NEW WASTEWATER TECHNOLOGIES TO MEET UPCOMING REGULATIONS




2018 Central West Texas Regional School

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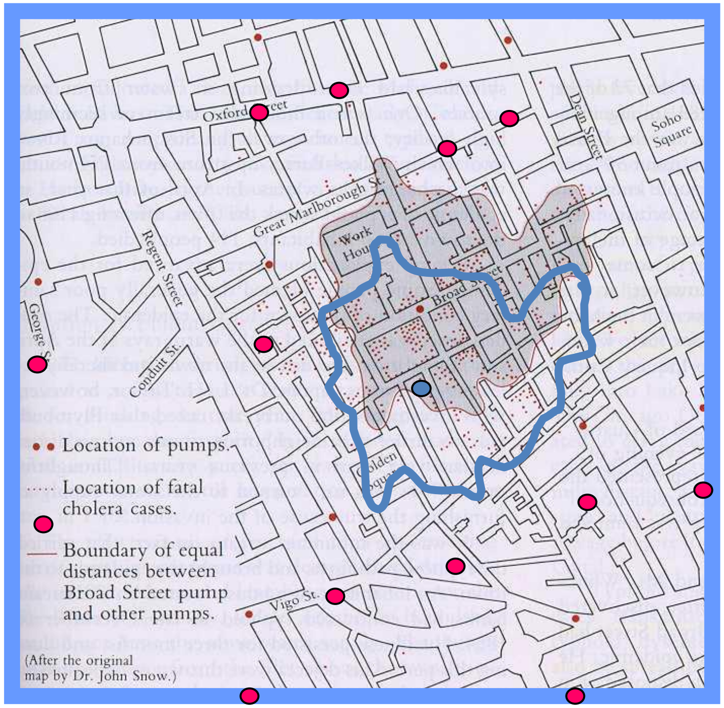
Outline

- History of Wastewater Treatment
- Typical Permit Requirements
- Typical Primary Treatment Technologies
- Typical Secondary Treatment Technologies
- Advanced Treatment Technologies
- Technologies on the Horizon
- Summary

History of Wastewater Treatment

History of Wastewater Treatment

Public Health



Investigation of an outbreak of cholera in London in 1854 provided one of the first links between sewage disposal, drinking water supply and waterborne disease.

Environmental Protection

A 1920s, study of the East and Fox Rivers in Green Bay was commissioned because workers in downtown could not open windows in summer due to the stench. Environmental problems plague this system to this day.

History of Wastewater Treatment in Texas

Why are we discussing new technologies anyway?

- Tighter Federal and State regulations and/or potential nutrient limits on the horizon
- Drought -> Demands for reuse water
- Increased conservation -> higher wastewater concentrations, more potential for shock loading
- Age and/or condition of existing plant requires improvements
- Cost of newer treatment technologies can be more competitive than older technologies under certain requirements
- Site space availability for expansions/upgrades

Typical Permit Requirements

Typical Permit Requirements

- What are typical current permit limits in Texas?
  - Natural Treatment (Lagoon) Systems
    - BOD – 30 mg/L
    - TSS – 90mg/L
  - Mechanical Treatment WWTPs
    - BOD (or cBOD) – 5-15 mg/L
    - TSS – 7-15 mg/L
    - NH_3 – 2-3 mg/L
  - Reuse
    - Type II Non-Potable Reuse
      - BOD (or cBOD) – 20 mg/L
    - Type I Non-Potable Reuse
      - BOD (or cBOD) – 5 mg/L
      - Turbidity – 3 NTU

Typical Permit Requirements

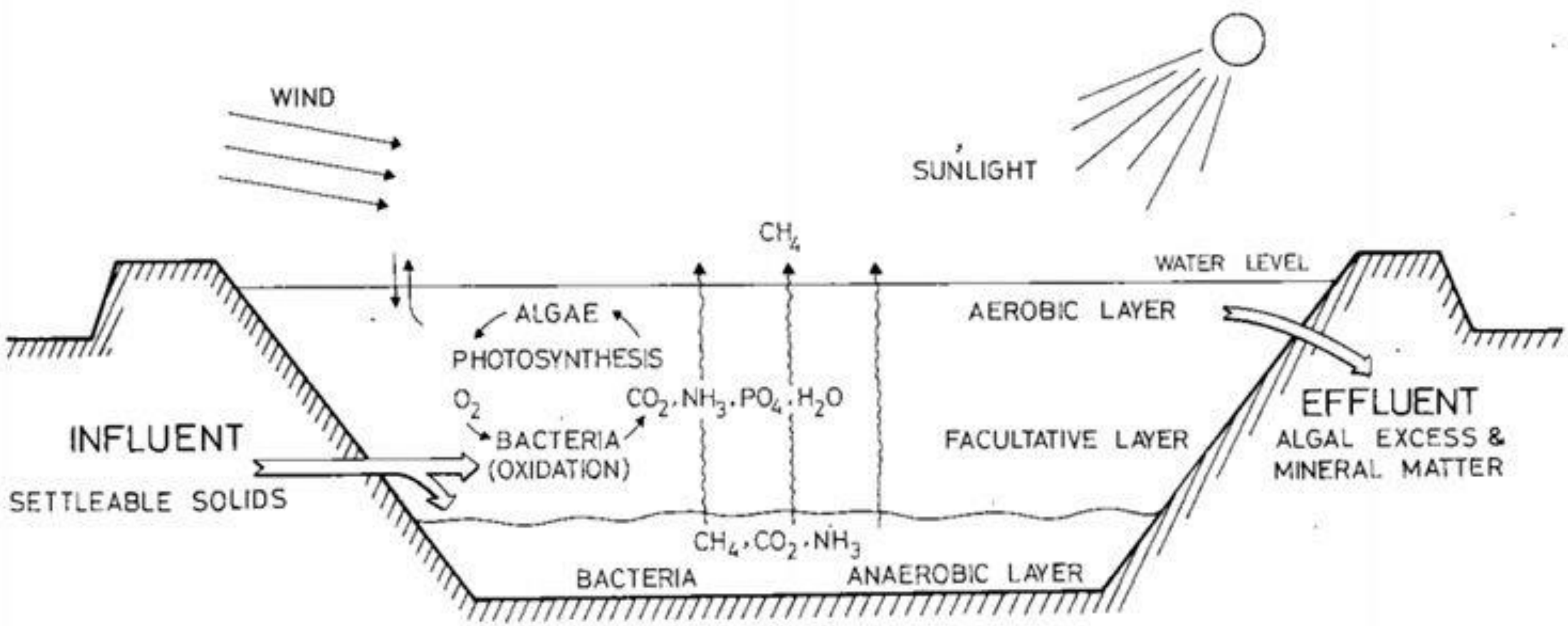
- What changes may be coming to permitting?
  - Numeric Nutrient Criteria Development Plan
    - WAS anticipated to become active in 2016
    - Intended to evaluate WWTPs for the potential of adding a total phosphorus (TP) and/or total nitrogen (TN) limit to permits
    - Triggers for further evaluation:
      - WWTP permit rating >= 0.5 MGD
      - TP in effluent >= 3.5 mg/L
      - TN in effluent >= 15 mg/L (primarily in coastal areas)
      - Discharge stream segment is impaired for anything

Typical Permit Requirements

- What if I get a nutrient limit added to my permit?
  - Total Nitrogen
    - Need to start planning for adding a nitrogen removal step
      - Biological Removal of Ammonia/Nitrate/Nitrite
  - Total Phosphorus
    - Need to start planning for adding a phosphorus removal step
      - Chemical Removal?
      - Biological Removal?
      - Filtration Removal?

