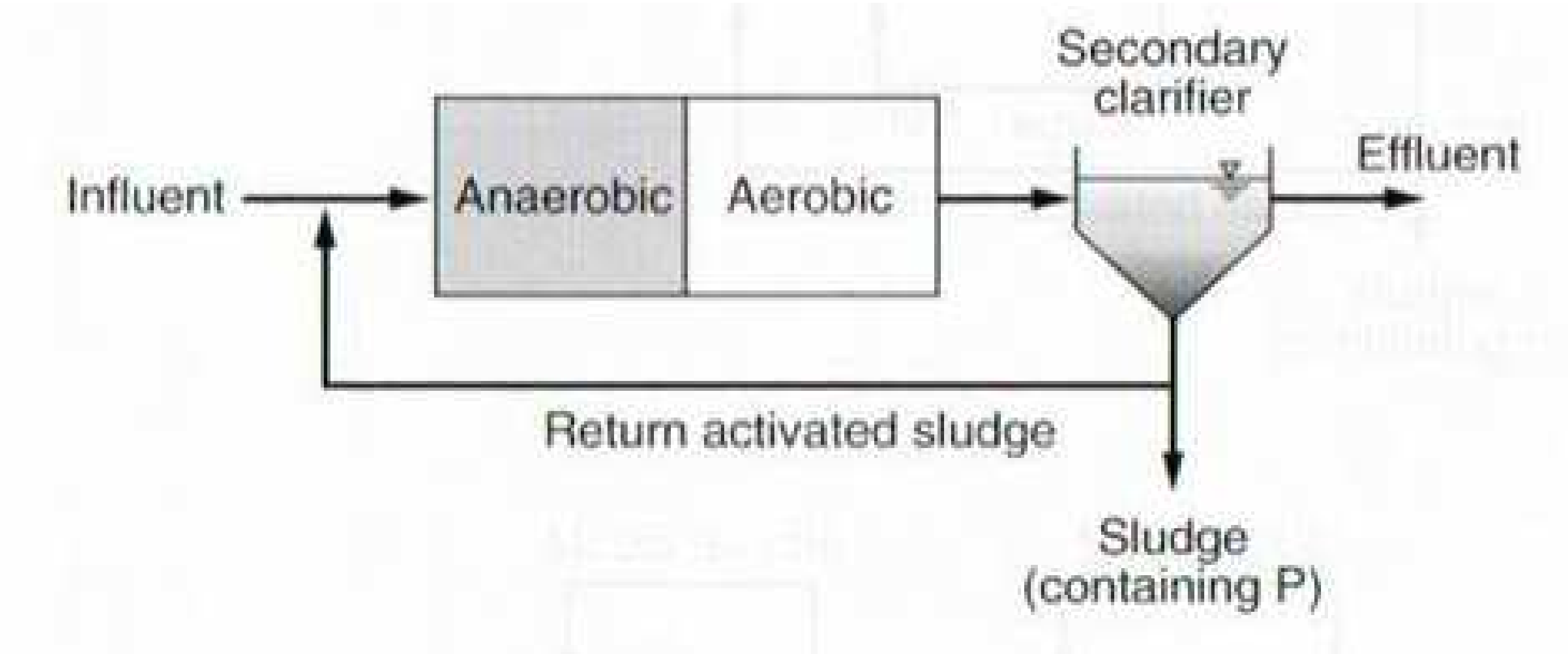
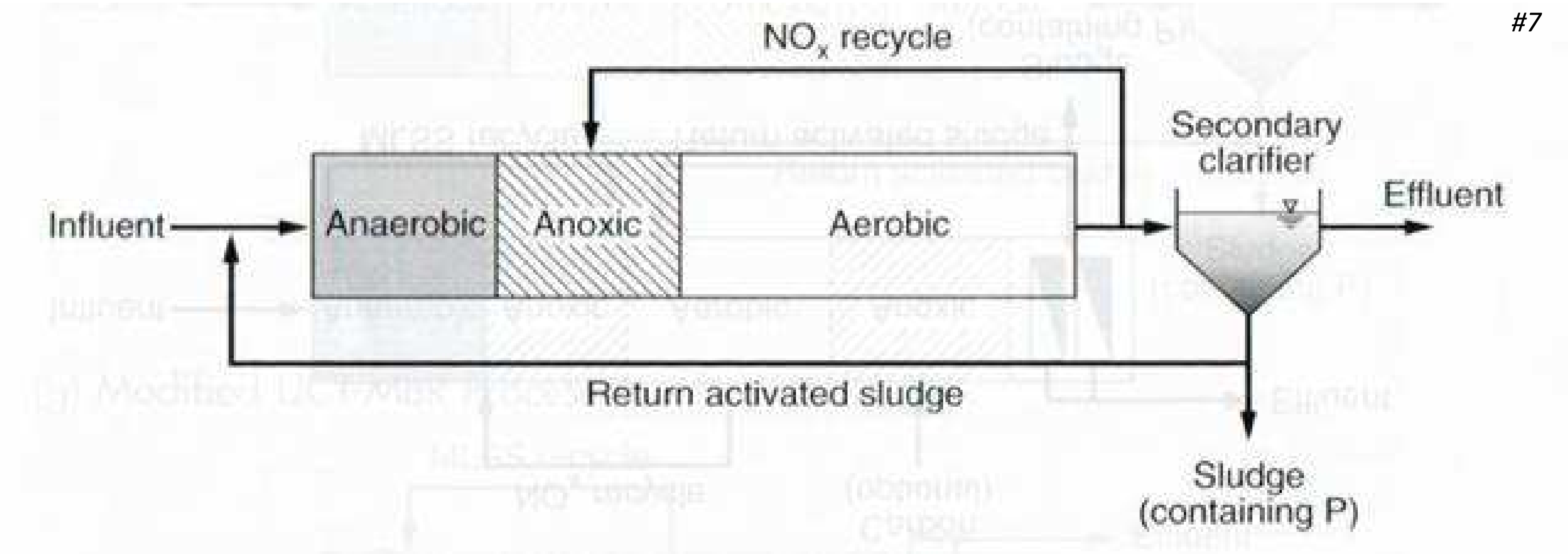
