Texas Water Utilities Association Permian Basin District

Fundamentals of Nutrient Removal and Membrane Bioreactors

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Joshua Berryhill, P.E.

Enprotec / Hibbs & Todd

Topics

- Fundamentals of Nutrient Removal (NR)
- Fundamentals of Membrane Bioreactors (MBR)
- Q&A

Introduction

- Joshua Berryhill, P.E.
  - Associate VP and Technical Director for eHT
  - Leads design, commissioning and evaluation efforts for all advanced water and wastewater facility designs for eHT
    - Design of one of the largest BNR facilities in Texas (22 MGD)
    - Design of one of the largest MBR facilities in Texas (12 MGD, one of the largest in the US)
    - Design of one of the largest potable reuse facilities in Texas (7 MGD)
    - Design of one of the largest surface water desalination facilities in Texas (16.75 MGD)
    - Design of one of the largest radionuclide treatment facilities in Texas (3 MGD)

Background

- Why are we discussing Nutrient Removal and Membrane Bioreactor technologies?
  - Tighter Federal and State regulations
  - Potential nutrient limits on the horizon
  - Drought -> Demands for reuse water
  - Increased conservation -> higher wastewater concentrations
  - Less susceptible to shock loading
  - Cost of membranes has become more competitive with conventional treatment
  - Site space availability for expansions/upgrades

    - Tired of discussing RO…?

NR – Current Permitting

- What are typical current permit limits?
  - Lagoon Systems
    - BOD – 30-60 mg/L
    - TSS – 60-100 mg/L
  - Mechanical WWTPs
    - BOD (or cBOD) – 5-15 mg/L
    - TSS – 7-15 mg/L
    - NH_3 – 1.5-3 mg/L

NR – Future Permitting

- What are anticipated changes to permitting?
  - Numeric Nutrient Criteria Development Plan
    - 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

NR – Compliance

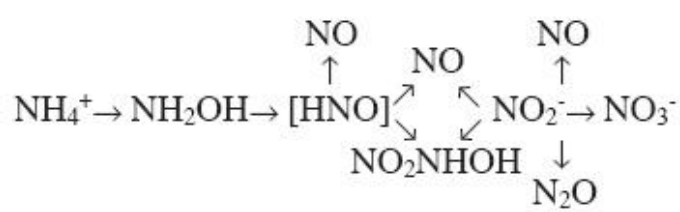
- What if I get a nutrient limit added to my permit?
  - Total Nitrogen
    - Need to start planning for adding a nitrogen removal step
      - Biological Removal of Ammonia/Nitrate/Nitrite?
      - Chemical Removal of Organic Nitrogen?
  - Total Phosphorus
    - Need to start planning for adding a phosphorus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

NR Terminology

- NR – nutrient removal
- BNR – biological nutrient removal
- BOD – biochemical oxygen demand
- NH_3 – ammonia
- NO_3 – nitrate
- NO_2 - nitrite
- TP – total phosphorus
- TN – total nitrogen
- MLSS – mixed liquor suspended solids
- ORP – oxidation/reduction potential
- DO – dissolved oxygen
- RAS – return activated sludge

NR – Nitrogen Removal

- How can nitrogen be removed at a WWTP?
  - 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



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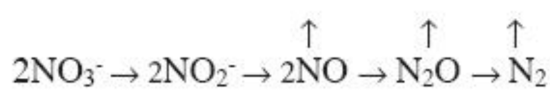

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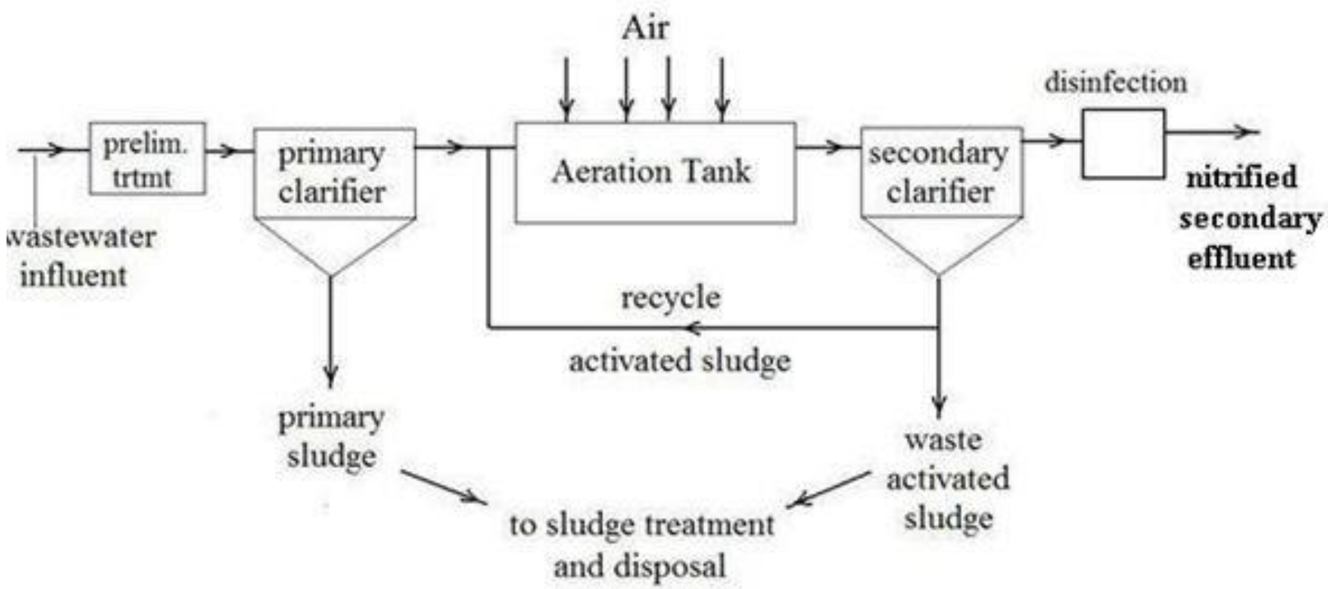
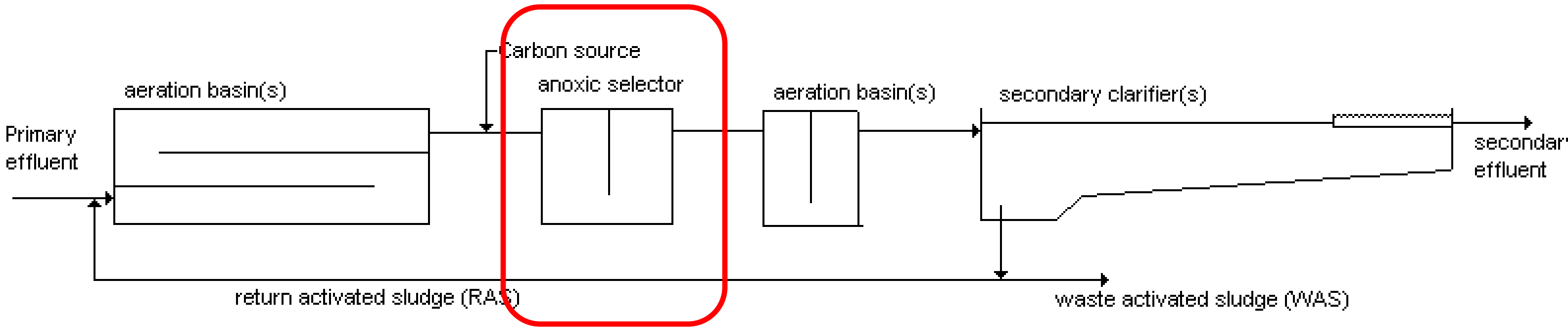
NR – Nitrogen Removal

