Practical applications of biological wastewater treatment

Suspended growth, for BOD removal (+Nitrif.)

- Conventional activated sludge process
  - Plug flow
  - Complete mix

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

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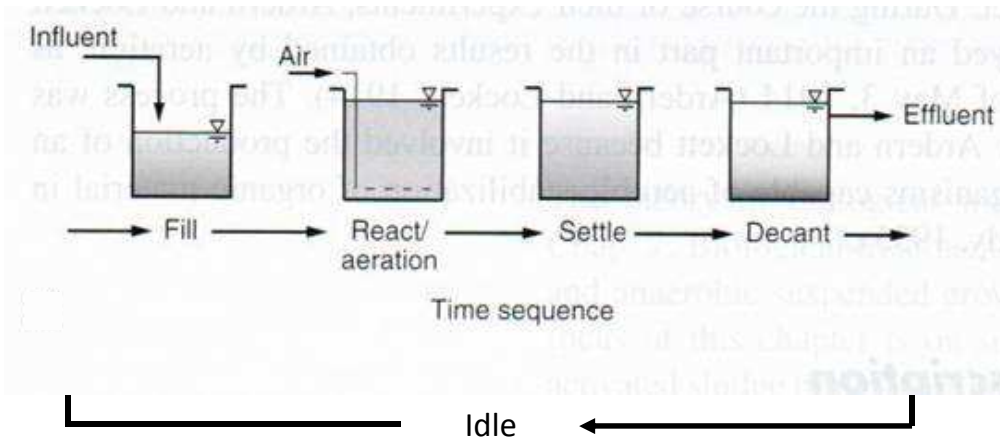
Sequential batch reactor

- 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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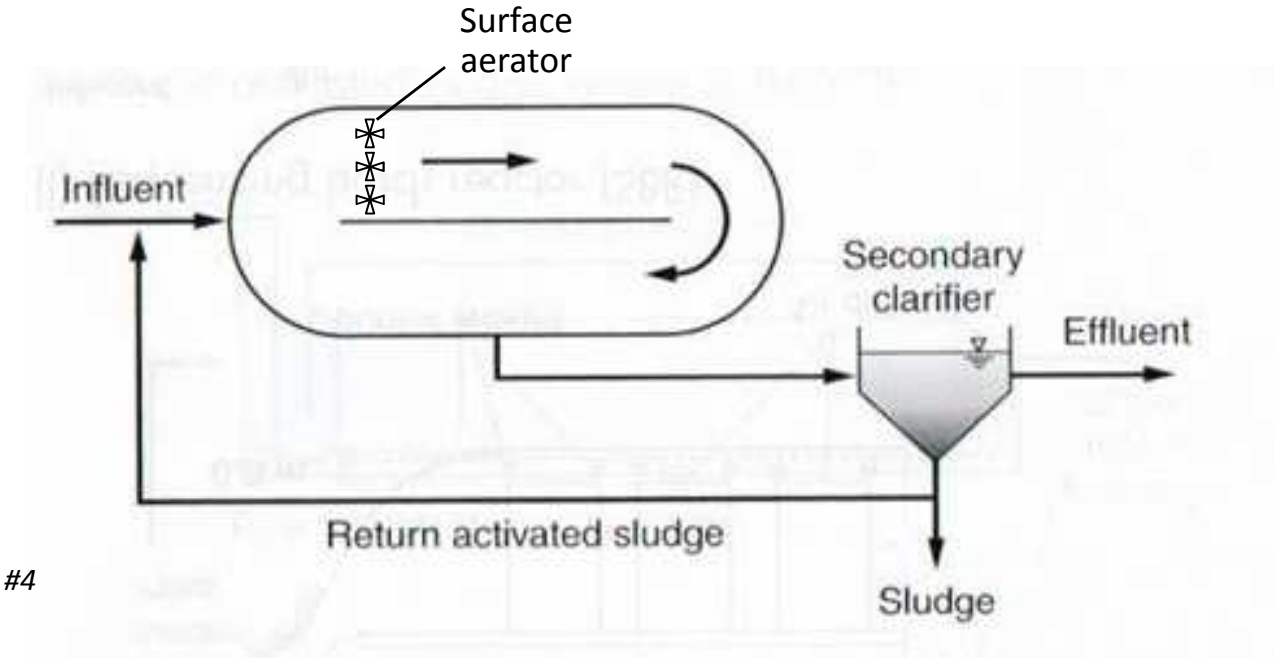
Oxidation ditch