Typical Primary Treatment Technologies

Typical Primary Treatment Technologies – Facultative Lagoon



Typical Primary Treatment Technologies – Facultative Lagoon

Typical Primary Treatment Technologies – Facultative Lagoon

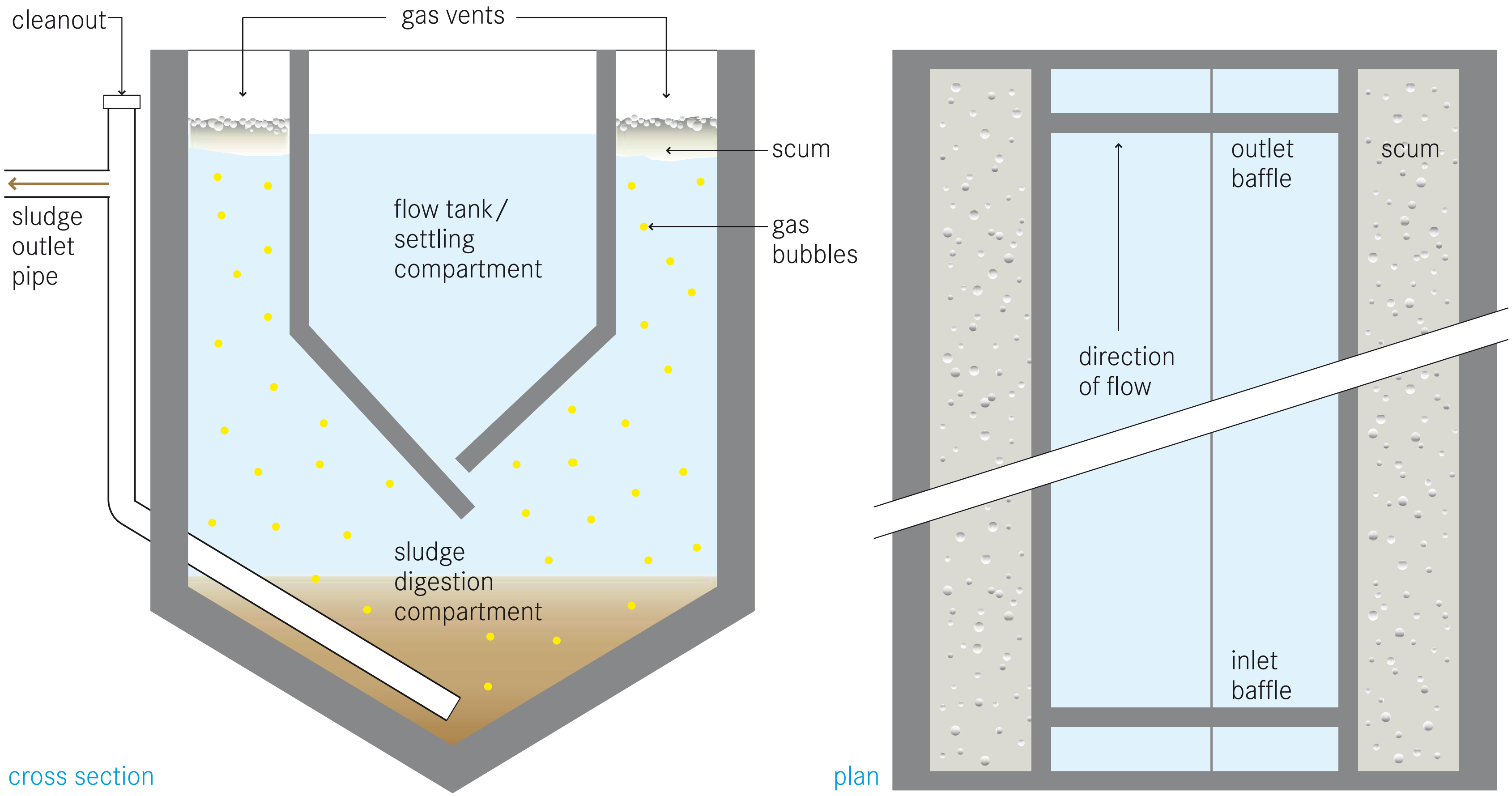
Advantages

- Low capital cost
- Low O&M cost

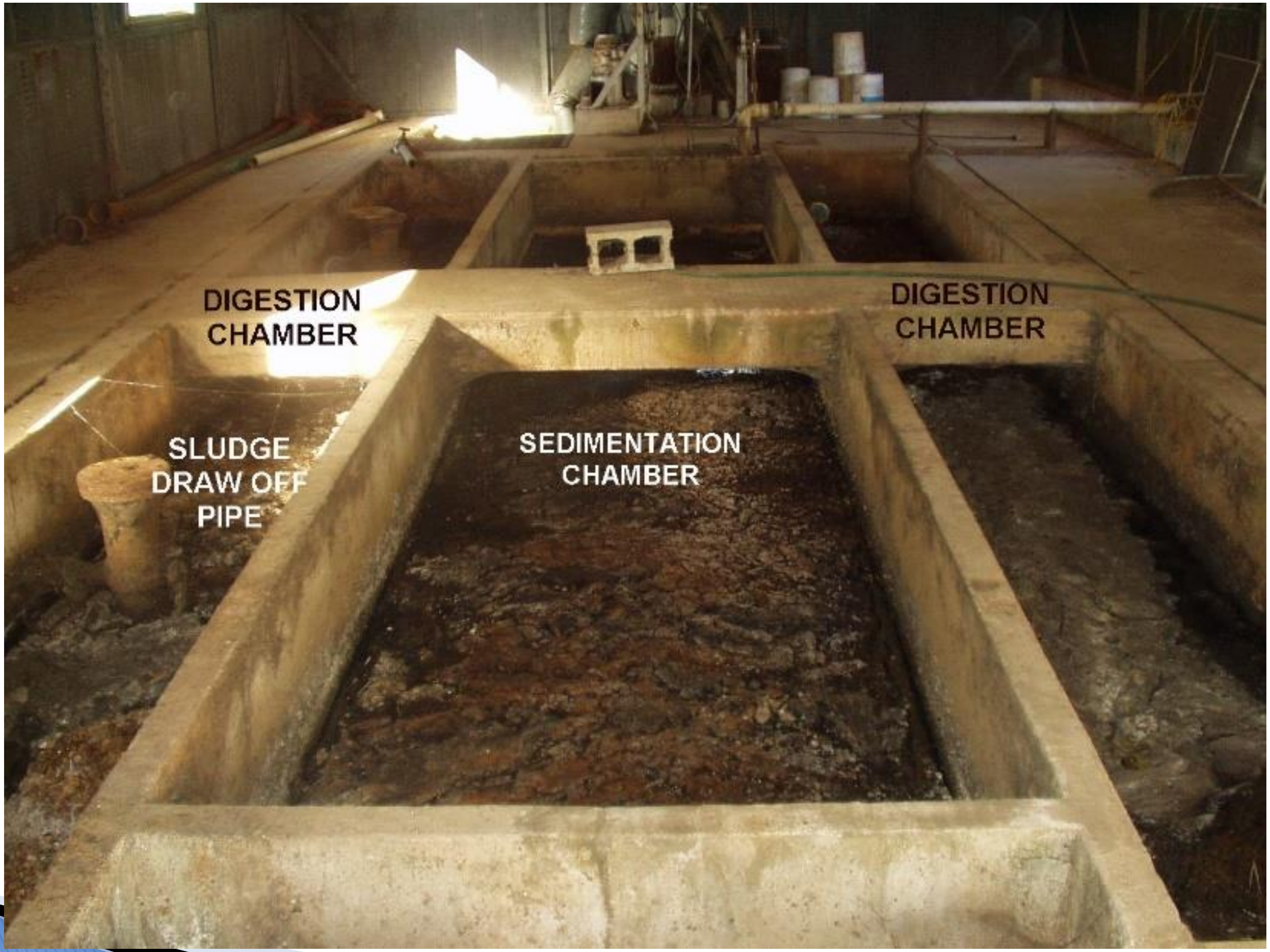
Disadvantages

- Large shallow ponds, 4-10 feet in depth
- Not mixed or aerated → Mostly anaerobic
- Long treatment times, odor emission
- Algae growth → Secondary pollution
- Can work as "Integrated System" for agricultural areas
- Nutrients → Algae → Zooplankton → Fish →
- Not suitable for highly populated areas (< 500,000 gpd)
- Average treatment time = Hydraulic Retention time = HRT = 20 to 200 days → Huge reactor volume

Typical Primary Treatment Technologies – Imhoff Tank



Typical Primary Treatment Technologies – Imhoff Tank



Typical Primary Treatment Technologies – Imhoff Tank

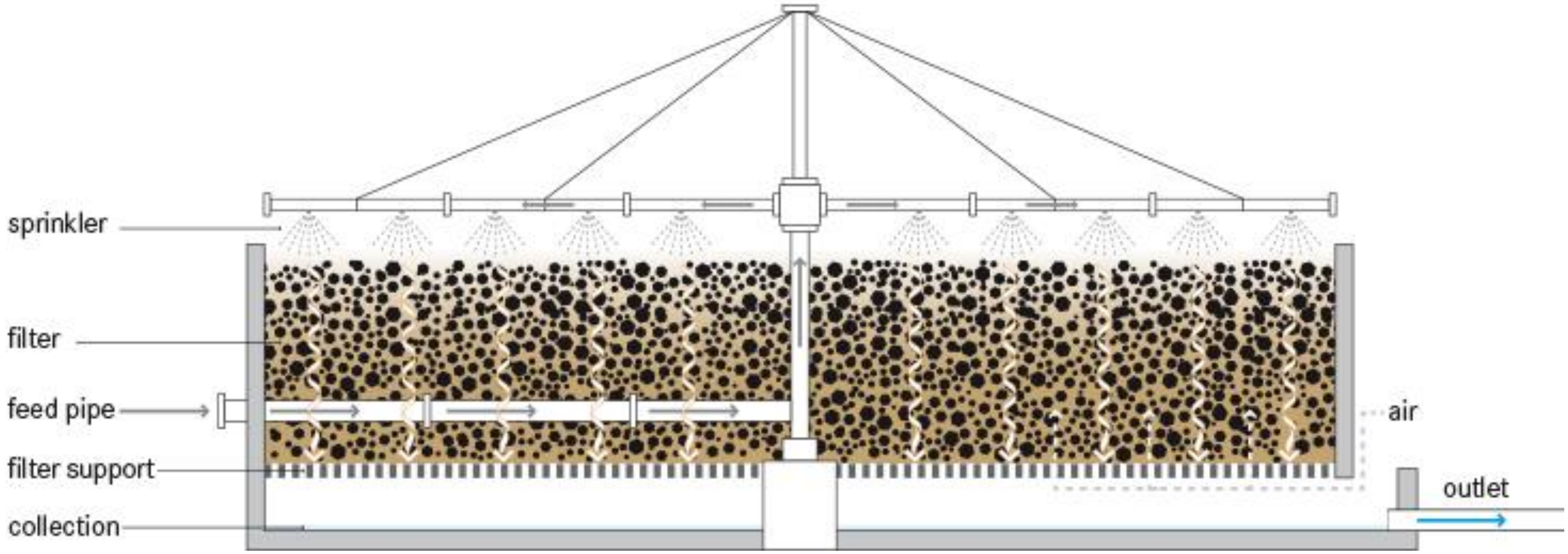
Advantages

- Low capital cost
- Low O&M cost

Disadvantages

- Limited BOD reduction (30-50%)
- Significant odor emission
- Requires additional treatment to meet discharge permit limits
- Sludge in dewatering also has high odor emission
- Not suitable for highly populated areas (< 250,000 gpd)

Typical Primary Treatment Technologies – Trickling Filter



Typical Primary Treatment Technologies – Trickling Filter

Typical Primary Treatment Technologies – Trickling Filter

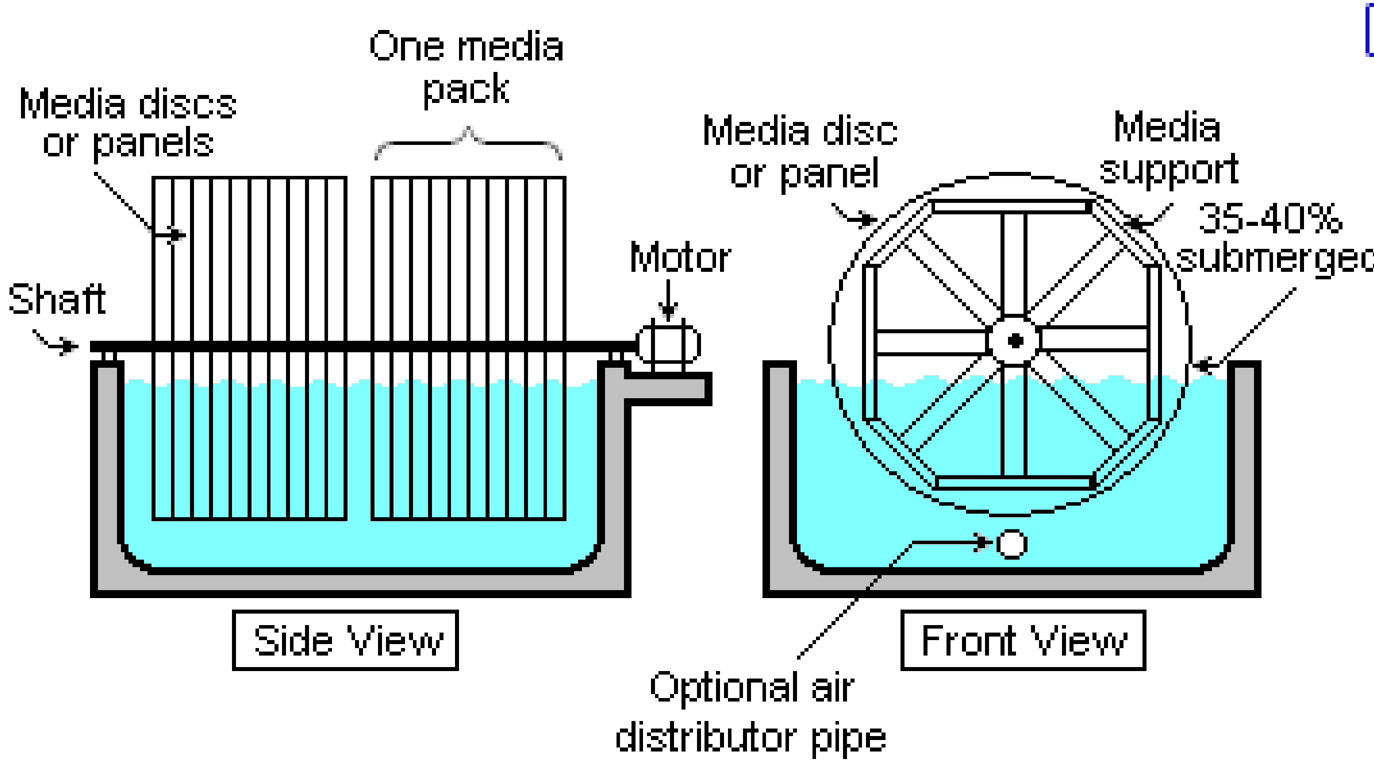
Advantages

- Low capital cost
- Low O&M cost

Disadvantages

- Limited BOD reduction (30-50%)
- Sloughing of biomass can result in large TSS spikes in effluent
- Requires additional treatment to meet discharge permit limits
- Not suitable for highly populated areas (< 500,000 gpd)
- Media replacement required intermittently to handle snail growth

Typical Primary Treatment Technologies – Rotating Biological Contactor



Typical Primary Treatment Technologies – Rotating Biological Contactor

Typical Primary Treatment Technologies – Rotating Biological Contactor

Advantages

- Low capital cost
- Low O&M cost

Disadvantages

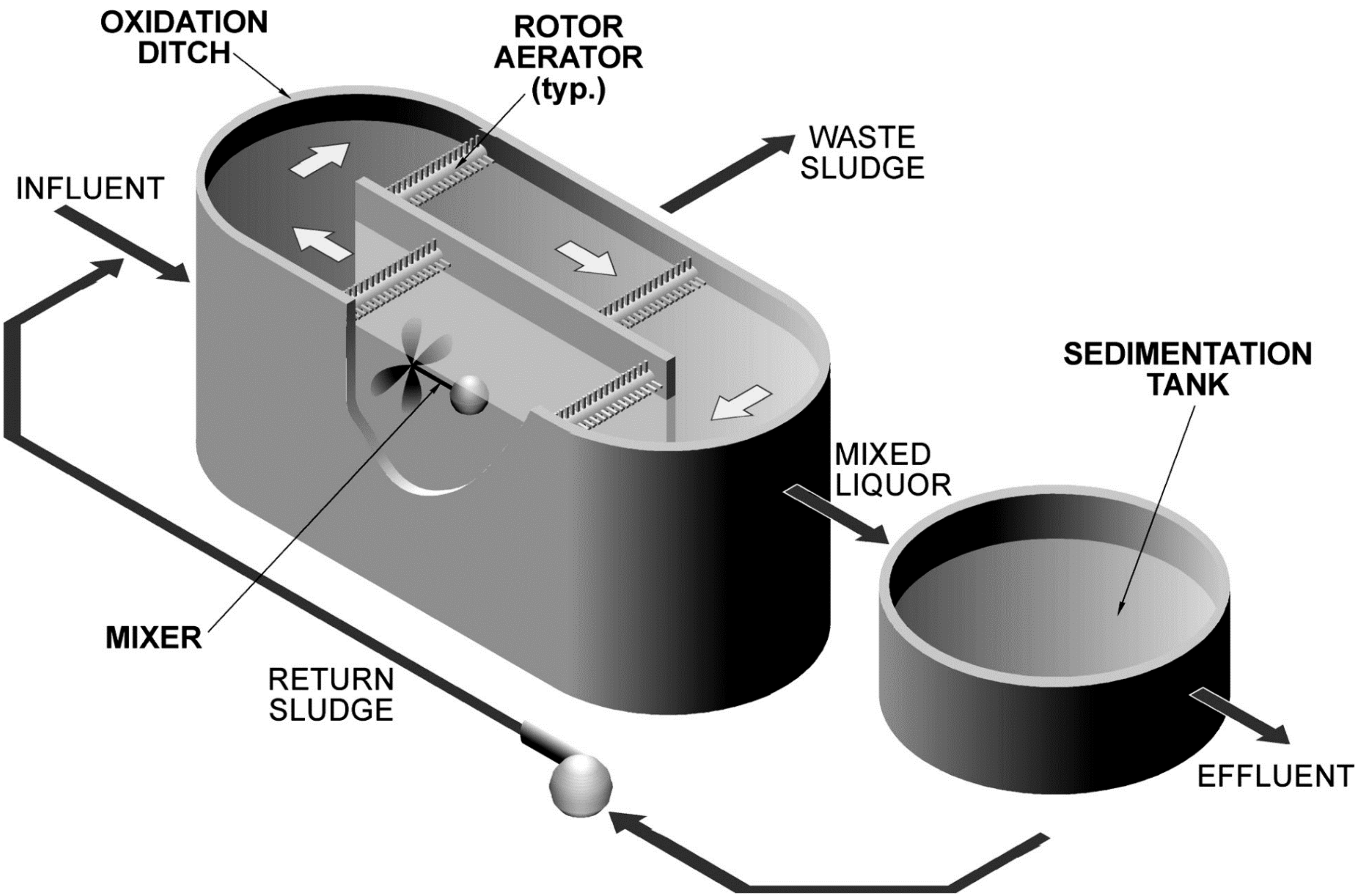
- Limited BOD reduction (30-50%) with old RBC design, can improve to 90+% reduction with newer designs
- Biomass can clog some types of RBC equipment, reducing aeration – long-term maintenance issue
- Requires additional treatment to meet low ammonia or nutrient permit limits
- Not suitable for highly populated areas (< 250,000 gpd)