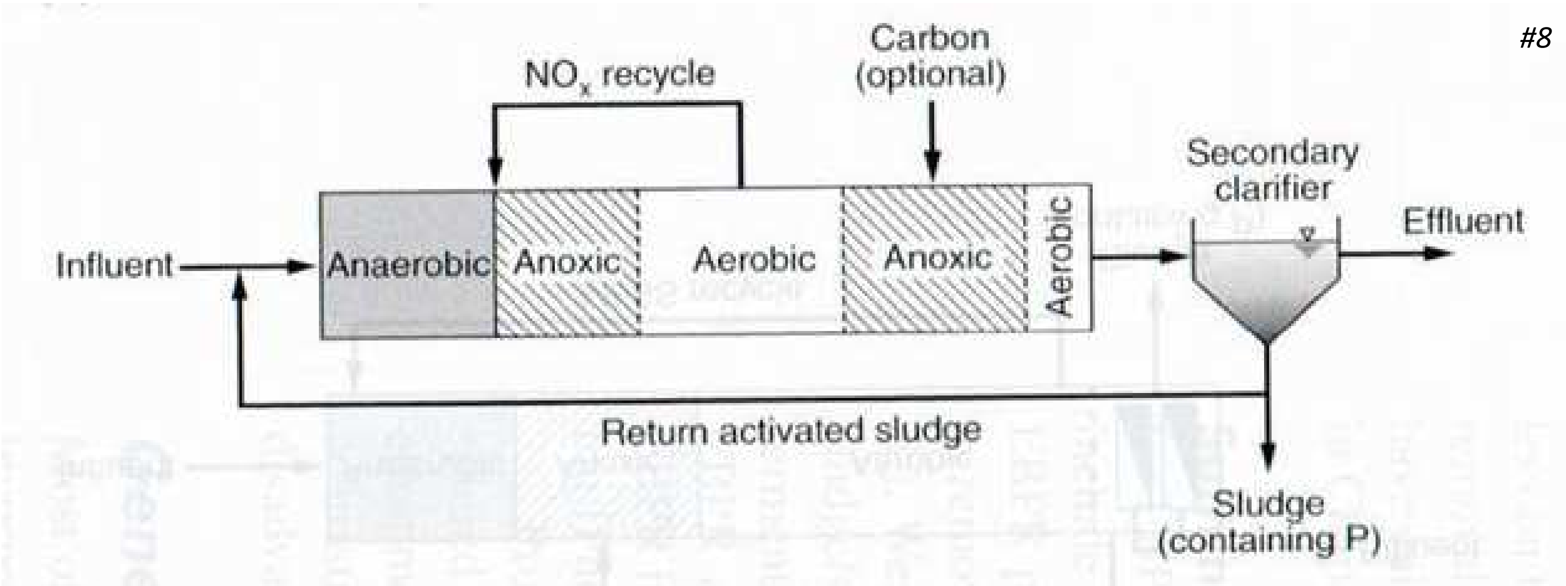