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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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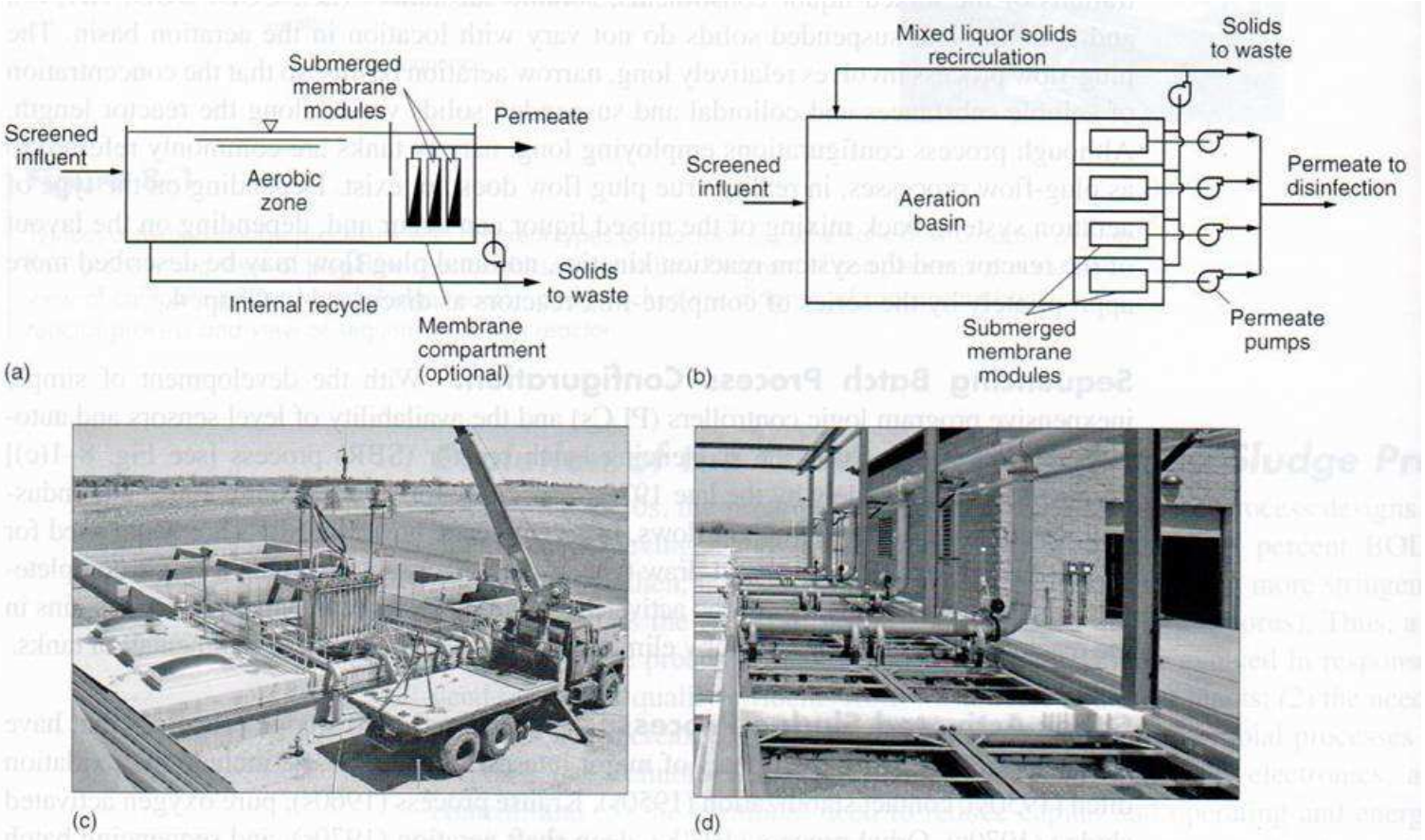

Figure 8–2

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: Concept & Performance

- Use membrane for solid/liquid separation
- Microfiltration or ultrafiltration membrane immersed directly into the reactor
- Effect: secondary treatment (aeration tank + clarifier) + tertiary treatment (granular media filtration)
- High removal efficiencies of BOD, SS, bacteria, and nutrients
- Membrane fouling a major concern: became feasible with advances in membrane manufacturing & configuration technique

MBR: Advantages & Disadvantages

- **Advantages**
  - 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

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

Suspended growth, enhanced N/P removal

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

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- For enhanced P removal
  - **Anaerobic/aerobic (A/O) process**
  - ….