Typical Secondary Treatment Technologies

Typical Secondary Treatment Technologies

- Conventional Nitrogen Reduction
  - Biological Removal
    - Ammonia (NH_3)
      - Removal via nitrification step in aerobic selector zone, conversion to nitrate (NO_3)

Typical Secondary Treatment Technologies - EA



Typical Secondary Treatment Technologies - EA

Typical Secondary Treatment Technologies - EA

Typical Secondary Treatment Technologies – EA

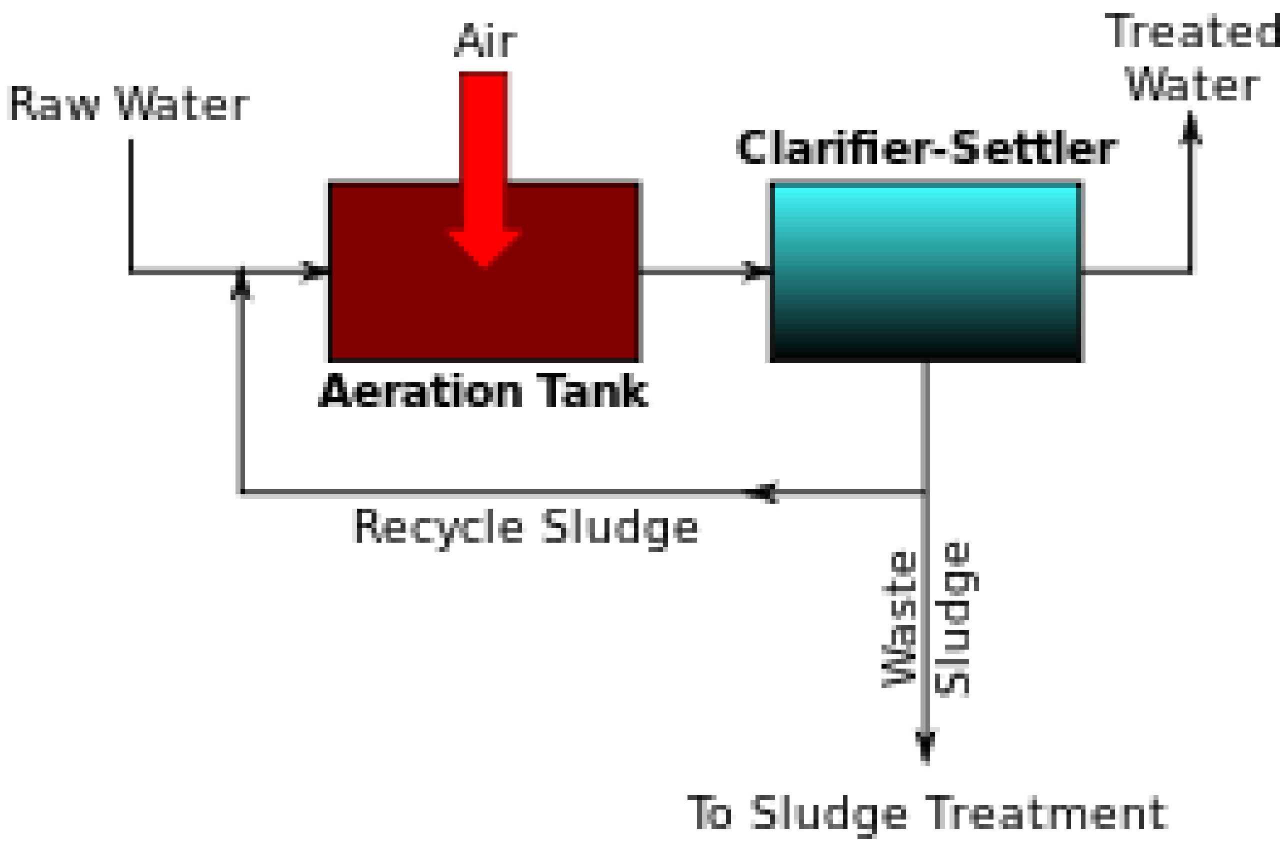
Advantages

- Low O&M cost
- Limited process control required
- Long HRT (20+ hrs) supports dilution of influent spikes

Disadvantages

- Large footprint, requires excess site space
- Shallow basin limits technology for aeration
- High HRT limits use for advanced nutrient removal
- Size of basin limits effective plant size to < 1 MGD

Typical Secondary Treatment Technologies - CAS



Typical Secondary Treatment Technologies - CAS

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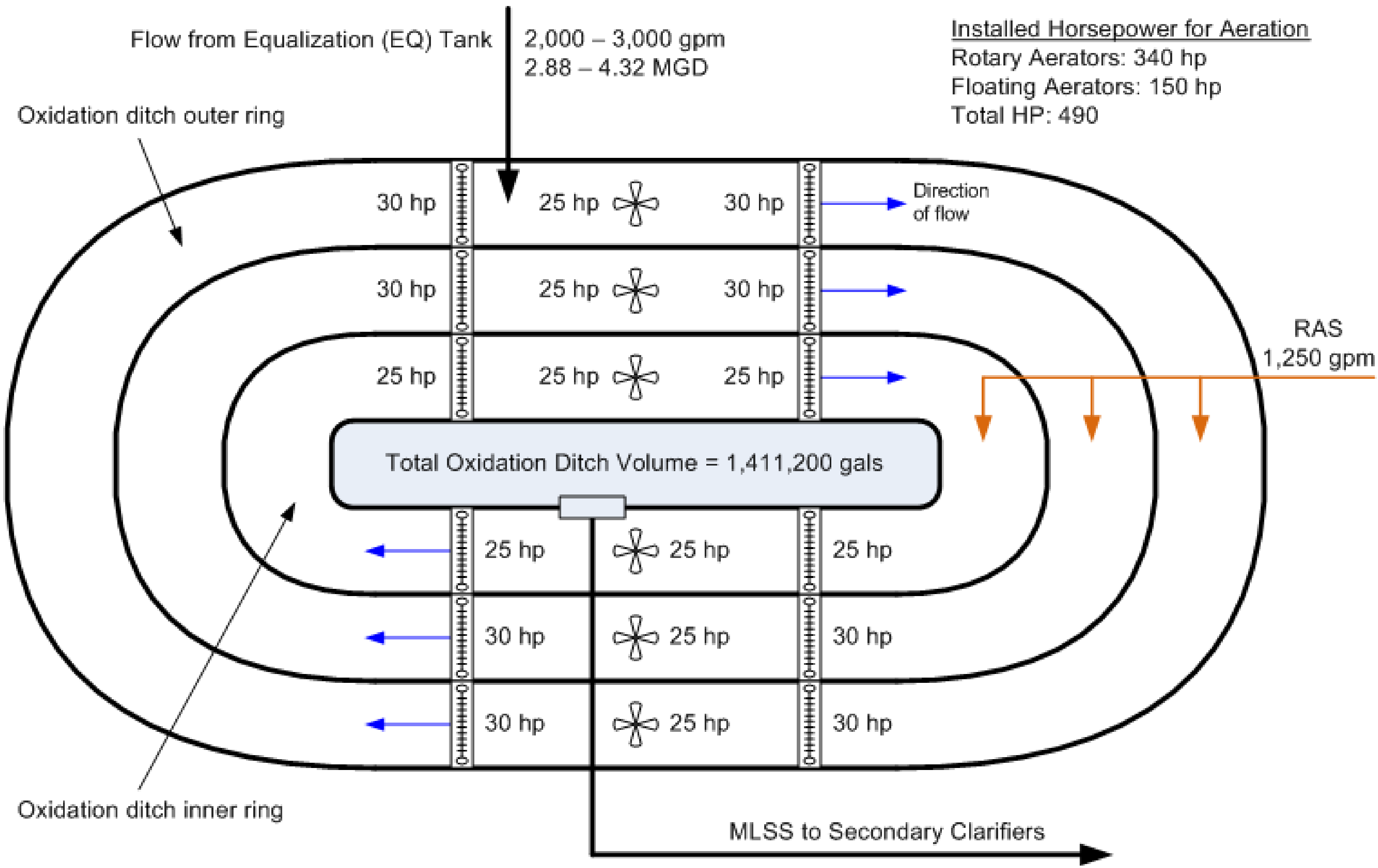


Typical Secondary Treatment Technologies - CAS

Typical Secondary Treatment Technologies – CAS

Advantages

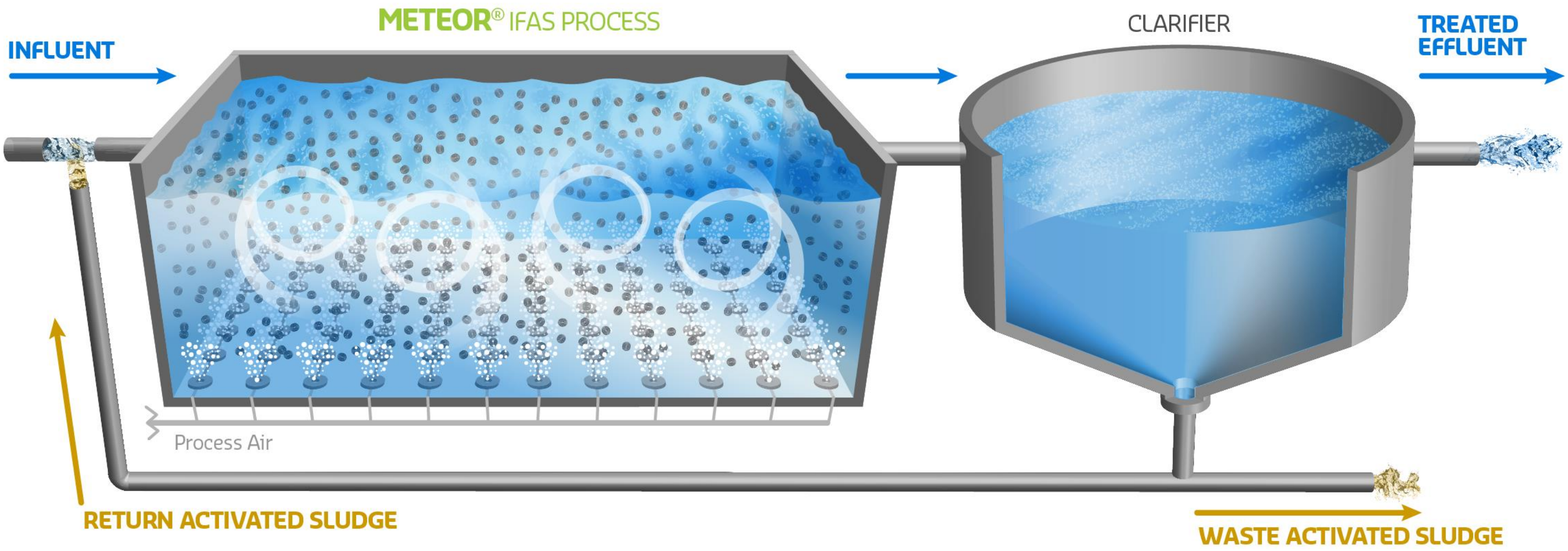
- Smaller footprint than older technologies
- Short HRT can result in process upsets during influent spikes
- Cost effective process for flows from 0.1-100+ MGD