Anaerobic/anoxic/aerobic (A^2O) process



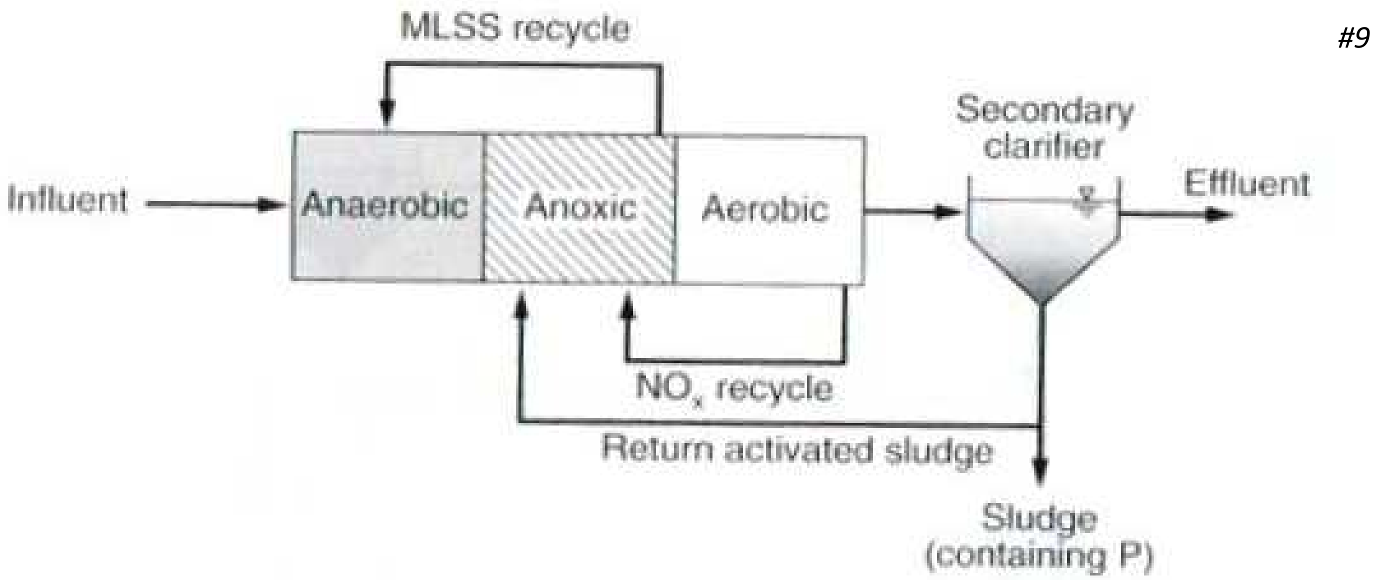
- Achieves improved removal for both N & P
  - Anaerobic tank: essential for enhanced P removal
  - Anoxic tank: essential for denitrification
- Improved performance of the anaerobic tank as a selector (compared to A/O): nitrate in the return activated sludge is minimized

Modified Bardenpho process



- Achieves improved removal for both N & P
- Can achieve quite high N removal efficiency
- Necessity of the final aerobic stage
  - Strip residual nitrogen gas from the mixed liquor
  - Minimize P release in the secondary clarifier (prevent low DO condition)

University of Capetown (UCT) process



- Return activated sludge is directed to the anoxic tank, not the anaerobic tank
- Mixed liquor of anoxic tank is fed to the anaerobic tank
- Consequence: high P removal efficiency by minimizing the entrance of NO_3^- to the anaerobic tank
  - Compare with the anaerobic tank of A/O or A^2O!