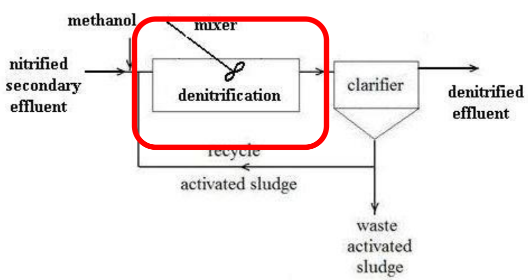
- Typical Conventional Process



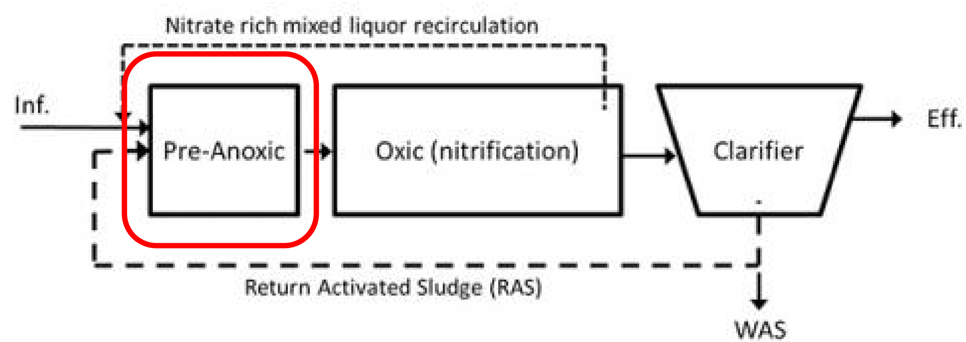
Activated Sludge Wastewater Treatment Flow Diagram