Disadvantages

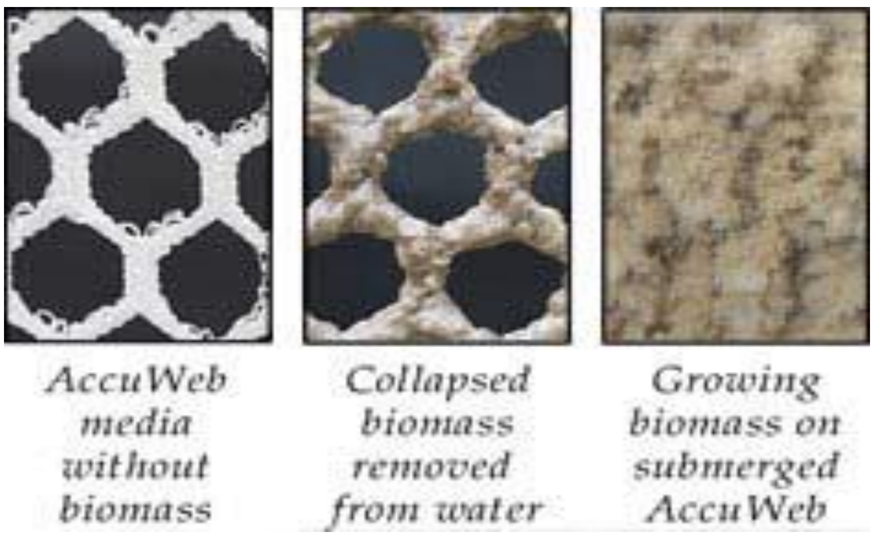
- Higher O&M cost than older technologies
- Increased process control required
- Additional modifications needed to enhance nutrient removal

Typical Secondary Treatment Technologies - IFAS

Integrated Fixed-Film Activated Sludge (IFAS) Process



Typical Secondary Treatment Technologies - IFAS



FIXED MEDIA SYSTEMS

FLOATING MEDIA SYSTEMS

Typical Secondary Treatment Technologies – IFAS

Advantages

- Potential for retrofitting into existing basins
- Can increase aeration basin capacity without additional structures
- Cost effective process for flows from 0.1-100+ MGD

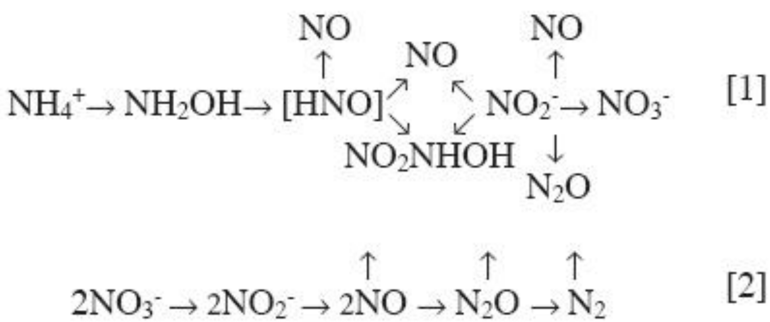
Disadvantages

- Improperly controlled attached growth can turn the aeration basin septic
- Higher O&M cost than older technologies
- Increased process control required
- Additional modifications needed to enhance nutrient removal

Advanced Treatment Technologies

Advanced Treatment Technologies

- Advanced Nitrogen Reduction
  - Biological Removal
    - Ammonia (NH_3)
      - Removal via nitrification step in aerobic selector zone, conversion to nitrate (NO_3)
    - Nitrate (NO_3) and Nitrite (NO_2)
      - Addition of an anoxic (zero free dissolved oxygen) selector zone upstream of the aerobic selector zone



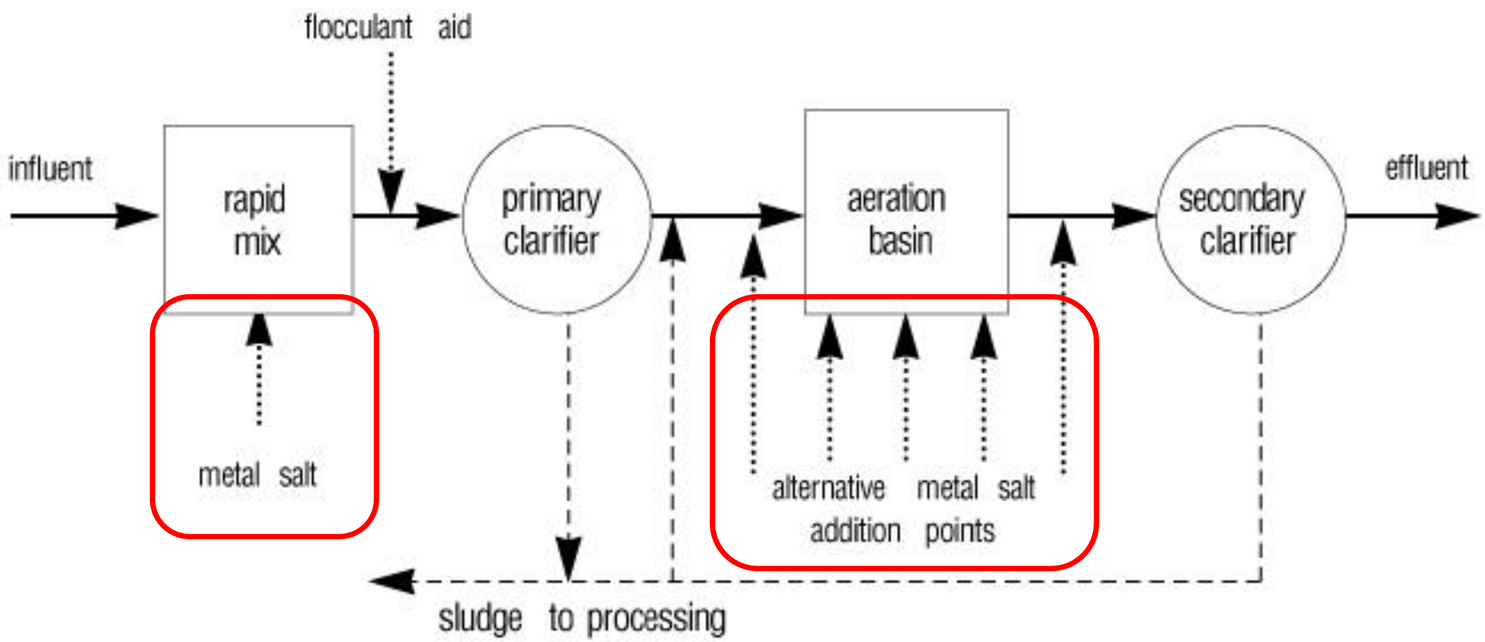
Advanced Treatment Technologies

- Phosphorus Reduction
  - Chemical Removal
    - Can remove orthophosphate (PO_4, HPO_4, H_2PO_4) via chemical bonding and precipitation
    - Addition of a metal salt such as alum (aluminum sulfate) or ferric (ferric sulfate) can bond with phosphorus
    - Can typically remove down to 0.5-1.0 mg/L

    - $Al + PO_4 \Rightarrow AlPO_4$
      - Works best at a pH range of 5-7
      - Potential nitrification impacts
    - $Fe + PO_4 \Rightarrow FePO_4$
      - Works best at a pH range of 6.5-7.5

Advanced Treatment Technologies

Fig. 1: **Multiple point application flow diagram**



Source: Bowker and Stensel (1990)

Advanced Treatment Technologies

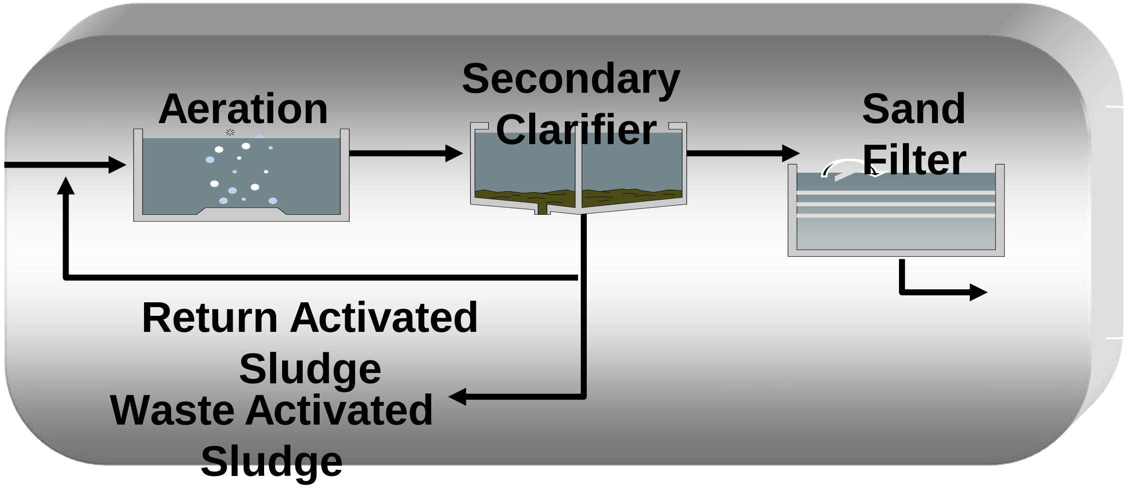
- Chemical TP Removal

- Advantages
  - Reliable
  - Low levels of TP in effluent possible
  - Retrofit for existing plant feasible for most mechanical plants
- Disadvantages
  - Cost of chemical feed system
  - Cost of chemicals
  - Substantial additional sludge production
  - Chemical sludge reuse or disposal may be more difficult
  - May need to adjust pH

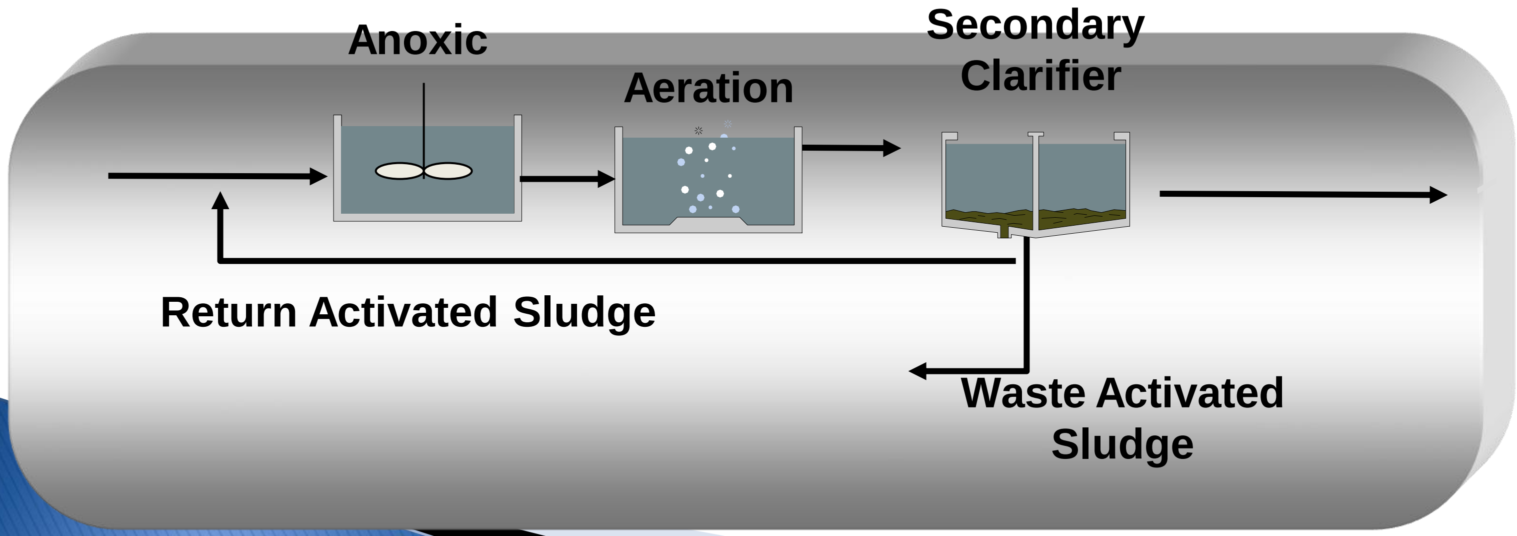
Advanced Treatment Technologies - BNR

- How can phosphorus be removed at a WWTP?
  - Biological Removal
    - Orthophosphate
      - Biomass does not readily absorb orthophosphate, the orthophosphate must be converted to polyphosphate for uptake
      - Conversion occurs via breakdown in an anaerobic selector zone (no presence of oxygen), along with the production of volatile fatty acids (VFAs)
    - Polyphosphate
      - Biomass in the aerobic selector zone called phosphorus accumulating organisms (PAOs) absorb excess phosphorus while consuming VFAs
    - Can typically remove phosphorus down to 0.5 mg/L