Attached & hybrid processes

- **Attached processes**
  - Trickling filter
  - Biological aerated filters
  - Fluidized bed bioreactor

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- **Hybrid (attached + suspended) processes**
  - Integrated fixed film activated sludge process
  - Moving bed biofilm reactor

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Attached growth processes: general features

1. Growth of the biomass on inert media to form biofilm
2. Removal of excess solids by sedimentation after solids sloughing off the biofilm or by backwashing the media
3. Need to provide oxygen by
   1) Air movement through the void volume (e.g., in trickling filters)
   2) Air sparging into fixed or moving submerged media
   3) Oxygenation of recycle flow in a fluidized bed reactor
4. Need to provide distribution and contact of the influent flow with the media surface area
5. Need for an underdrain or other methods of collecting the treated effluent

Trickling filter

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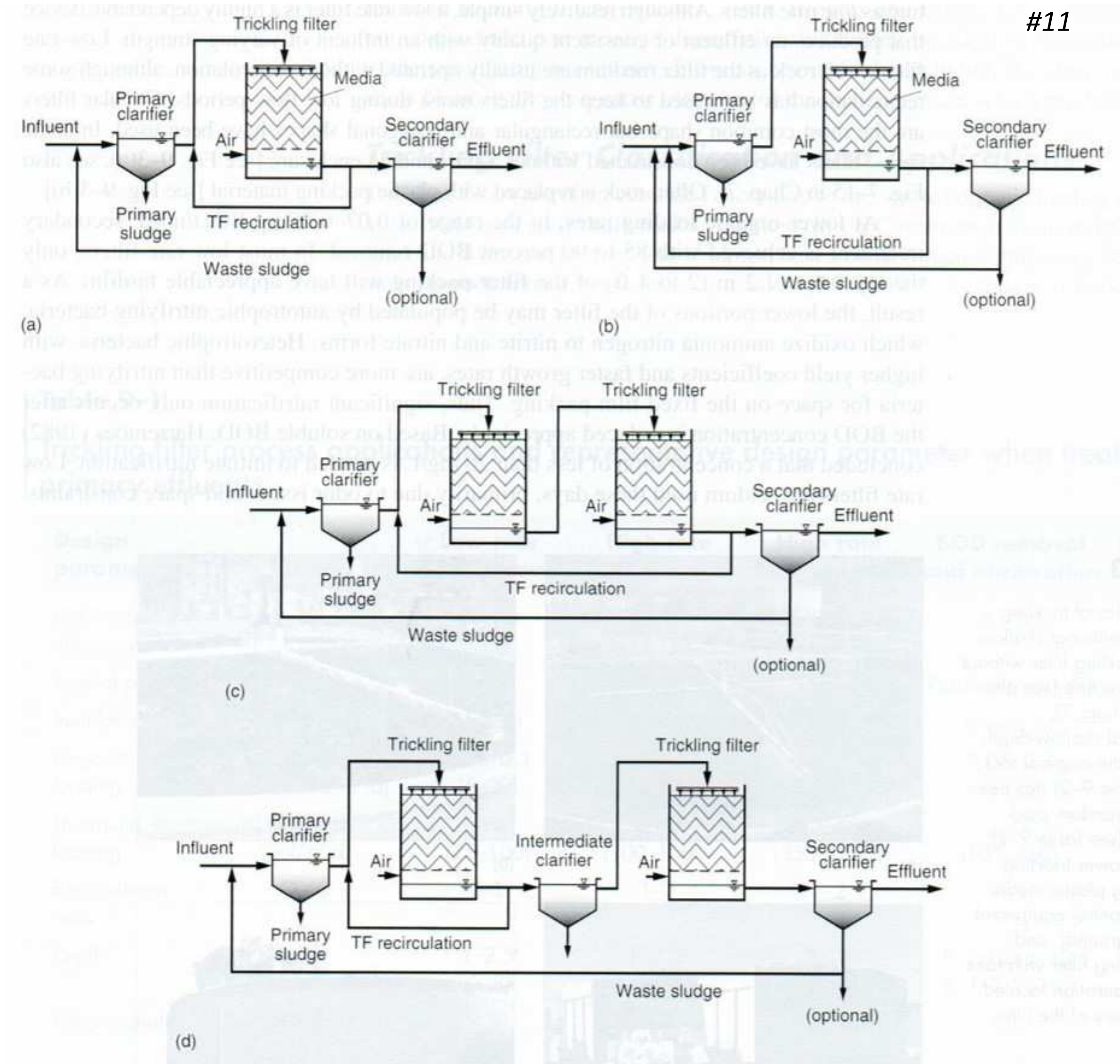