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

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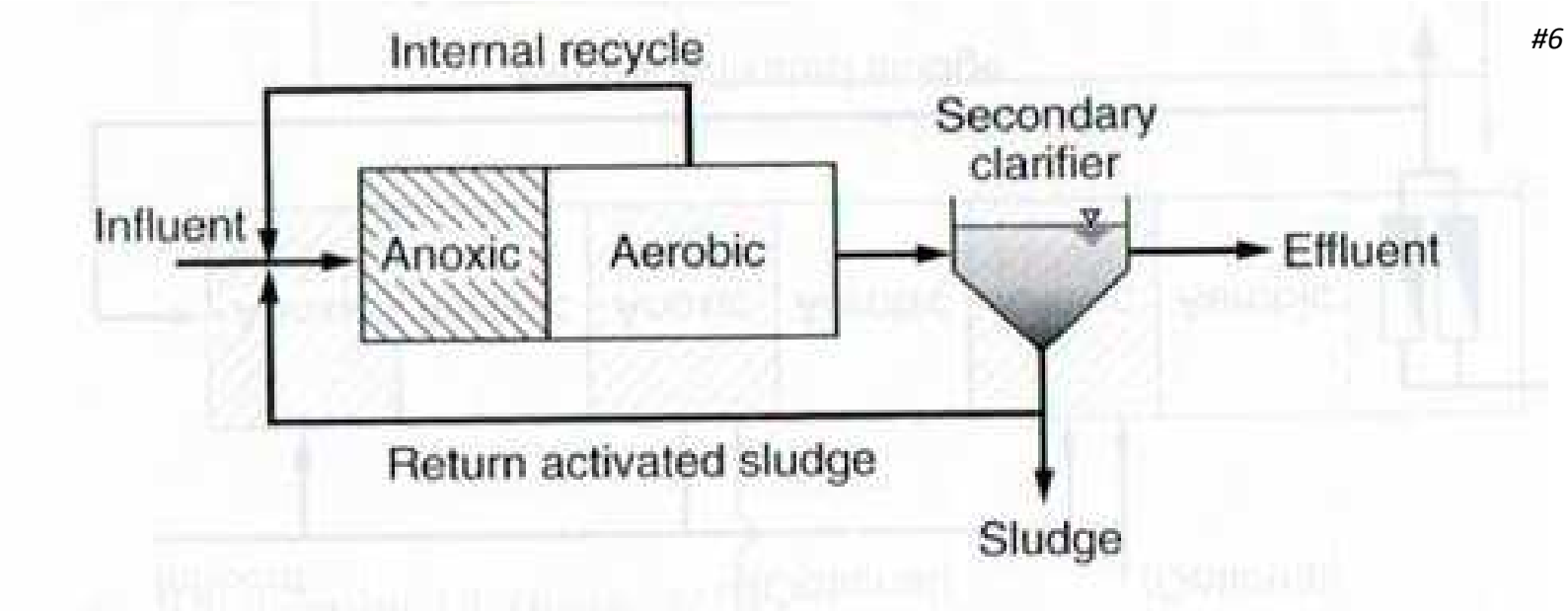
Modified Ludzak-Ettinger (MLE)