Advanced Treatment Technologies - BNR

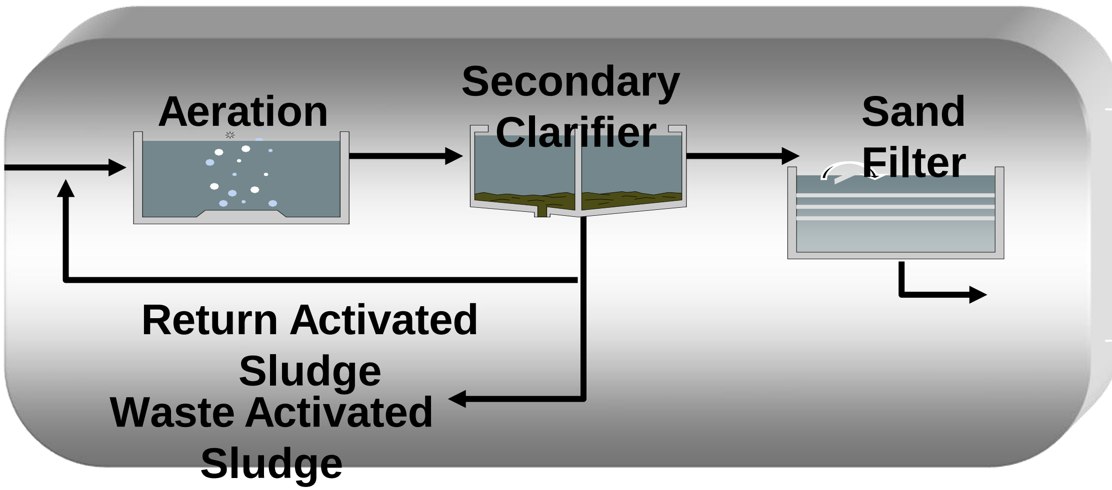


CAS

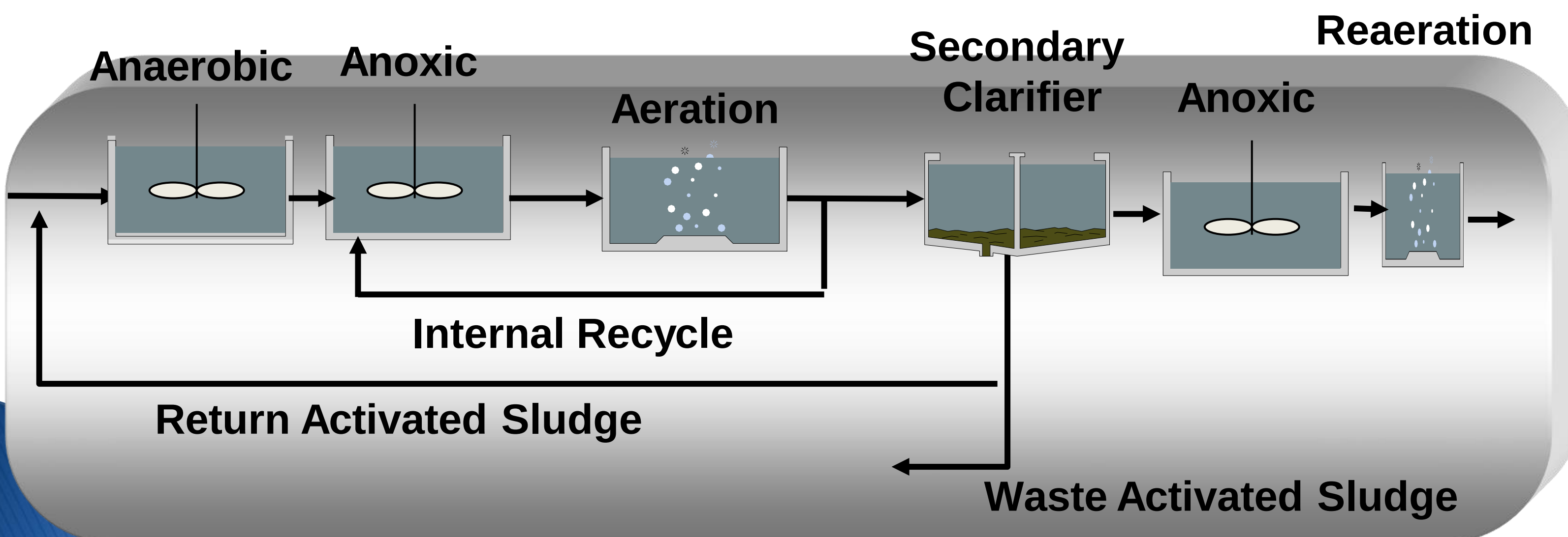


MLE Process

Advanced Treatment Technologies - BNR

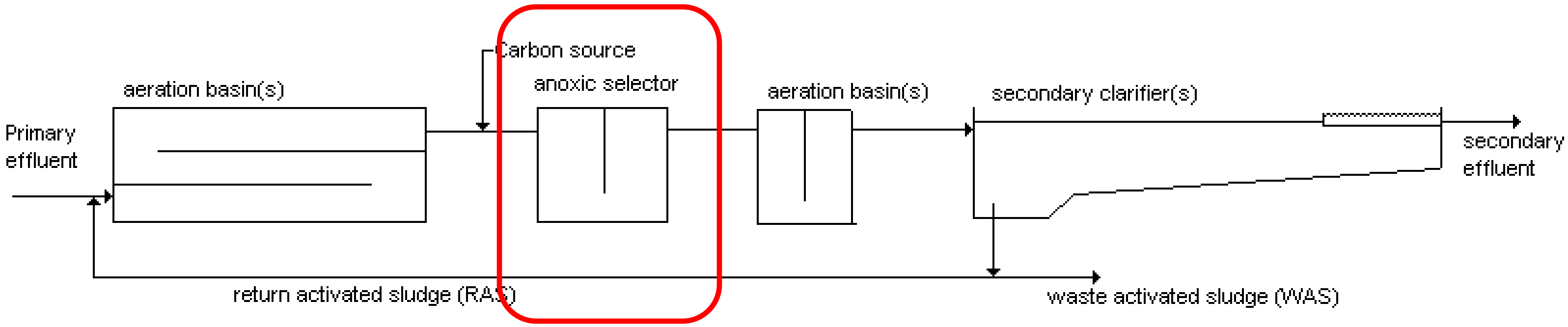


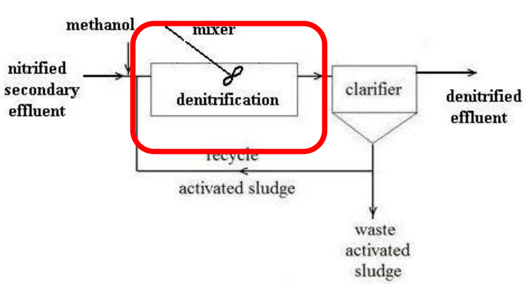
CAS



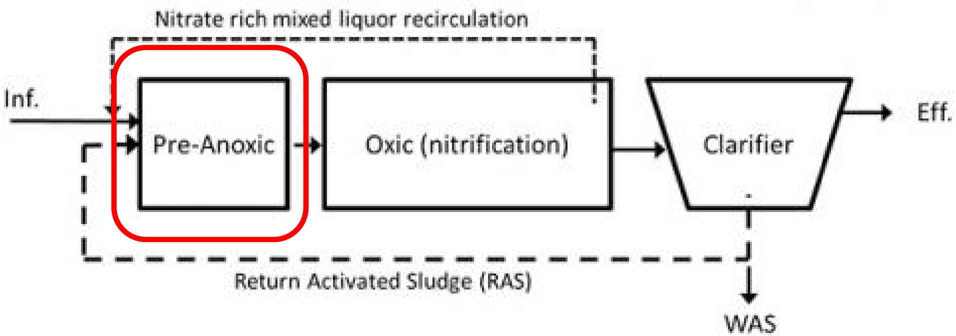
Bardenpho Process

Advanced Treatment Technologies - BNR





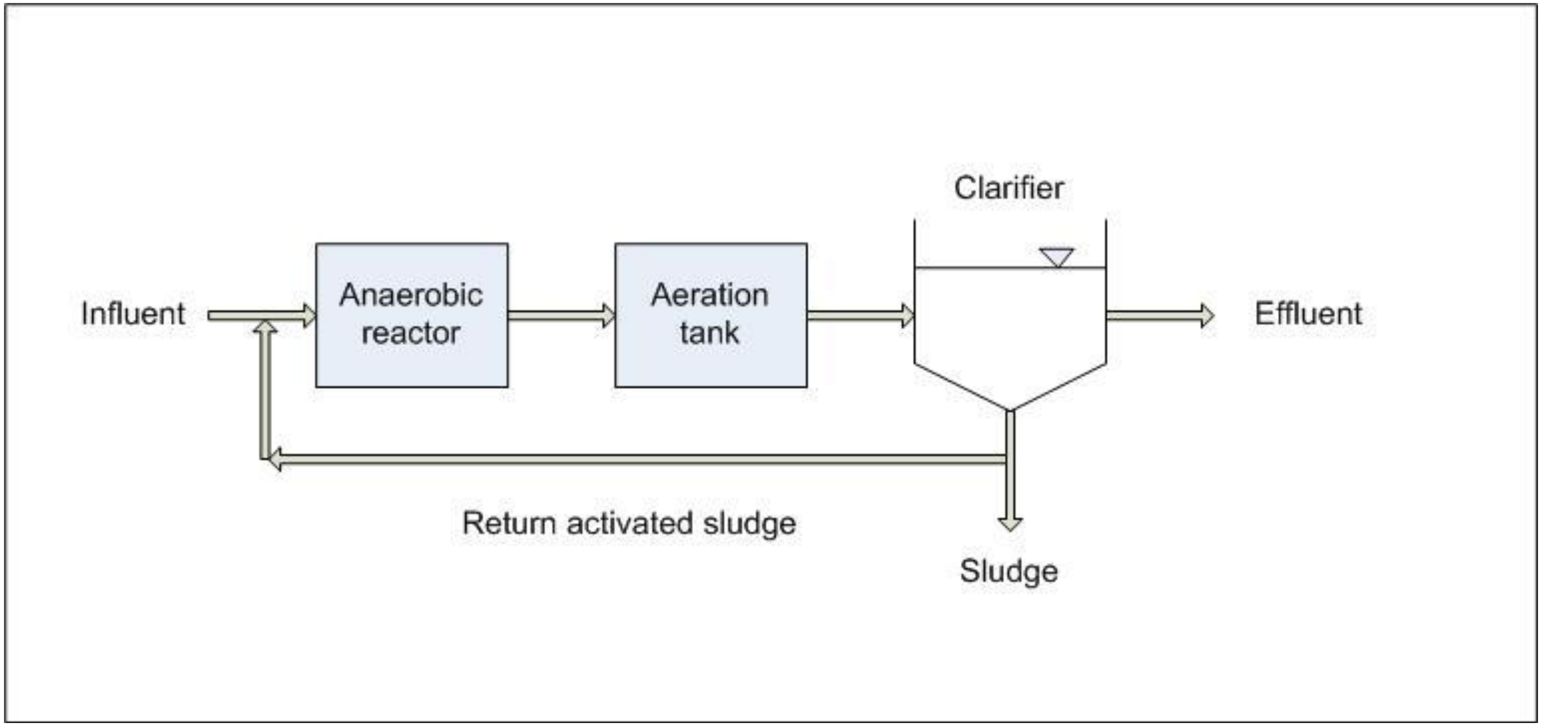
Denitrification Process Flow Diagram



Modified Ludzack-Ettinger (MLE) Process

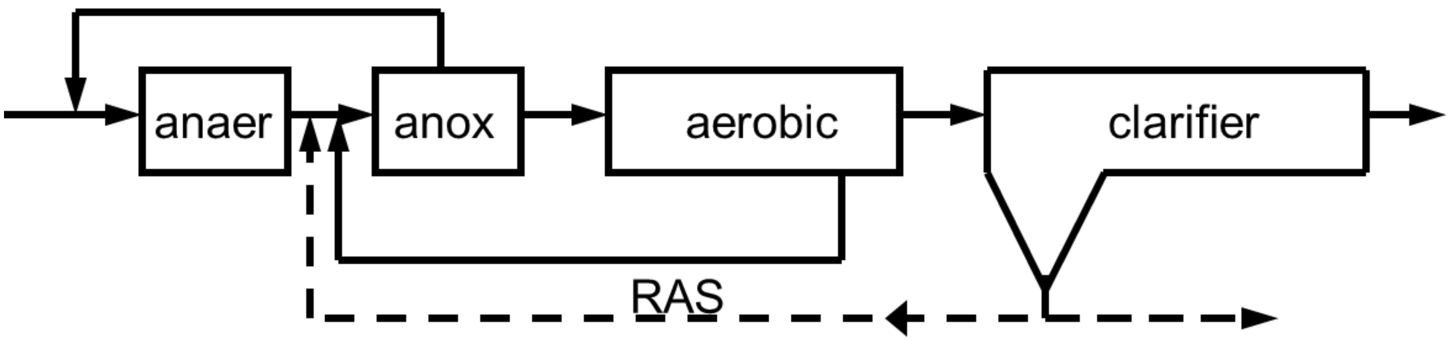
Advanced Treatment Technologies - BNR

- Anaerobic-Oxic (AO) Process



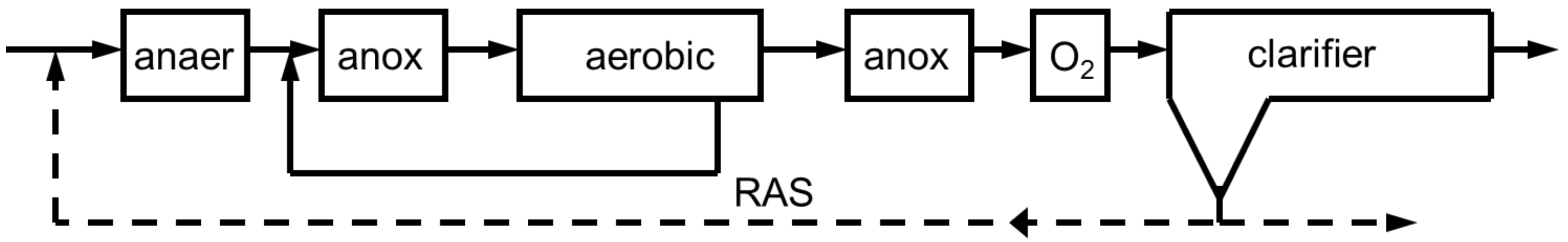
Advanced Treatment Technologies - BNR

- University of Capetown (UCT) Process



Advanced Treatment Technologies - BNR

- Bardenpho Process



Advanced Treatment Technologies - BNR

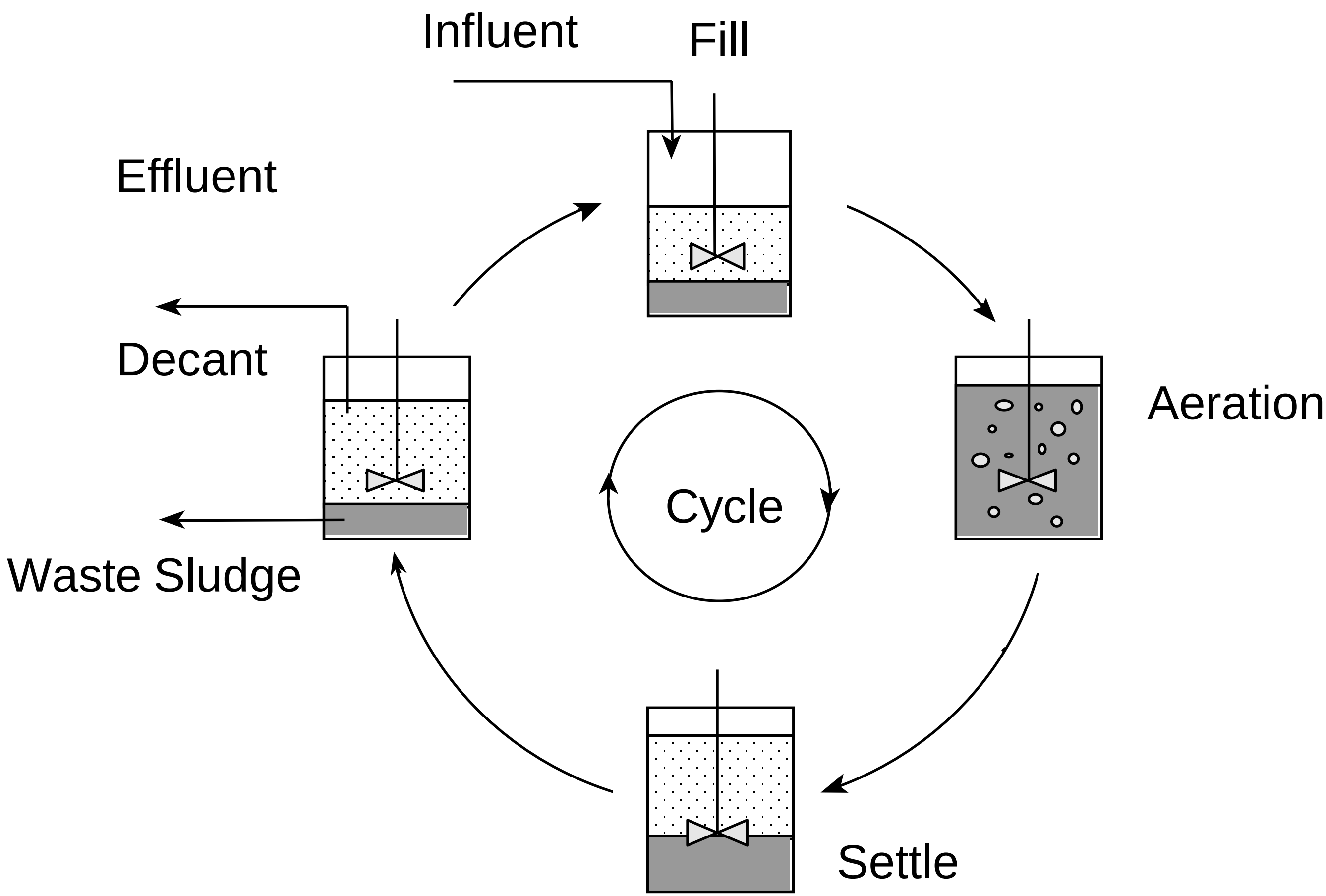
Advantages

- Reliable
- Internal recycles can return alkalinity and maintain pH
- Internal recycles reduce impacts from shock loading