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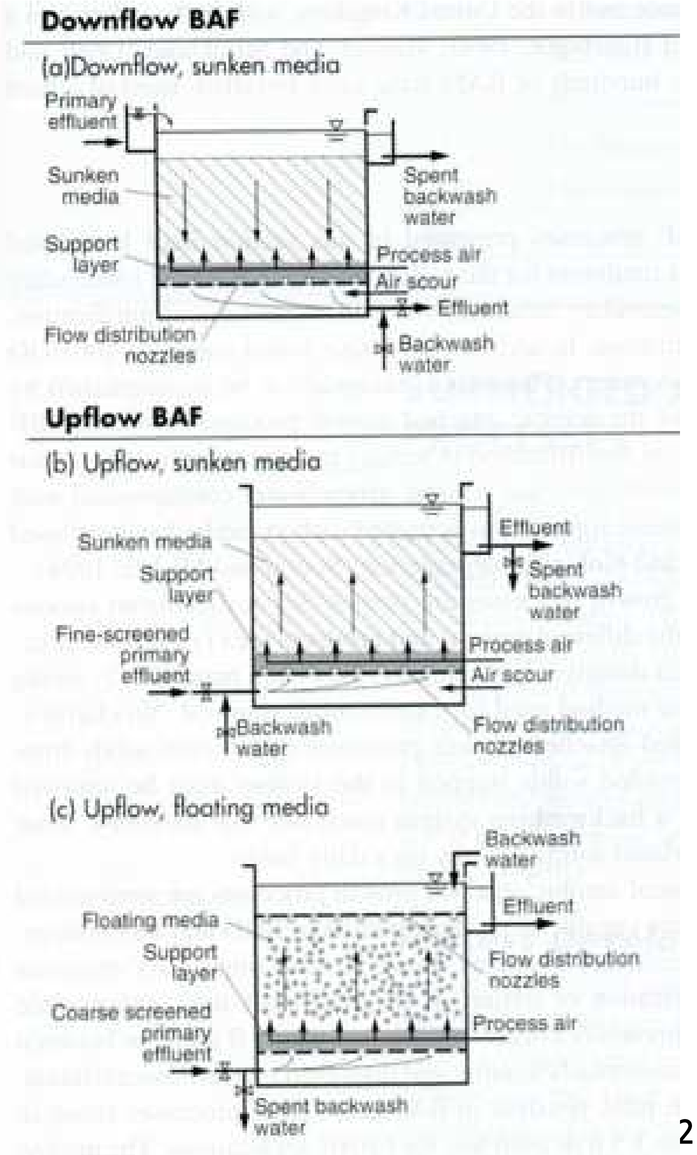
Trickling filters – adv. & disadv.

Advantages	Disadvantages
1. Less energy required	1. Generally poorer effluent quality than activated sludge process
2. Simpler operation	2. High sensitivity to low temperature
3. NO problems of bulking sludge in secondary clarifiers	3. Odor production
4. Better sludge thickening properties	4. Uncontrolled solids sloughing events
5. Better recovery from shock toxic loads	

Biological aerated filters (BAFs)

- **Upflow or downflow**
- **Sunken or floating media**
  - Floating media for upflow only
  - Sunken media: Use a bed of heavy media (expanded clay or shale, specific gravity of about 1.6)
  - Floating media: use media lighter than water



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Fluidized bed bioreactor

- Wastewater is fed upward at a relatively high velocity to expand the media bed
- Use sand or activated carbon as media
- Usually provide oxygen in the recycle flow