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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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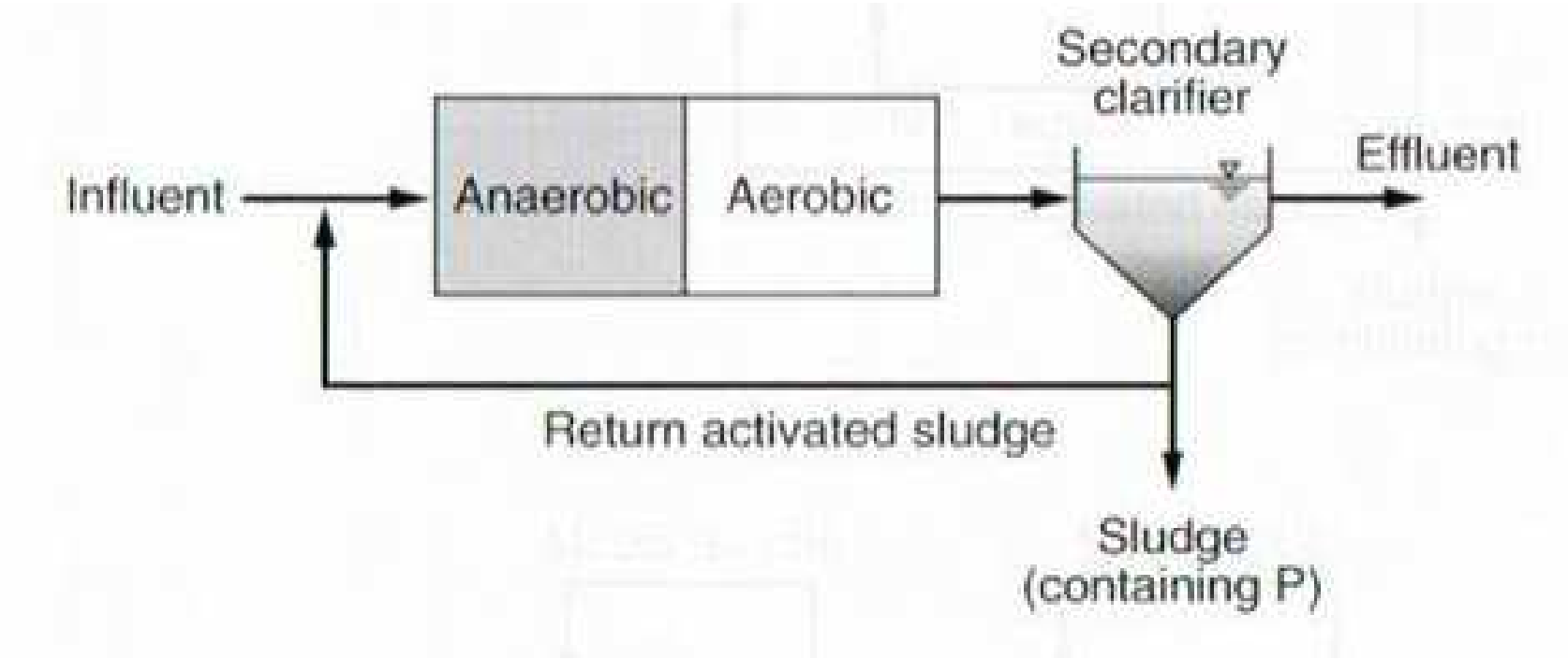
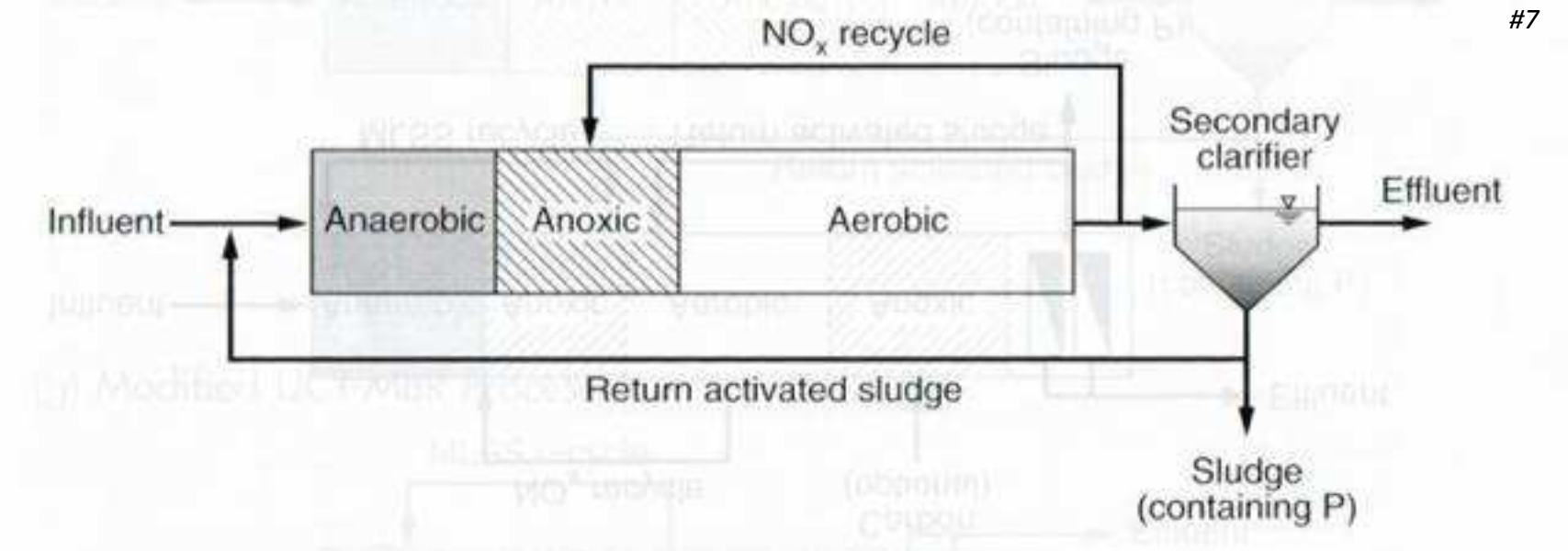
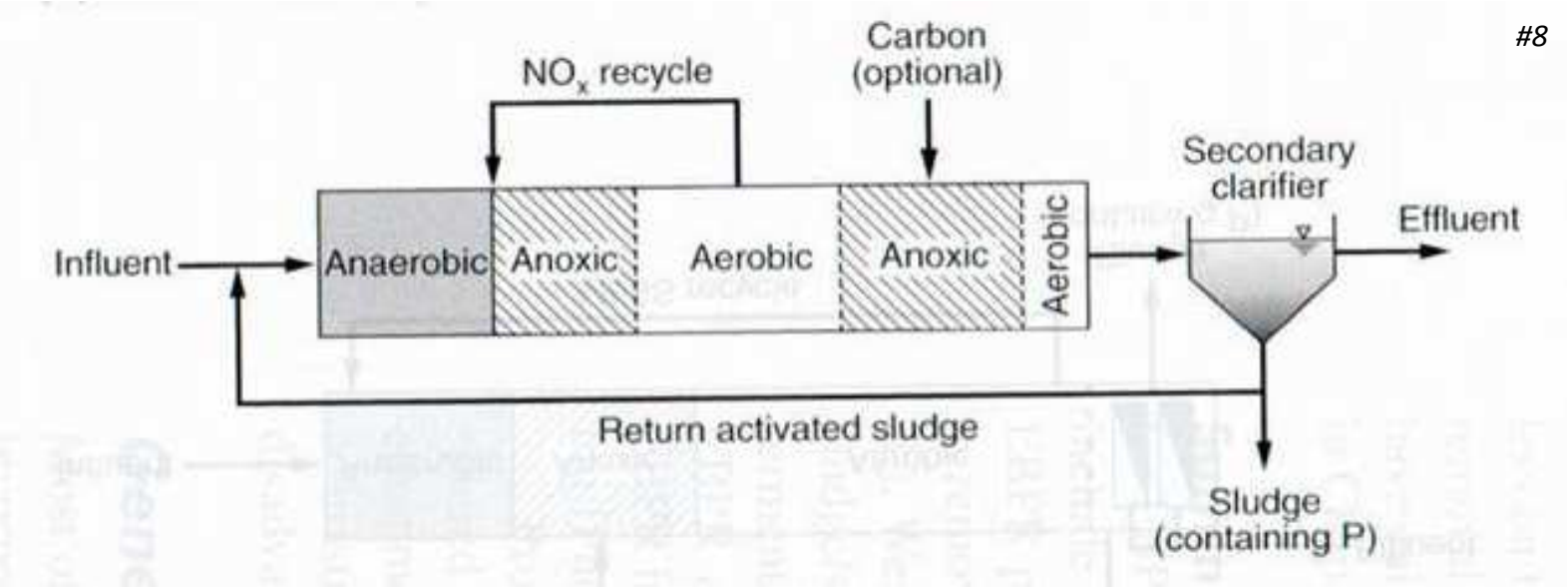