NR – Nitrogen Removal





Denitrification Process Flow Diagram

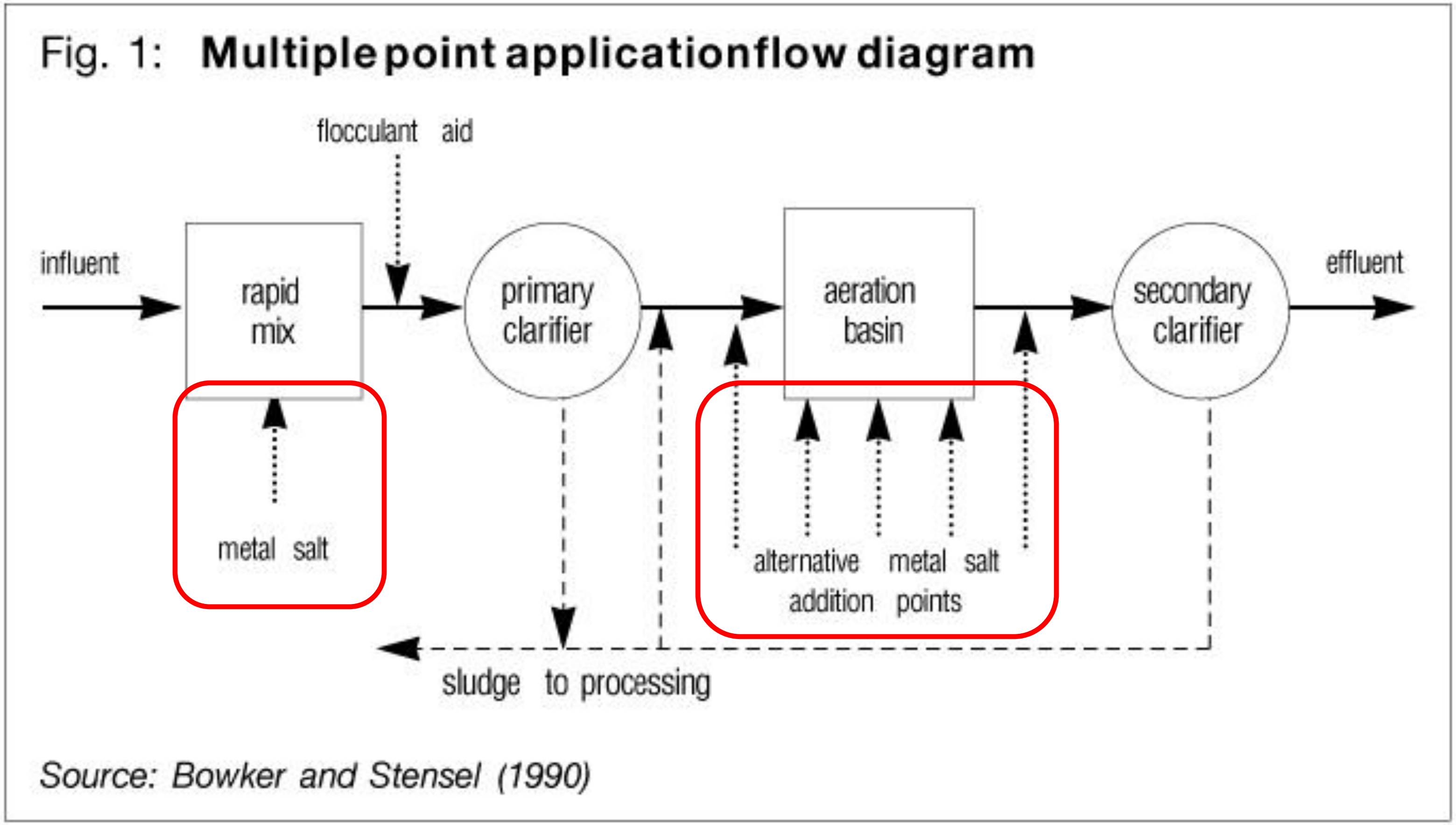


Modified Ludzack-Ettinger (MLE) Process

NR – Phosphorus Removal

- How can phosphorus be removed at a WWTP?
  - 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

NR – Phosphorus Removal



NR – Phosphorus Removal

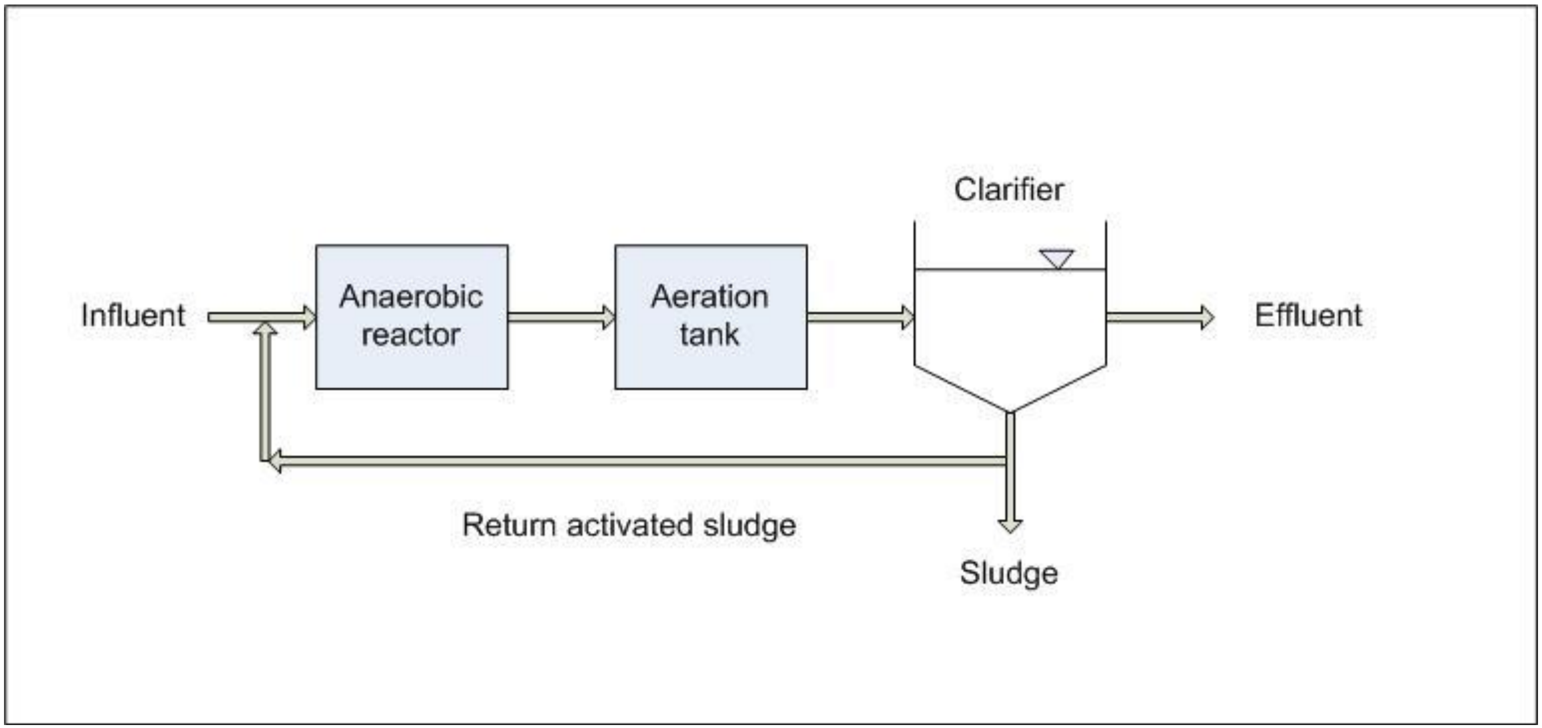
- Chemical TP Removal
- Advantages
  - Reliable
  - Low levels of TP in effluent possible
  - Retrofit for existing plant feasible for most mechanical plants
- Disadvantages
  - Cost of chemical feed system
  - Cost of chemicals
  - Substantial additional sludge production
  - Chemical sludge reuse or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