- Little additional sludge production

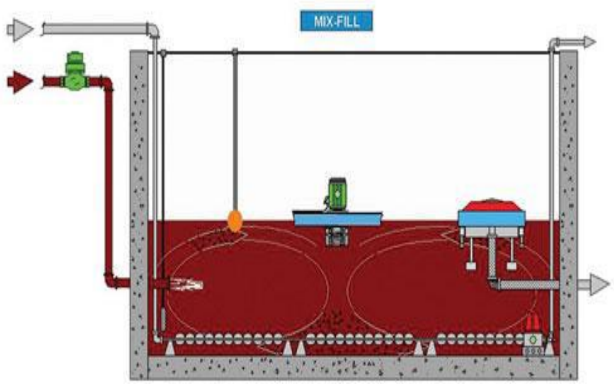
Disadvantages

- Requires minimum BOD:P ratio of 25:1 to be effective
- Cost of BNR equipment and structural modifications
- Effluent TP levels of 0.5 mg/L or less will likely require chemical and or filtration polishing
- Retrofit for existing plant may not be feasible for some plants

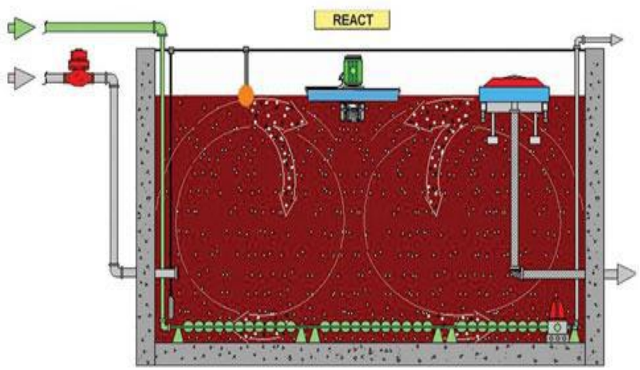
Advanced Treatment Technologies - SBR



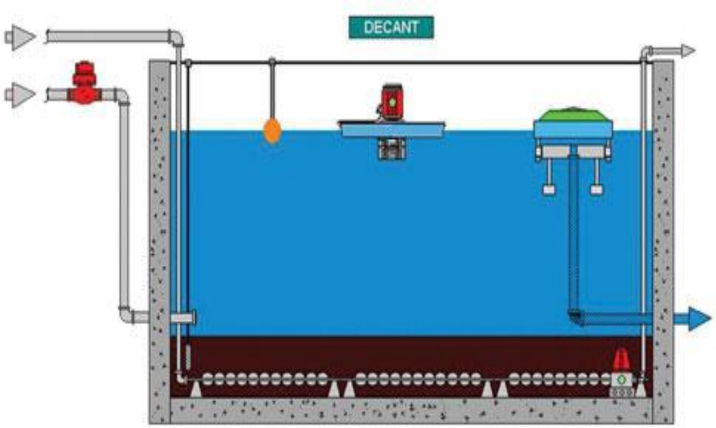
Advanced Treatment Technologies - SBR



FILL

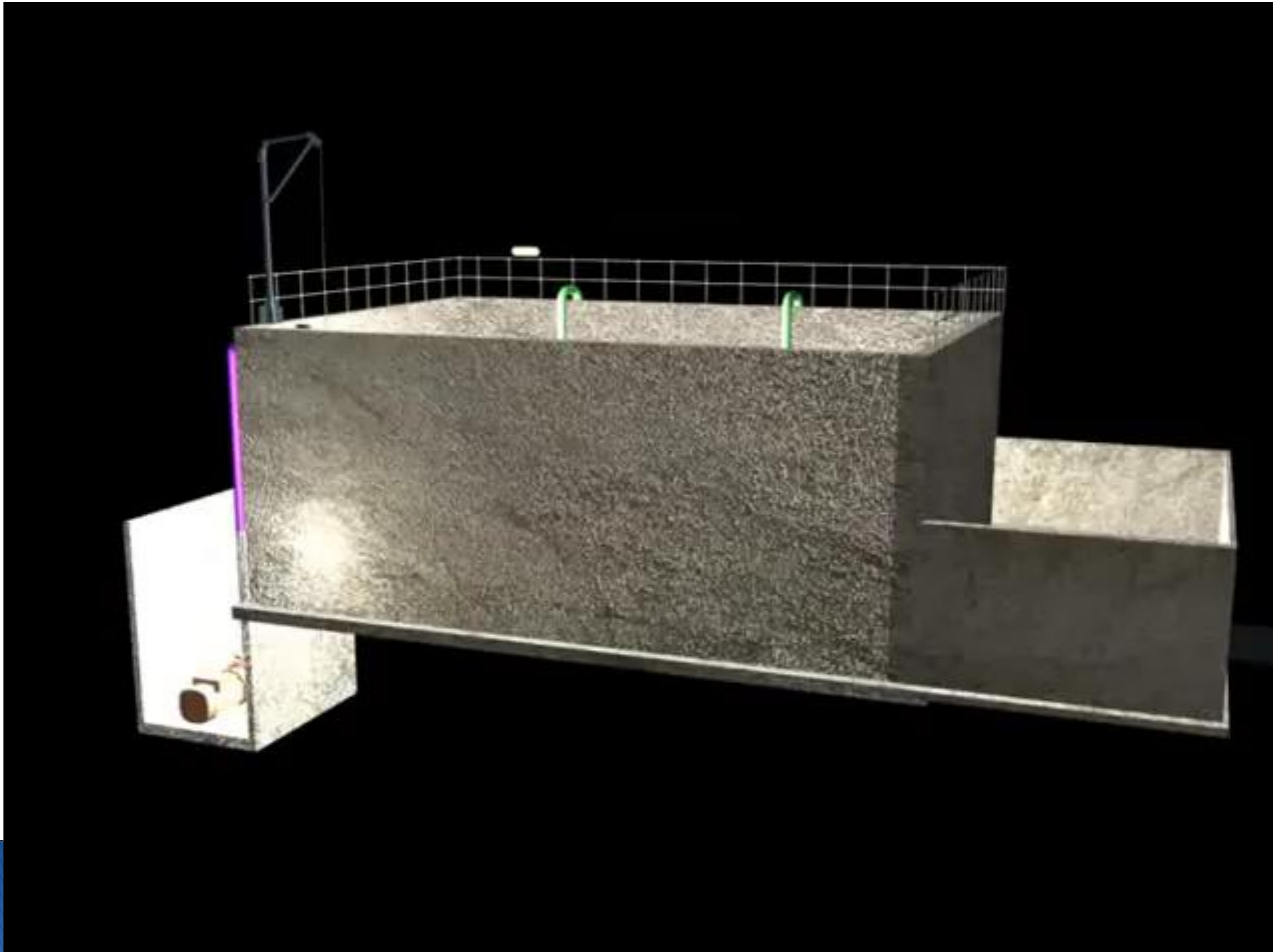


REACT



SETTLE/DECANT

Advanced Treatment Technologies - SBR



Advanced Treatment Technologies - SBR

Advanced Treatment Technologies - SBR

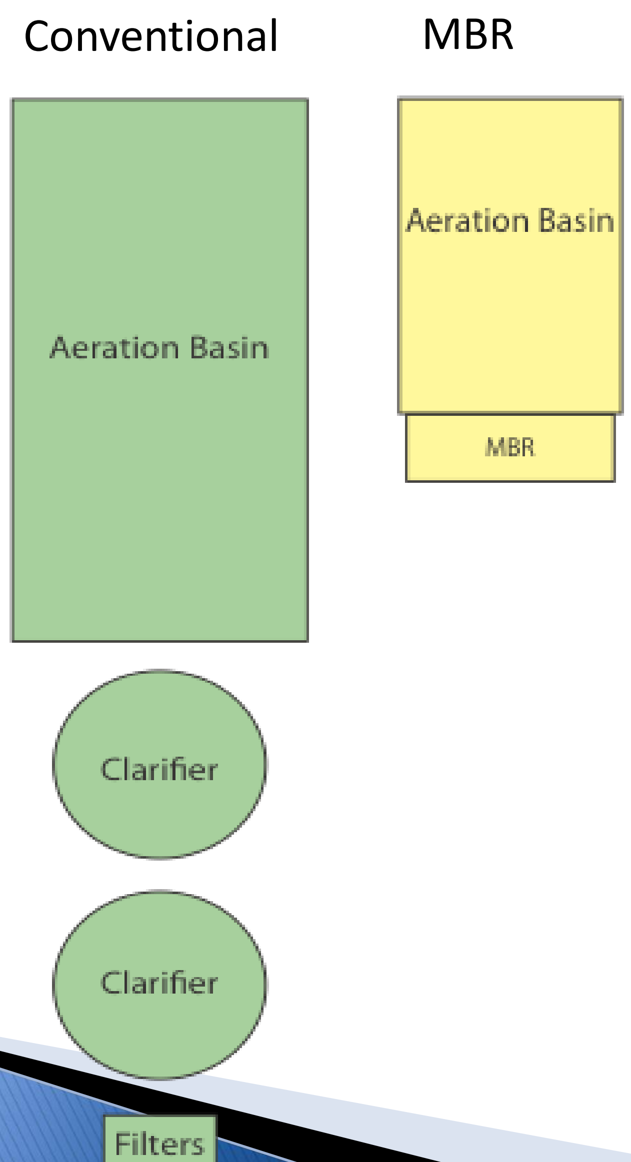
Advantages

- All phases occur in one reactor basin
- Phases separated only by time
- No need for additional clarifier
- Phases of operation can be reduced to support up to 4Q flow
- Potential to implement BNR by modifying phase setpoints