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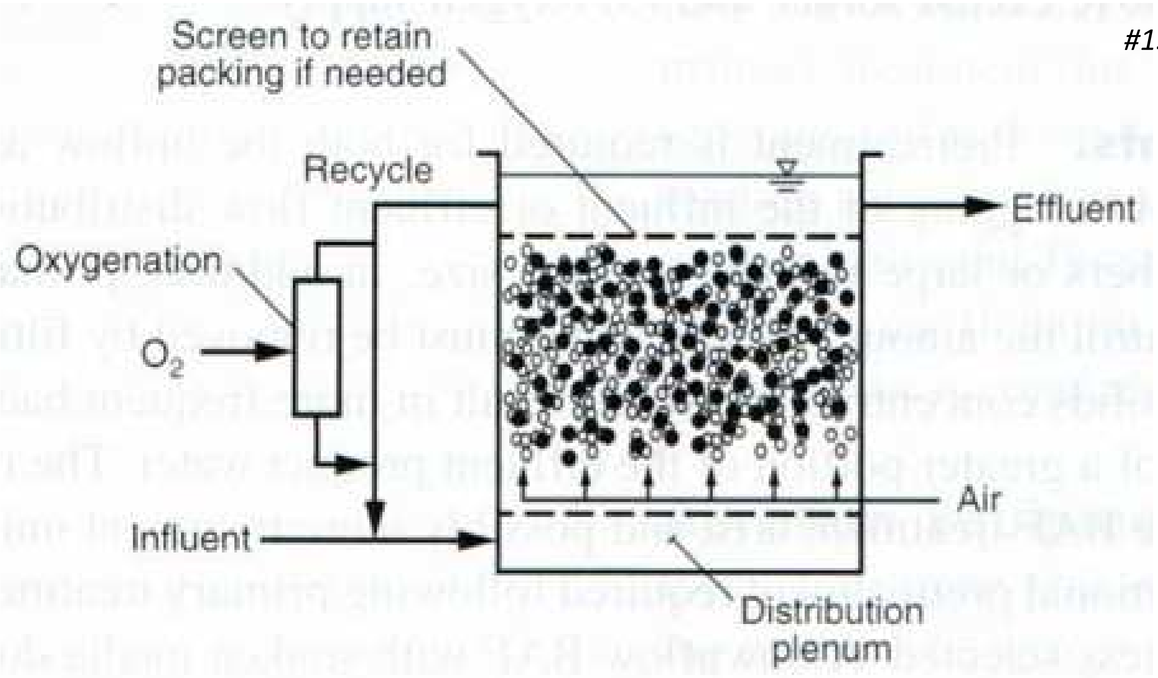

Integrated fixed film AS process

- **Activated sludge system in which a material to support attached biomass growth is added**
- **Higher biomass concentration achievable in the aeration tank**
  - Can use higher volumetric OLR
  - Provide conditions for nitrification

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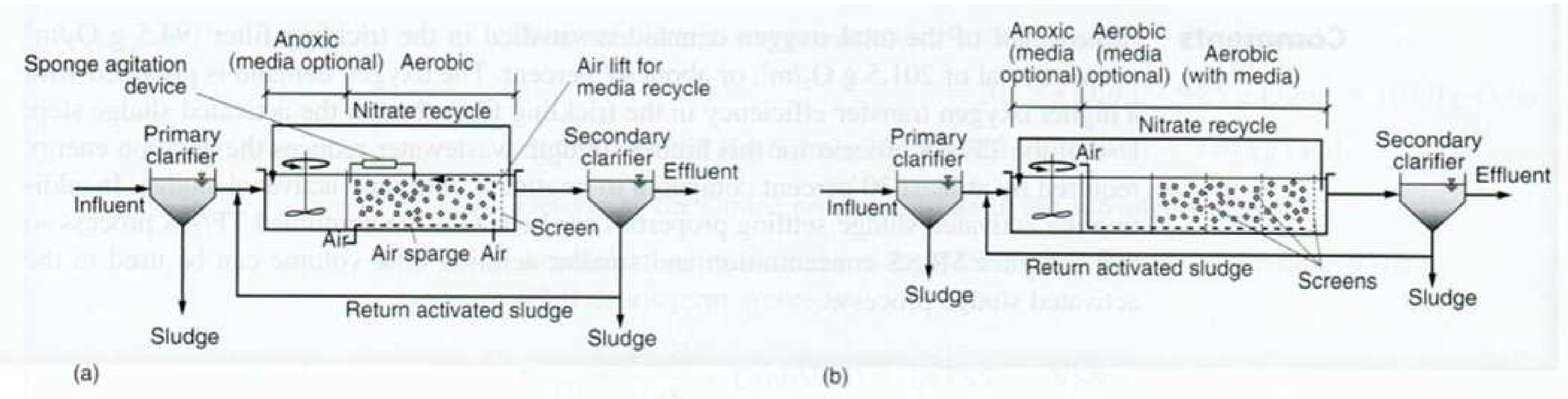