NR – Phosphorus Removal

- 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

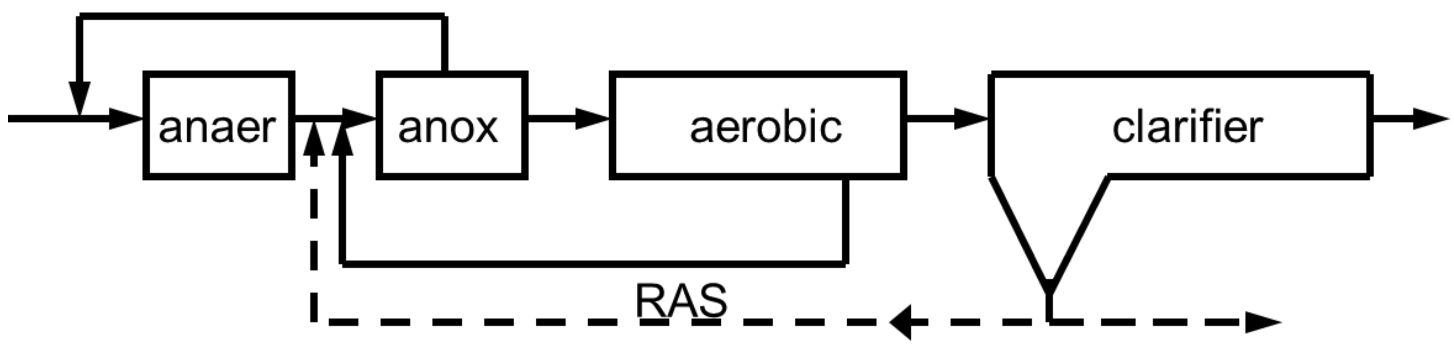
NR – Phosphorus Removal

- Anaerobic-Oxic (AO) Process



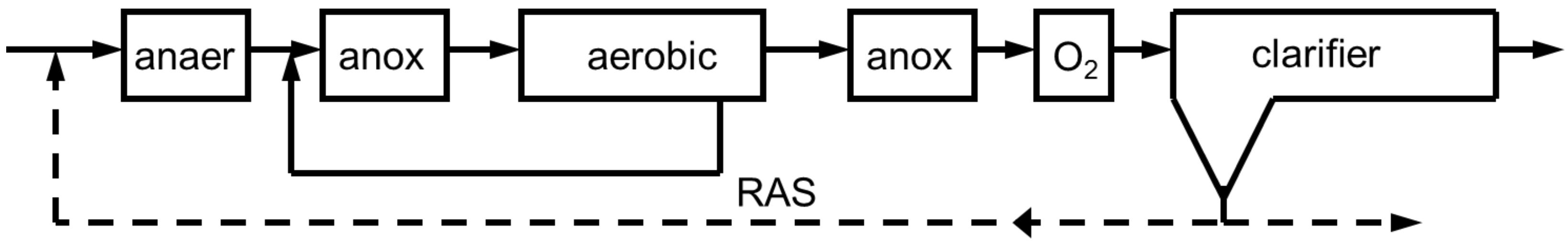
NR – Phosphorus Removal

- University of Capetown (UCT) Process



NR – Phosphorus Removal

- Bardenpho Process



NR – Phosphorus Removal

- Biological TP Removal
- 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

NR – Phosphorus Removal

- How can phosphorus be removed at a WWTP?
  - Filtration Removal
    - Orthophosphate
      - Removal via chemical polishing and polymer addition prior to filtration step
        - The majority of orthophosphate converted to polyphosphate would also be removed by the aeration basin biomass
      - Can remove approximately 0.25-0.5 mg/L of TP with conventional media filters
        - Removal of above 0.5 mg/L can be accomplished with membrane filtration

NR – Phosphorus Removal

- Filtration TP Removal
- Advantages
  - Reliable
  - Little additional sludge production
- Disadvantages
  - Cost of filtration equipment and chemical feed system
  - Provides polishing removal of TP, but less than 1.0 mg/L of TP removal
  - Increased backwashing required for TP precipitation on filter media, potential for re-release if recycling backwash
  - Retrofit for existing plant may not be feasible for some plants

NR Summary

- How can we remove nutrients?
  - Nitrogen – Biological removal only
  - Phosphorus – Chemical, biological and/or filtration
- Which is better, chemical removal or BNR?
  - Capital cost for chemical TP removal is always less expensive than BNR
  - The operational cost for BNR is typically significantly less than chemical phosphorus removal
  - The best path forward is to complete a site-specific analysis and develop a 10-20 year life cycle cost comparison of biological vs. chemical removal

If Selecting BNR…

- How is BNR different from what we're doing now?
  - Most mechanical plants currently operate under a conventional activated sludge mode to reduce BOD and NH_3
  - BNR will remove BOD, NH_3, TP and a portion of TN
- What do the BNR selector zones do?
  - Anaerobic Selector Zones
    - Convert orthophosphate to polyphosphate (aids TP uptake in aerobic zone)
  - Anoxic Selector Zones
    - Denitrification, removal of TN, energy recovery
  - Aerobic Selector Zones
    - Remove BOD, uptake phosphorus, (polyphosphate) remove NH_3

If Selecting BNR…

- How is BNR different from what we're doing now?
  - External Recycle Streams
    - Return Activated Sludge (CURRENT) – Typically returned from end of clarifiers to the head of the aeration basins – 100% recycle
      - Under BNR, RAS is normally returned to either the Anaerobic or Anoxic Selector Zone
      - If also using MBR, this recycle should instead be sent instead to the head of the aeration basin
  - Internal Recycle Streams
    - Aerated Recycle (NEW) – Recycling of aerated MLSS (high in nitrate) from the end of the aeration basin to the head of the Anoxic Selector Zone to enhance denitrification – 100-200% recycle
    - Denitrified Recycle (NEW) – Recycling of denitrified MLSS (zero nitrate, zero DO) to the head of the Anaerobic Selector Zone to enhance phosphorus release and conversion to polyphosphate for biological uptake in the aeration basin – 100-200% recycle

Nutrient Removal – Q&A

Q&A

&

Break?