Disadvantages

- Not a continuous flow process – batch flow
- Still susceptible to biological upsets

Advanced Treatment Technologies - MBR



MBR Issues

- Scum control
- ***Pretreatment!!!***
- Peak flows
- Air scour (HP)
- Membrane cleaning
- Membrane replacement

Conventional Issues

- Scum control
- Sludge settleability
- Weir cleaning
- Filter cleaning
- Filter replacement/maintenance

Advanced Treatment Technologies - MBR

Advanced Treatment Technologies - MBR

- MBR separates solids and filters in **one** step
- Why use MBR?
  - More efficient at solids separation than clarifiers
  - Bulking is no longer a concern!
  - Advanced membrane filtration is built-in, Type I (3 NTU max) reuse water requirements can easily be met
    - Typical MBR effluent turbidity is 0.1-0.3 NTU
  - If considering additional polishing in the future, MBR quality effluent may be required
- How does MBR work?
  - Sludge builds up on the surface of the membrane. A pump draws a vacuum through the membrane (can also flow by gravity), drawing clean water through the membrane.

Advanced Treatment Technologies - MBR

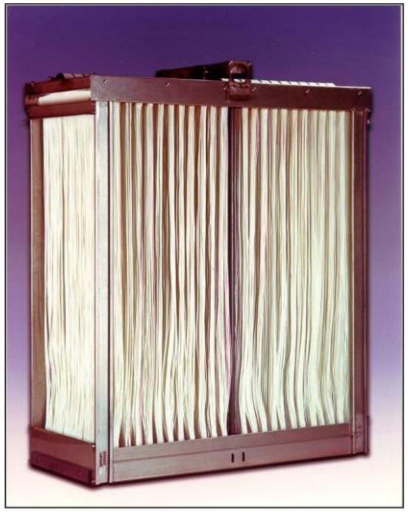
Equipment Manufacturer	Membrane Manufacturer	Membrane			Global Experience		
		Type	Pore Size (um)	Material	No.	Largest MGD	Longest Years
Suez	ZeeWeed 500 Series	Hollow Fiber	0.04	PVDF	460+	57.6 (12 MGD max in TX)	22
Ovivo/Kubota	Kubota	Flat Sheet	0.4	CPE	5,600+	42.7 (3 MGD max in TX)	23
Ovivo	Microdyne	Flat Sheet	0.1	PVDF	53	10.0 (0.8 MGD max in TX)	5
Evoqua	Memcor	Hollow Fiber	0.1	PVDF	138	28.5 (0 in TX)	16
Kruger	Toray	Flat Sheet	0.08	PVDF	8	1.0 (0 in TX)	10
Koch	Koch	Hollow Fiber	0.04	PVDF	8	3.4 (O in TX)	8
H2O	Multiple Options	Flat Sheet or Hollow Fiber	0.04-0.1	Mult.	29	4.6 (0.1 MGD max in TX)	12

Other manufacturers with limited U.S. (higher outside U.S.) experience:

- NoritXFlow
- Westech – Partnered with Alta Laval Membrane
- A3-USA
- Fibracast

Advanced Treatment Technologies - MBR

- System Type – Hollow Fiber



Advanced Treatment Technologies - MBR

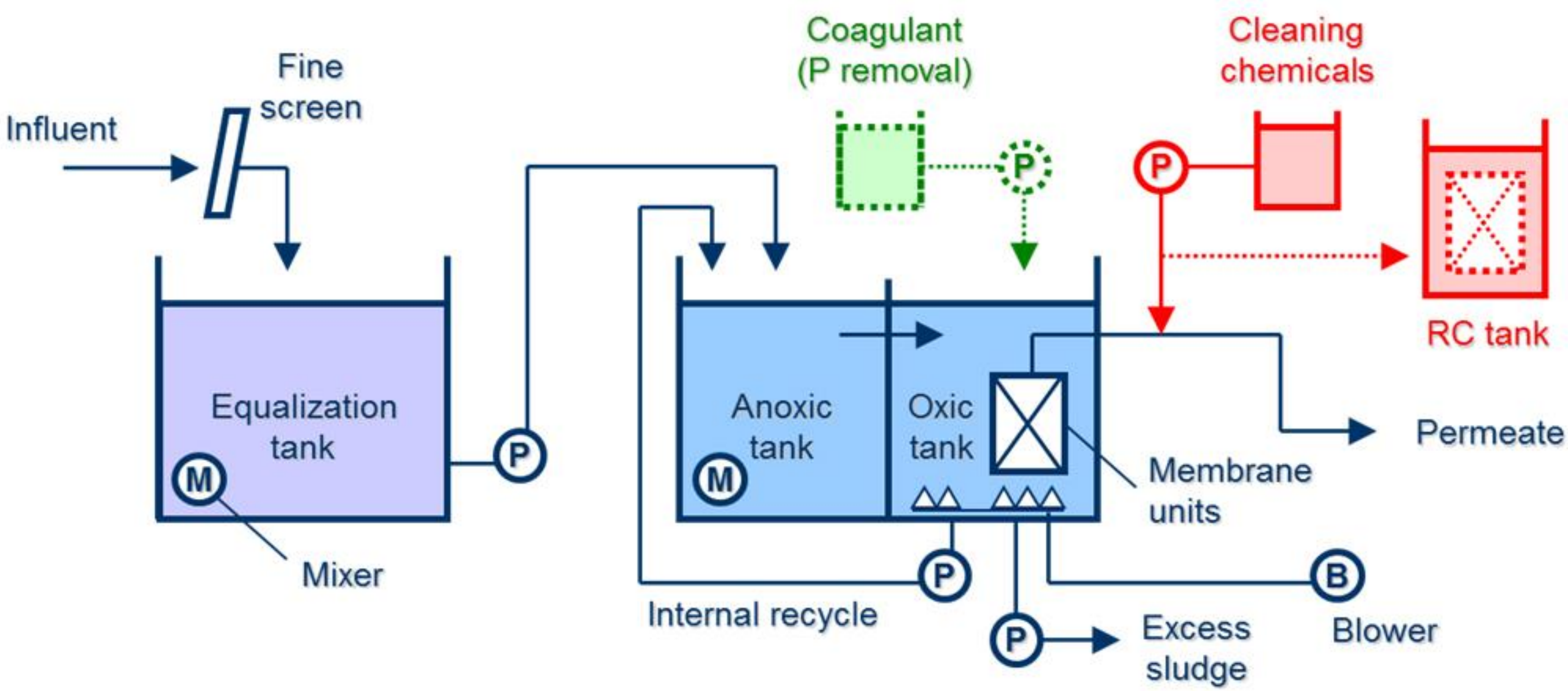
- System Type – Flat Sheet





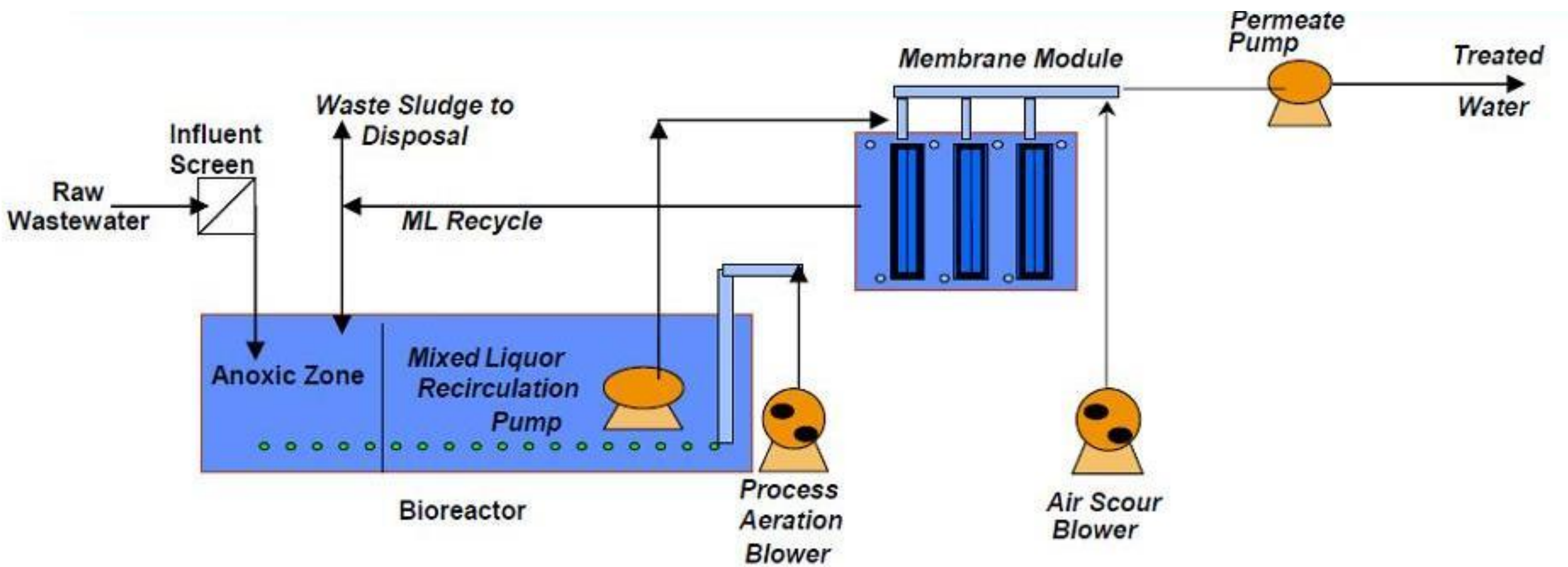
Advanced Treatment Technologies - MBR

- Historical Compact MBR Design



Advanced Treatment Technologies - MBR

- Historical Custom MBR Design



Advanced Treatment Technologies - MBR

Advantages

- Extremely small footprint due to high MLSS
- Sludge bulking not really a problem!
- Type I reuse built-in
- Potential for potable reuse – especially for hollow fiber

Disadvantages

- Typically highest capital cost
- Typically highest O&M cost
- Flow limitation to 2Q – requires flow equalization
- Membrane replacement cost in 8-10 years

Technologies on the Horizon

Technologies on the Horizon – Ceramic MBR

- Ceramic MBR Design

Technologies on the Horizon – Ceramic MBR

Advantages

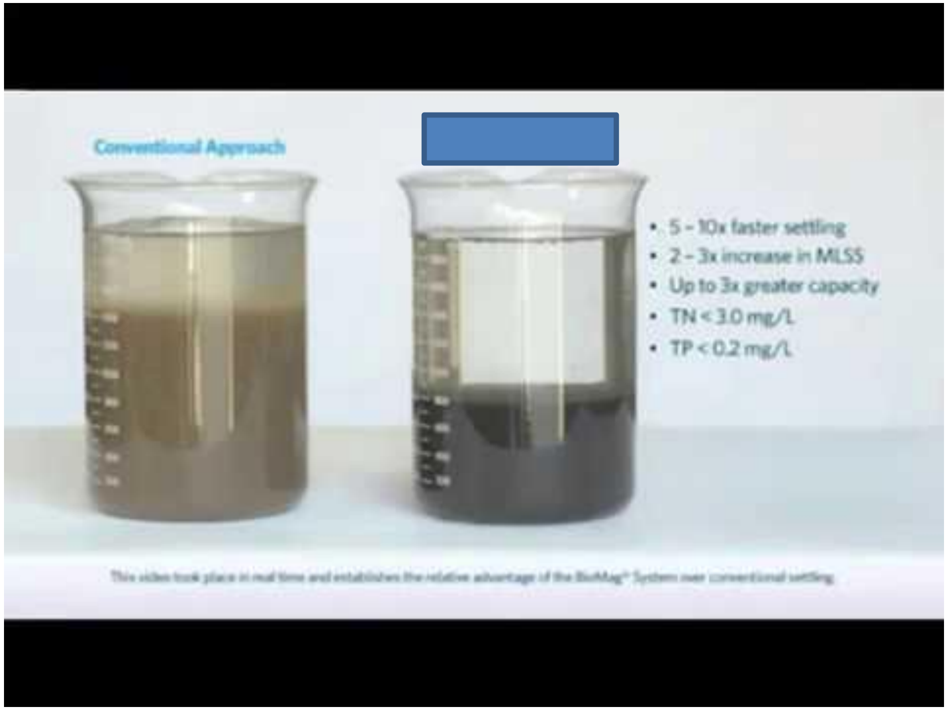
- Extremely small footprint due to high MLSS
- Sludge bulking not a problem!
- Type I reuse built-in
- Possibility for potable reuse
- Membrane life extended to 20+ years