Anaerobic/anoxic/aerobic (A^2O) process



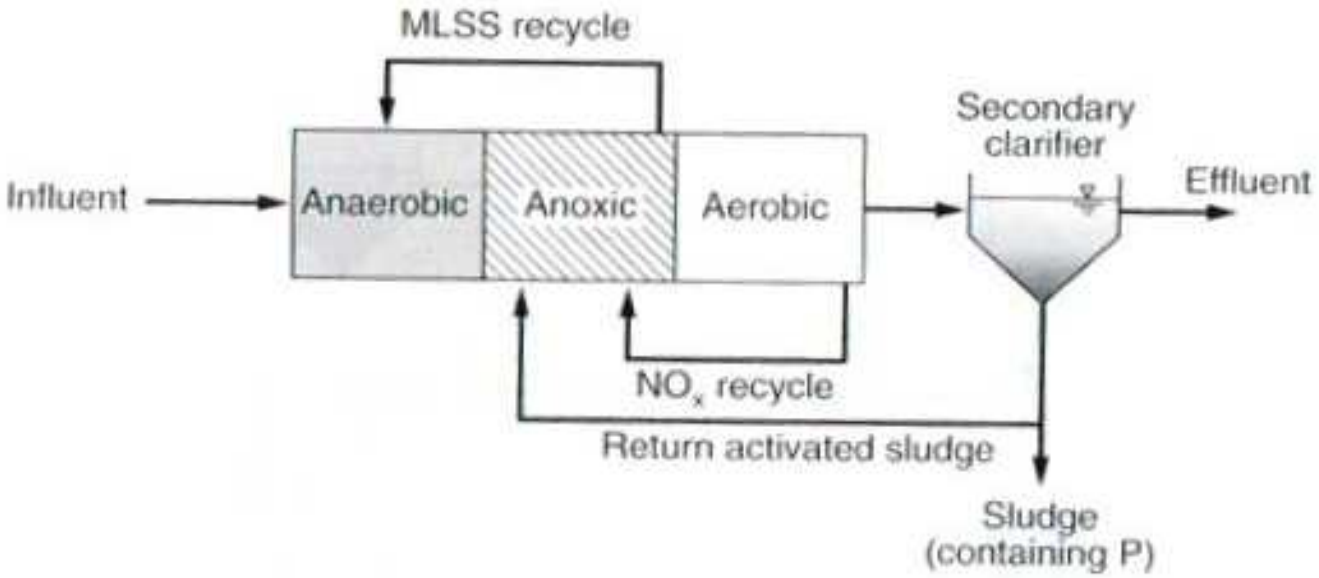
- Achieves improved removal for both N & P
  - Anaerobic tank: essential for enhanced P removal
  - Anoxic tank: essential for denitrification
- Improved performance of the anaerobic tank as a selector (compared to A/O): nitrate in the return activated sludge is minimized

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



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- 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
  - Moving bed biofilm reactor

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Trickling filter & rotating biological contactor

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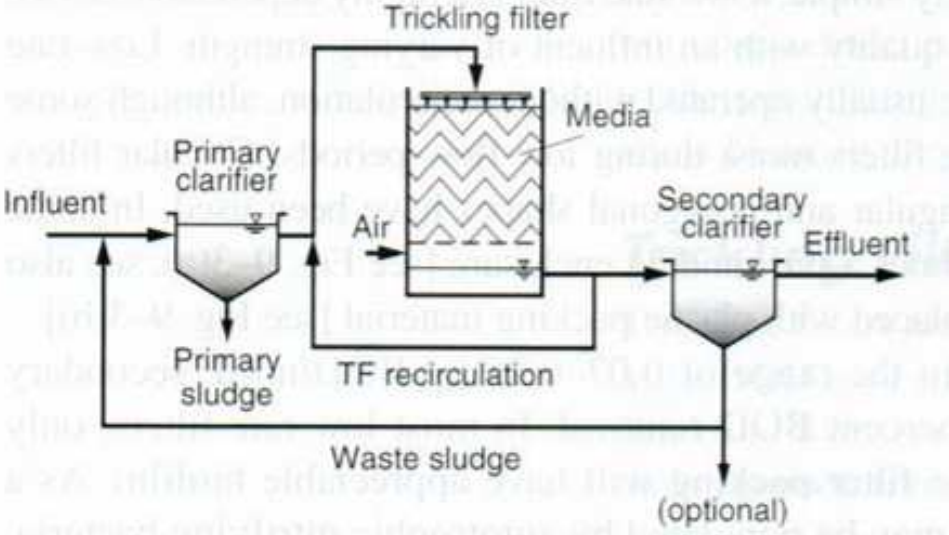

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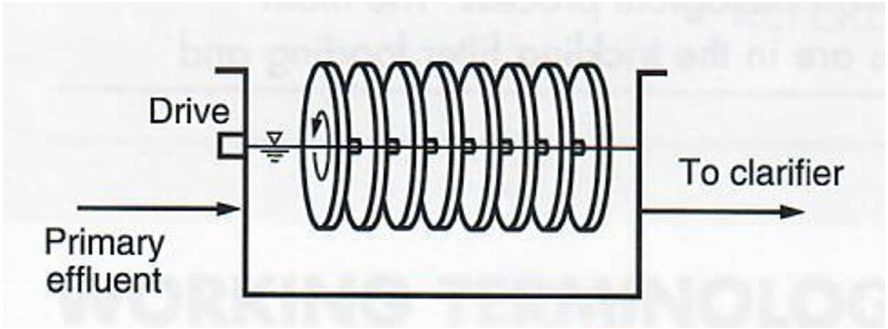