Introduction

- Why are we discussing Nutrient Removal and Membrane Bioreactor technologies?
  - Tighter Federal and State regulations
  - Potential nutrient limits on the horizon
  - Drought -> Demands for reuse water
  - Increased conservation -> higher wastewater concentrations
  - Less susceptible to shock loading
  - Cost of membranes has become more competitive with conventional treatment
  - Site space availability for expansions/upgrades

MBR System Overview

- 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 0.01-0.10 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, drawing clean water through the membrane.

MBR System Overview

- History of MBR
  - Original MBR was a tertiary filtration system
    - Replaced conventional filtration only (similar to current MF and UF filtration systems in water treatment)
    - Operating flux was 20-30 gallons per square foot per day (gfd)
      - Water treatment membranes are designed for 50-70 gfd typically
    - Significant issues with membrane fouling
  - Current MBR design replaces clarification and filtration
    - Recommended operating flux is now 10-15 gfd to minimize fiber breakage
    - RAS is returned from the MBR system back to the biological process
    - Membrane fouling substantially reduced

MBR - Membrane Costs Overview

- What are typical capital costs?
  - Historical WWTP membrane equipment costs (per gallon)
    - Conventional - $1.00-$3.00
    - MF/UF - $0.50 - $1.50 (installed downstream of conventional processes)
    - MBR - $8.00 - $10.00 (installed in aeration basins)
  - Current WWTP membrane equipment costs (per gallon)
    - Conventional - $2.00-$4.00
    - MF/UF - $0.50 - $1.50 (installed downstream of conventional processes)
    - MBR - $4.00 - $6.00 (installed in aeration basins)
  - What has changed?
    - More competition in the MBR market
    - More installations allowing for profit on volume, not project-specific

MBR - Membrane Costs Overview

- What are typical operating costs?
  - Historical WWTP O&M costs (per 1,000 gallons)
    - Conventional - $1.00-$2.00
    - MF/UF - $1.00 - $2.00 (installed downstream of conventional processes)
    - MBR - $4.00 - $6.00 (installed in aeration basins)
  - Current WWTP O&M costs (per 1,000 gallons)
    - Conventional - $1.00-$2.00
    - MF/UF - $2.00 - $3.00 (installed downstream of conventional processes)
    - MBR - $1.00 - $2.00 (installed in aeration basins)
  - What has changed?
    - Hollow Fiber MBR – Significant reductions in energy required for air scour
    - Flat Sheet MBR – Reduced number of staff required for operations

MBR - Deciding to Use Membranes

- Why not continue conventional treatment?
- Are other upgrade technologies available instead of membranes?
- When is it appropriate to enhance existing processes with membranes?
- When is it appropriate to replace existing processes with membranes?

MBR - Deciding to Use Membranes

- Why not continue conventional treatment?
  - Newer Federal and State regulations
  - Cost of membranes has become more competitive with conventional treatment
  - Need for expansion / Limitations on plant space
  - Demands for reuse water (especially Type I reuse)

MBR - Deciding to Use Membranes

- Are other upgrade technologies available instead of membranes?
  - WWTP process alternatives
    - BNR – If only looking at nutrient removal needs
    - SBR – Sequencing Batch Reactors - Combines biological treatment and clarification into a single basin
    - Chemical precipitation of nutrients – If only looking at removal of phosphorus
    - Cloth filtration (disc filters) – If only looking at Type I reuse

MBR - Deciding to Use Membranes

- When is it appropriate to enhance existing processes with membranes?
  - Meet Type I reuse limits **and** reduce nutrients
  - Continued difficulty in handling solids / repeated clarifier upsets
  - Need expansion but facility is landlocked
  - Preparing for indirect/direct potable reuse in the future

MBR - Deciding to Use Membranes

- When is it appropriate to replace existing processes with membranes?
  - Tighter TPDES permit limits (addition of low nutrient limits
  - Age of existing processes is leading to full replacement
  - Consideration of satellite or new WWTP facility for non-potable or potable reuse

MBR - Selecting and Designing

- How do we determine level of treatment needed?
- Do we treat full-stream or side-stream?
- What are the design requirements?
- How do membranes impact solids handling in wastewater processes?

MBR - Selecting and Designing

- How do we determine level of treatment needed (what are the treatment drivers)?
  - Removal of nutrients?
    - TN, TP, or both?
  - Need to produce Type I or better quality reuse water?