Moving bed biofilm reactor

- **Similar to the IFAS process, but no sludge return**
  - Media fill volume is higher
  - TSS concentration in the flow to the secondary clarifier much smaller

- **Processes for BOD removal:**

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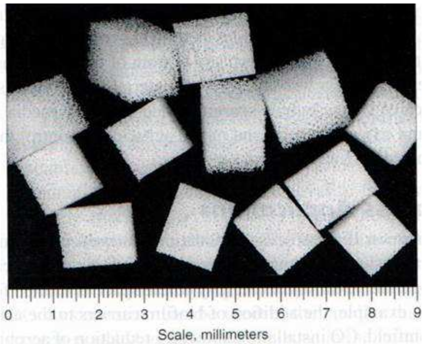
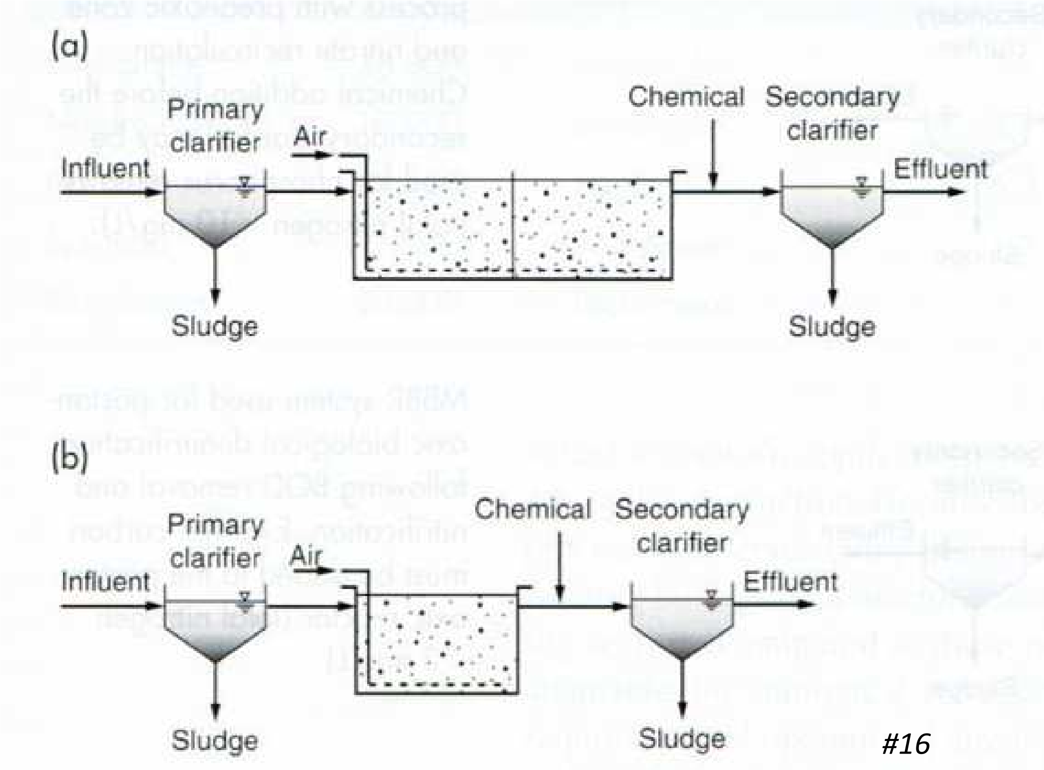


Media used for IFAS or MBBR processes



#16

References

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