Moving bed biofilm reactor (MBBR)

- 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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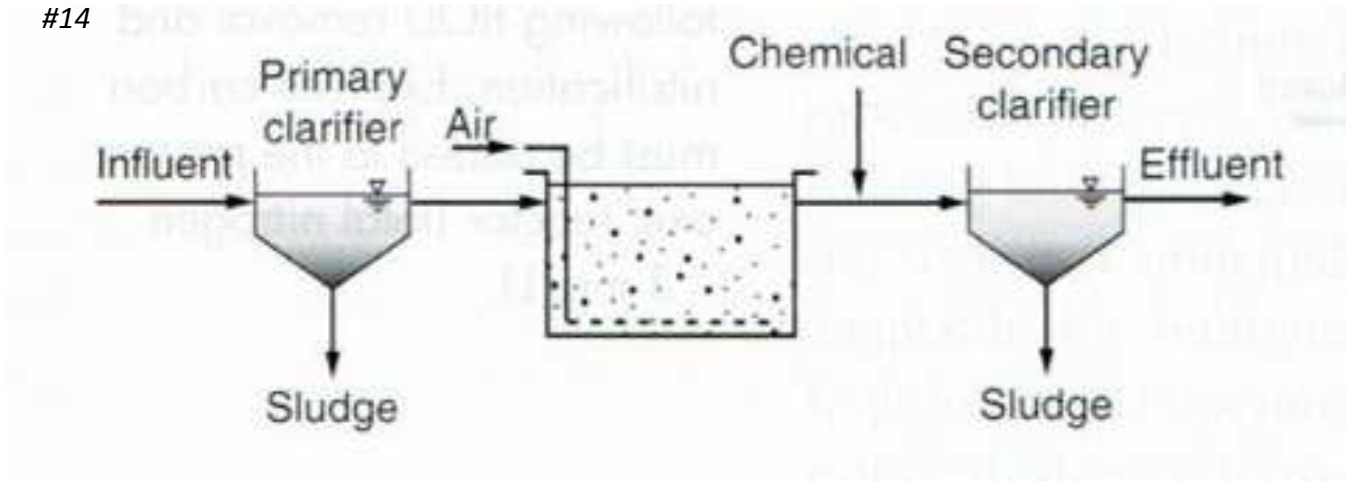

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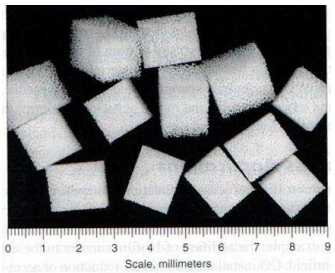
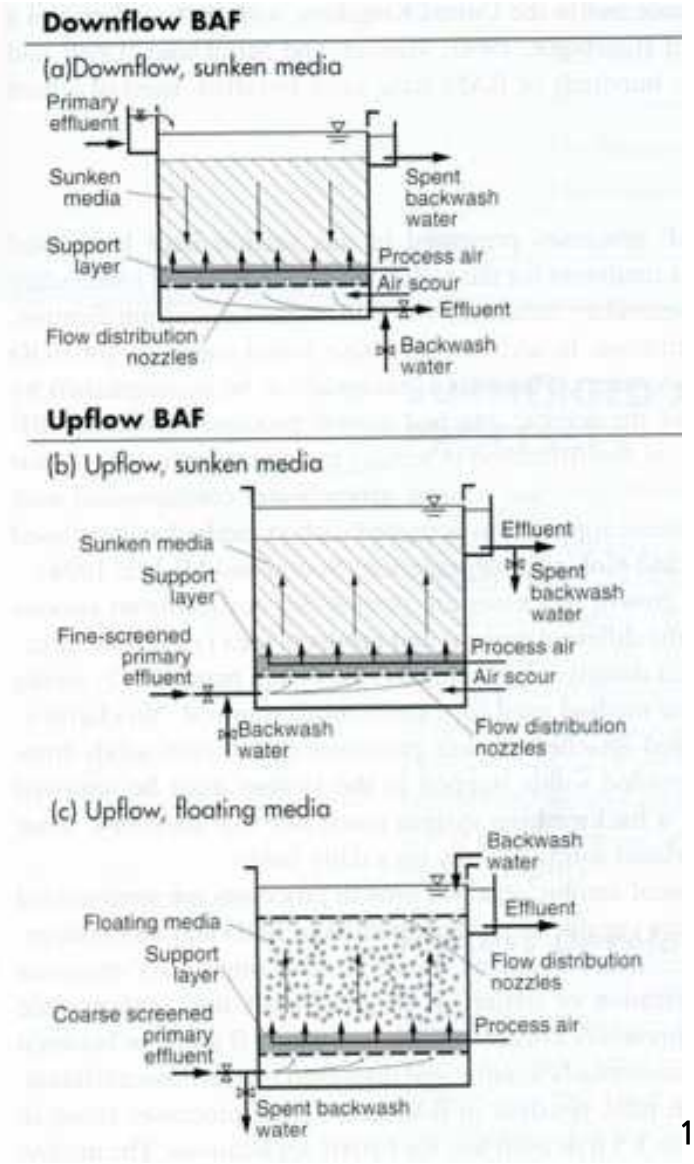