MBR - Selecting and Designing

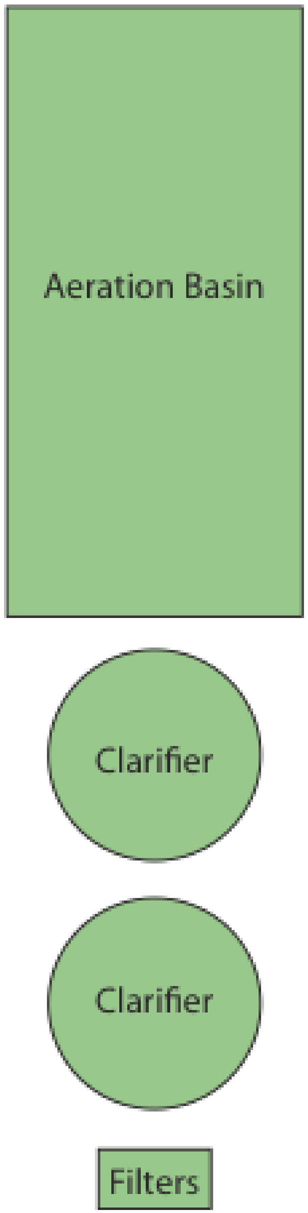
- Do we treat full-stream or side-stream?
- Full-Stream Treatment
  - Implies treating the entire flow in the plant
  - Usually required if replacing an entire existing filtration system
- Side-Stream Treatment
  - Implies treating part of the plant flow and blending with the remaining non-membrane-filtered stream
  - This approach is typically used to reduce the initial capital cost of the membrane system
    - Most membrane systems are modular in design and can be expanded easily, if designed for future expandability
    - However, increased complexity in operating parallel treatment plants!
  - Side-stream treatment designs must be reviewed with TCEQ to ensure that blended effluent quality can meet treatment requirements

MBR - Selecting and Designing

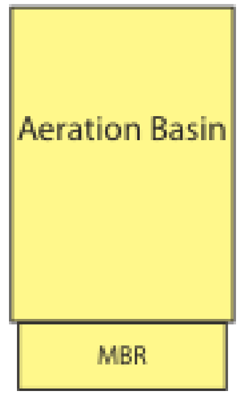
- How do membranes impact solids handling in wastewater processes?
  - Conventional Solids Handling
    - Secondary Clarification, RAS/WAS Pumping, Solids thickening, solids dewatering and disposal
    - Sludge in aeration basin – 2,000 – 4,000 mg/L MLSS
  - Membrane System Solids Handling
    - MBR, Waste solids from MBR basin, solids dewatering and disposal
    - Sludge in aeration basin – 4,000 – 10,000 mg/L MLSS
    - Sludge in MBR basin – 6,000 – 12,000 mg/L MLSS
      - Some MBR systems have been operated at up to 20,000 mg/L !

MBR - Comparison of Current Design to Conventional

Conventional



MBR



MBR Issues

- ***Pretreatment!!***
- Peak flows
- Air scour (Additional hp)
- Membrane cleaning
- Membrane replacement

Conventional Issues

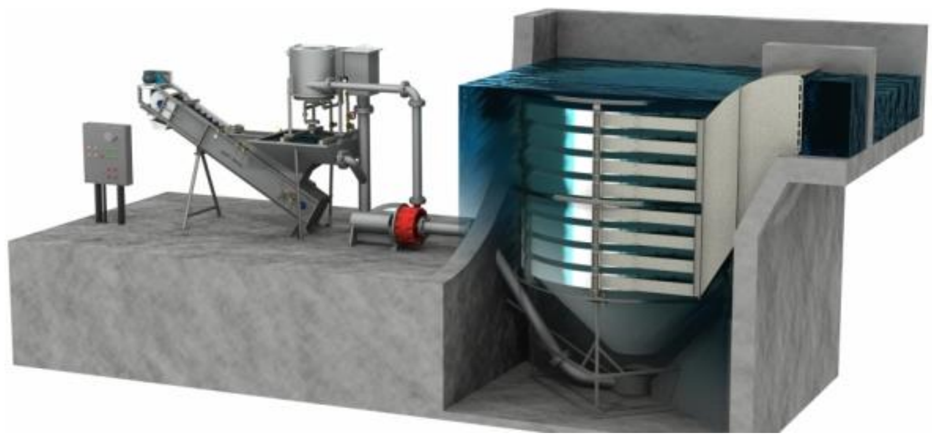
- Sludge settleability
- Weir cleaning
- Filter cleaning
- Filter replacement/maintenance

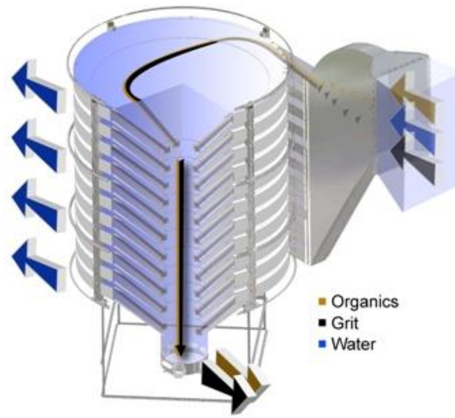
MBR - Pretreatment

- What pretreatment is required?
  - Conventional treatment systems
    - Under Chapter 317, TCEQ required use of a "fine screen", sized for approximately 0.25-inch (6 mm) spacing
    - Under Chapter 217, any screen spacing 0.25-inch or larger is considered to be a "coarse screen"
    - Under Chapter 217, a "fine screen" is now considered to be a screen with spacing smaller than 0.25-inch (6 mm)
  - Lessons learned on MBR design
    - Flat sheet MBR manufacturers require the installation of a fine screen (max 3 mm) and grit removal upstream of MBR
    - Hollow fiber MBR manufacturers require the installation of a fine screen (max 2 mm) and grit removal upstream of MBR

MBR - Pretreatment

- What pretreatment is required?