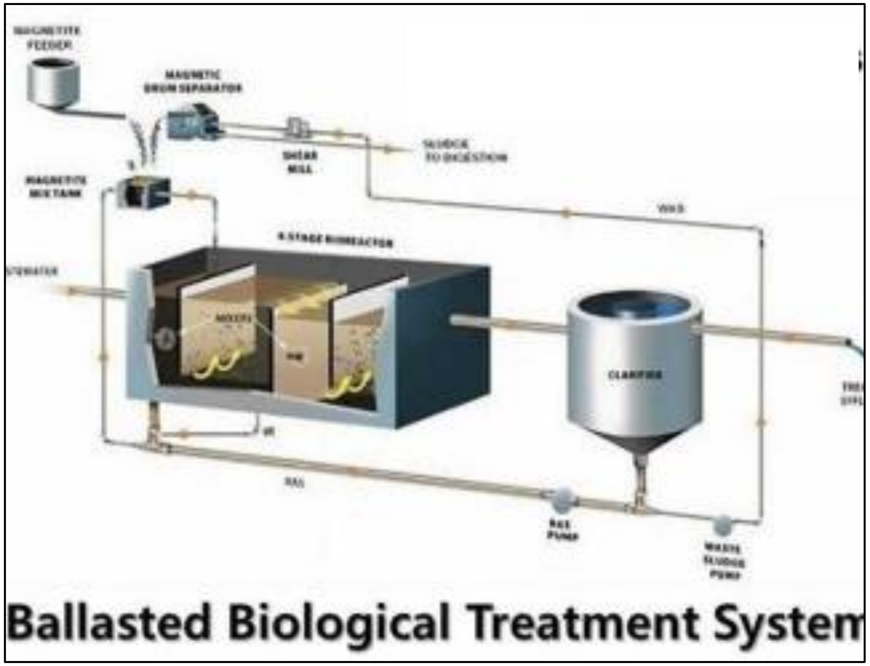
Disadvantages

- Significantly higher capital cost than everything else
- Highest O&M cost
- Flow limitation to 2Q – requires flow equalization
- No installations in TX yet

Technologies on the Horizon – Magnetite Ballasted Treatment

- Magnetite Ballasted Biological Treatment System





Technologies on the Horizon –
Magnetite Ballasted Treatment

- Magnetite Ballasted Biological Treatment System

Technologies on the Horizon – Magnetite Ballasted Treatment

- Magnetite Ballasted Biological Treatment System

Technologies on the Horizon – Magnetite Ballasted Treatment

Advantages

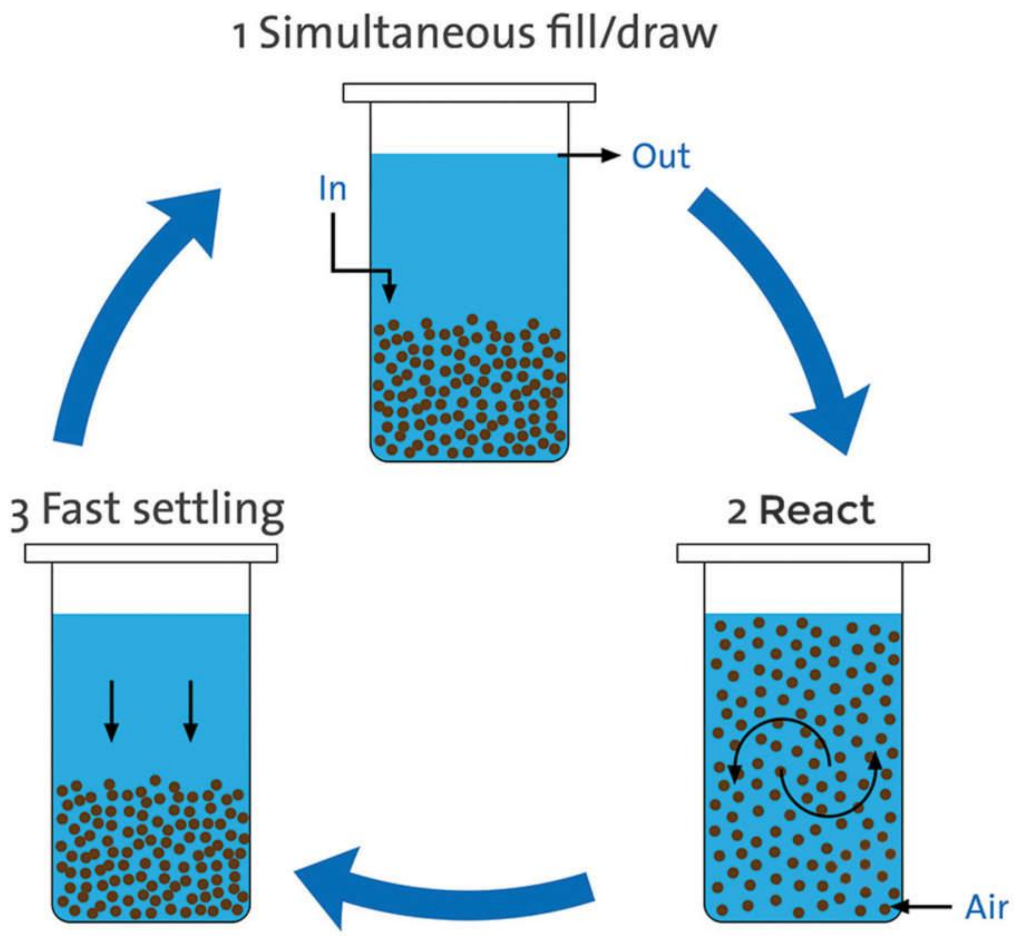
- Can retrofit existing basins to increase capacity – most cost effective for expansion projects
- Magnetite enhancement can increase hydraulic throughput up to 10Q
- Type I reuse turbidity capability
- Can recycle up to 95% of original magnetite

Disadvantages

- Higher capital cost than everything but membranes
- Higher O&M cost than older technologies
- Only 1 installation in TX so far, with several more this year – this has been vetted already by TCEQ though

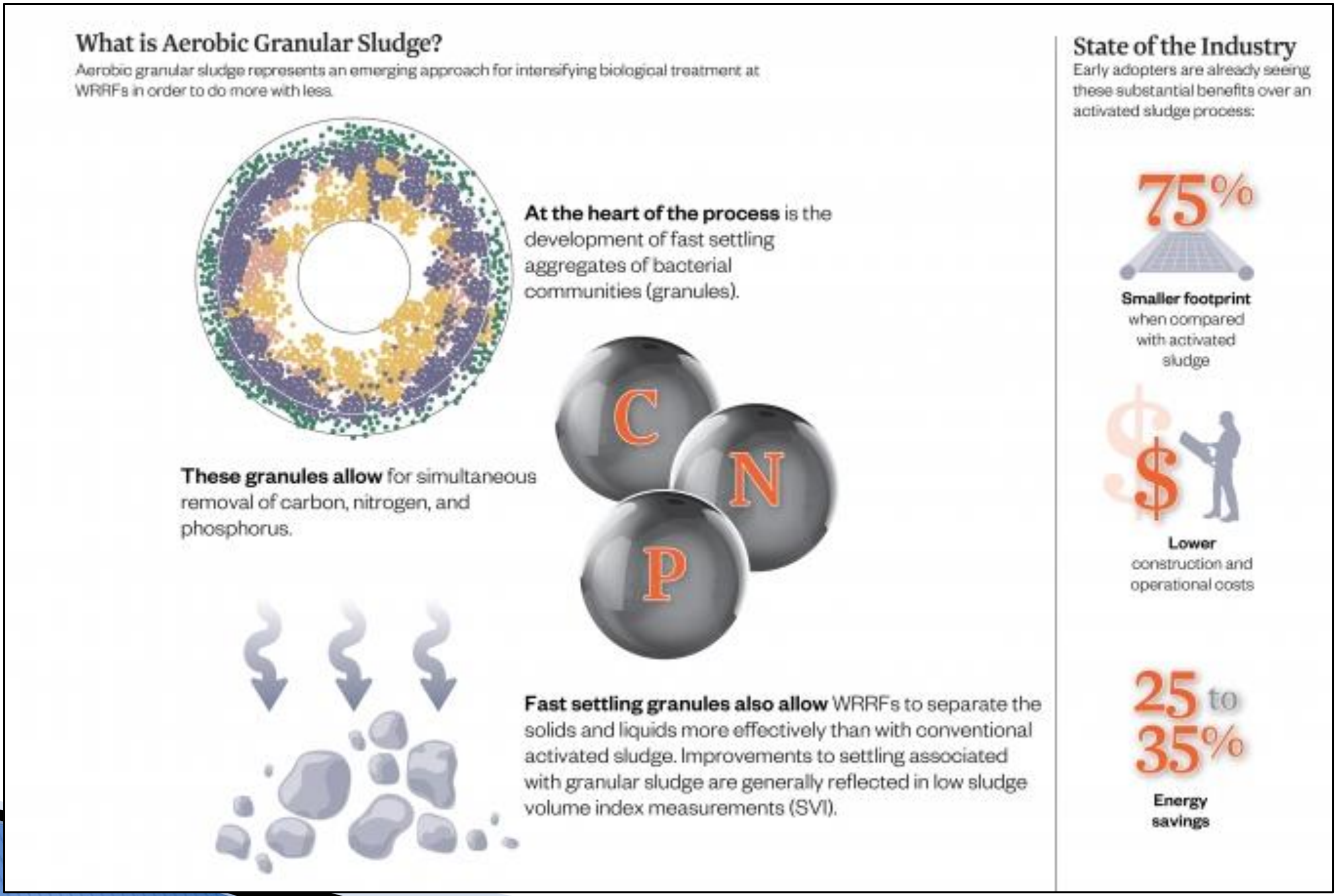
Technologies on the Horizon – Granular Biological Treatment

- Granular Biological Treatment System



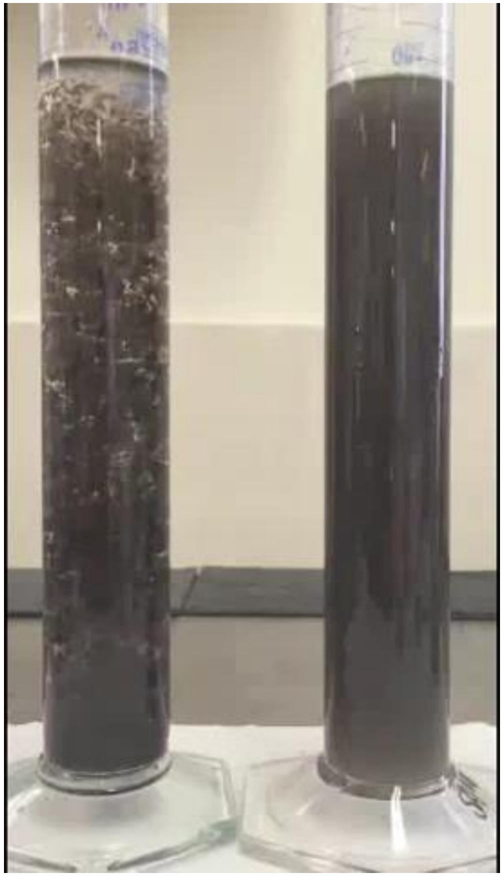
Technologies on the Horizon – Granular Biological Treatment

- Granular Biological Treatment System



Technologies on the Horizon – Granular Biological Treatment

- Granular Biological Treatment System



Technologies on the Horizon – Granular Biological Treatment

Advantages

- Can retrofit existing basins to increase capacity – cost effective for both expansion and new plant projects
- Process does not require clarification!
- Type I reuse turbidity capability
- Lower capital cost when comparing against other technologies in a holistic approach
- Lower O&M cost than newer technologies for the same level of treatment

Disadvantages

- No installations in TX yet, also still has to be vetted by TCEQ (anticipate additional bonding requirements)

Summary

Summary

- Treatment technologies should be selected based on anticipated permit needs and/or needs for reuse
- Technologies should be selected based on the appropriate treatment goals and operational capabilities
- Newer is not necessarily better…however, newer can sometimes improve quality at a lower cost!