Media used for MBBR

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



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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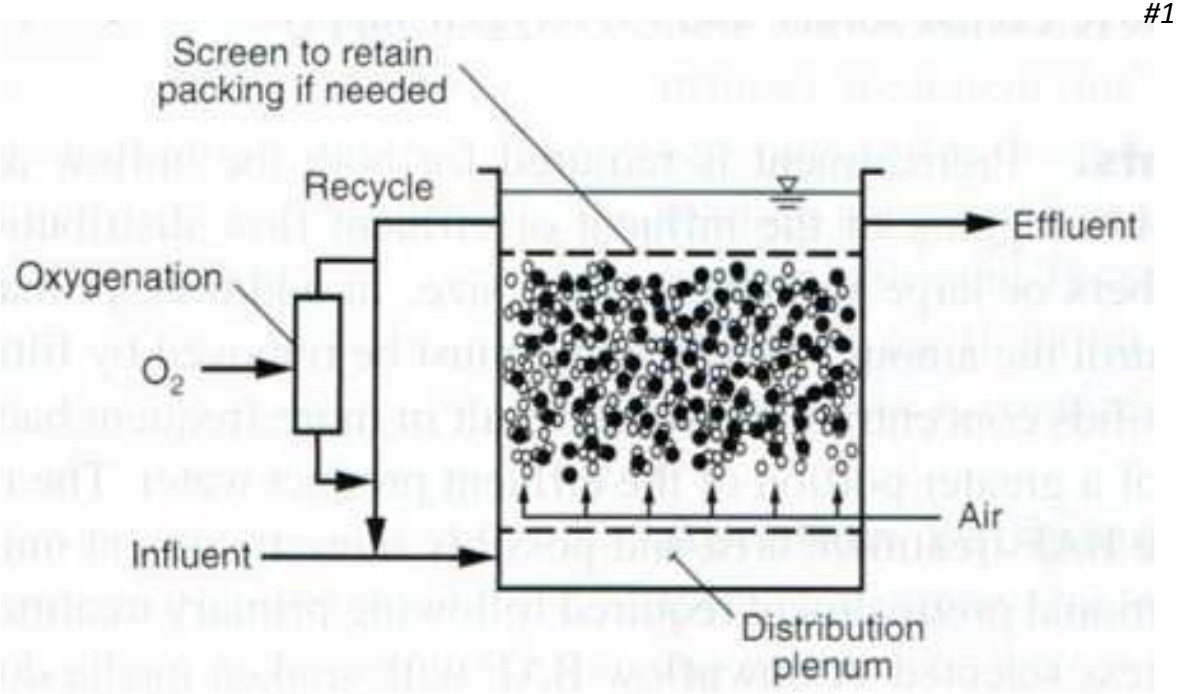

References

#1, #2, #3, #4, #5, #6, #7, #8, #9) Metcalf & Eddy, Aecom (2014) Wastewater Engineering: Treatment and Resource Recovery, 5th ed. McGraw-Hill, p. 620, 649, 788, 789, 704, 839, 865, 866, 867.

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#11) https://sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/semi-centralised-wastewater-treatments/rotating-biological-contactors

#12, #13, #14, #15, #16, #17) Metcalf & Eddy, Aecom (2014) Wastewater Engineering: Treatment and Resource Recovery, 5th ed. McGraw-Hill, p. 952, 944, 999, 1017, 1028, 1029.