MBR – Peak Flows

- What is the hydraulic capacity of MBR?
  - Typical MBR manufacturer design
    - MBR manufacturers recommend a peaking factor of no more than 2:1 for flows through the MBR
      - i.e. Average flow of 1 mgd -> Peak flow of 2 mgd
    - Since many utilities see flow peaks during wet weather events at 3:1 to 5:1, flow equalization storage to "shave" flow peaks is normally required for most MBR installations
  - TCEQ requirements for hydraulic design
    - Chapter 217 currently allows for a maximum peaking factor of 1.5:1 (unless using pilot data or full-scale data to challenge requirement)
    - Coordination with TCEQ is recommended during design to ensure that TCEQ will approve the final design parameters

MBR – Air Scour

- What is air scour for?
  - Typical MBR MLSS ranges from 6,000-12,000 mg/L
    - Buildup of sludge on the membrane surface requires fairly constant air scouring of membrane surface to prevent “blinding”
    - Requires a separate, dedicated air system to provide air scour (typically do not tie process air and air scour systems together)

MBR - Membrane System Terms

MBR

Module

Cassette or Rack

Membrane

CEB

Hollow Fiber Membrane

EFM

Skid or basin or train

Flux rate

CIP

Flat Sheet Membrane

TMP

MBR - Terminology

- What terminology is used with membranes?
  - Membrane – Material where the lateral dimensions (length, width) are much greater than the material thickness
  - Filtrate – Filtered water that passes through the pores (openings in membrane) of an MF/UF membrane to a downstream process
    - Comparable to "filter effluent"
  - Flux – A measure of the rate at which the permeate passes through the membrane per unit of membrane surface area, expressed as gallons per square foot per day (gfd)
    - Comparable to "filter surface loading rate"
  - Membrane Bioreactor (MBR) – A type of MF/UF system used in conjunction with WWTP processes
  - MLSS – Mixed liquor suspended solids

MBR - Terminology

- What terminology is used with membranes?
  - Transmembrane Pressure (TMP) – Measurement of the force required to push/pull filtrate across an MF/UF membrane surface, physical indicator of membrane fouling
    - Comparable to "filter head loss"
  - Fouling – Loss of performance due to suspended or dissolved material deposition on the membrane surface
    - Comparable to "dirtying of a filter"
  - Pressure Vessel – A cylindrical container designed to house membrane elements, if using a pressure system
  - Backpulse – A method of cleaning membranes by forcing filtrate back through the membrane to clean off the feed side of the membrane
    - Comparable to "filter backwash"

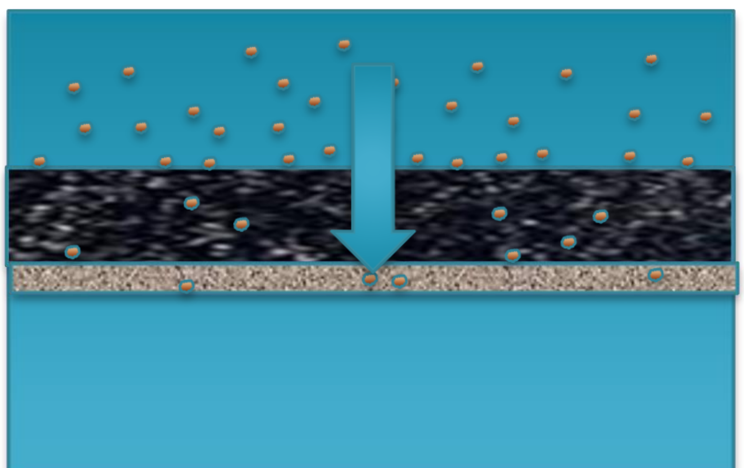
MBR - Terminology

- What terminology is used with membranes?
  - Clean-In-Place (CIP) – A method of cleaning the membranes by soaking in chemical solutions while still inside the pressure vessels or membrane tanks
  - Recovery – Ratio of filtrate produced compared to the original feed water flow rate, expressed as a percentage
  - Maintenance Clean – A method of cleaning where the membranes are filled with cleaning solution (such as hypochlorite) without draining the system, then placing back online
  - Recovery Clean – A method of cleaning where the membrane system is drained and flushed, then filled with cleaning solution (such as hypochlorite or acid), then flushed and drained before being placed back online

MBR - Membrane Technology Comparison

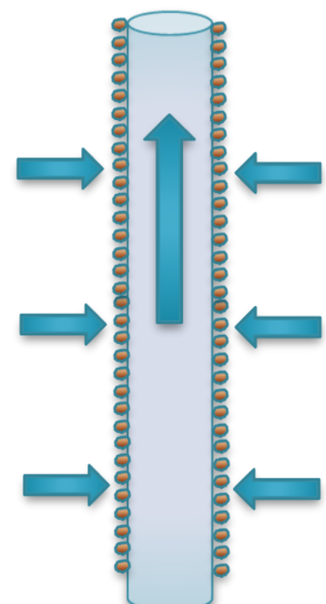
Granular Media

- **Irregular Pore Size Distribution**
  (50 -70 micron between grains)
- **Probable Filtration**

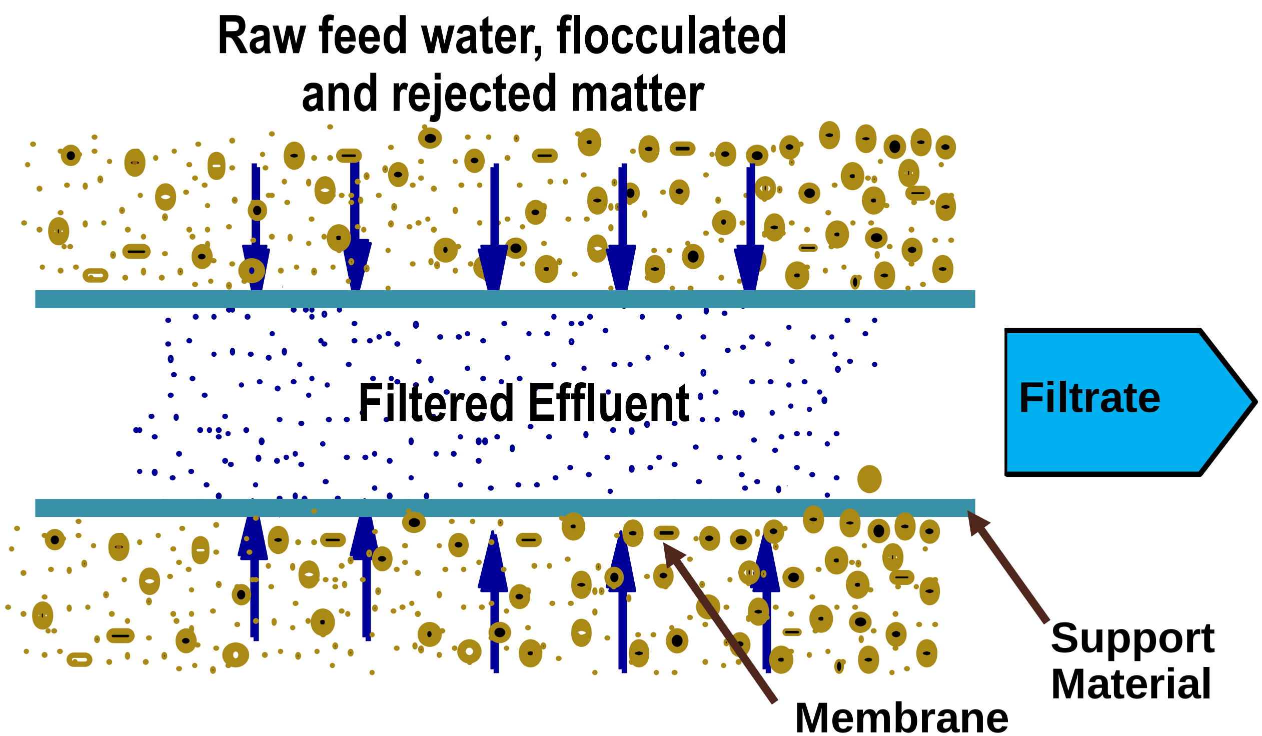


Membrane Media

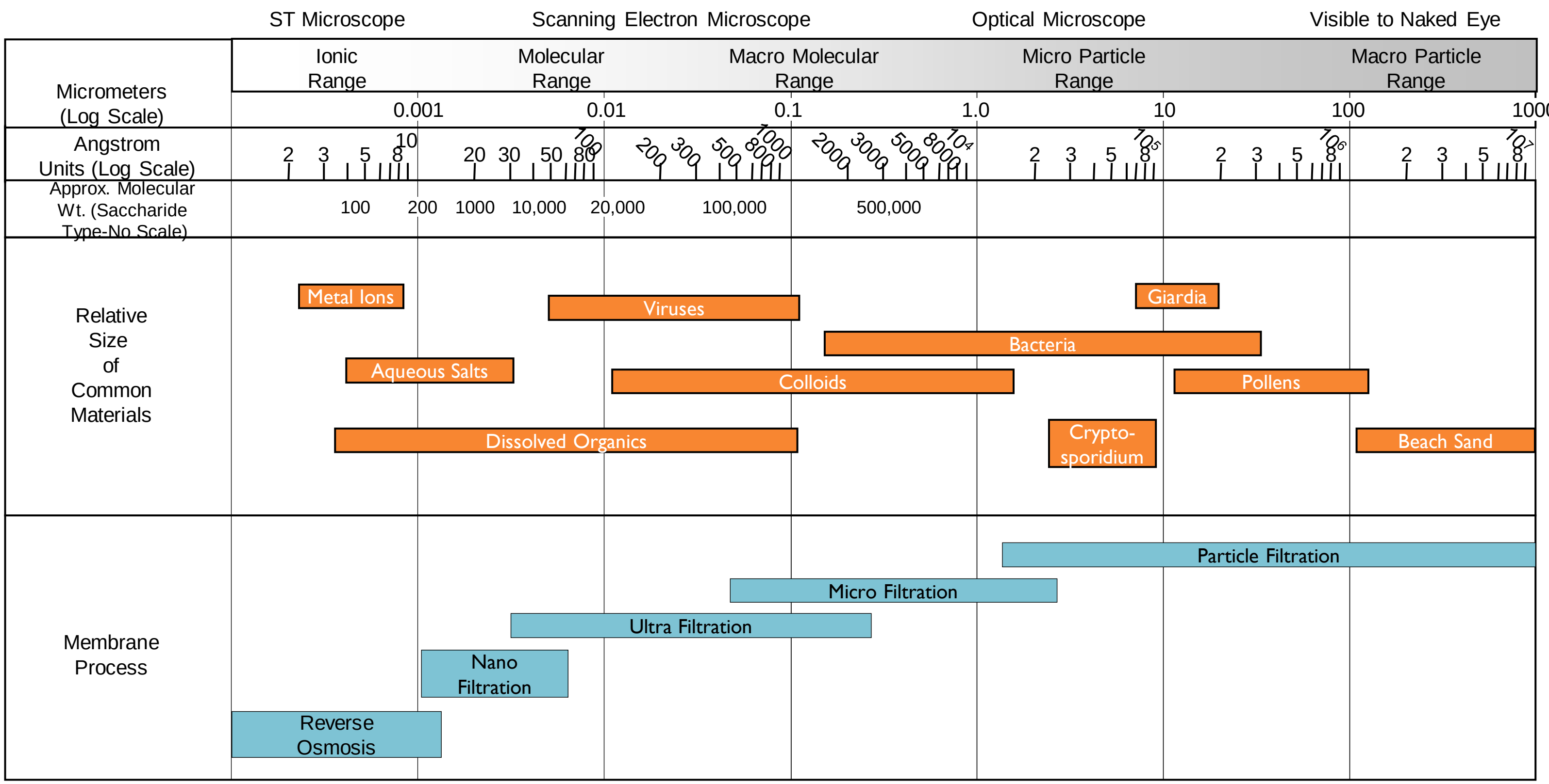
- **Controlled Pore Size Distribution**
- **0.01-0.4 micron pore spacing**
- **Absolute Filtration**



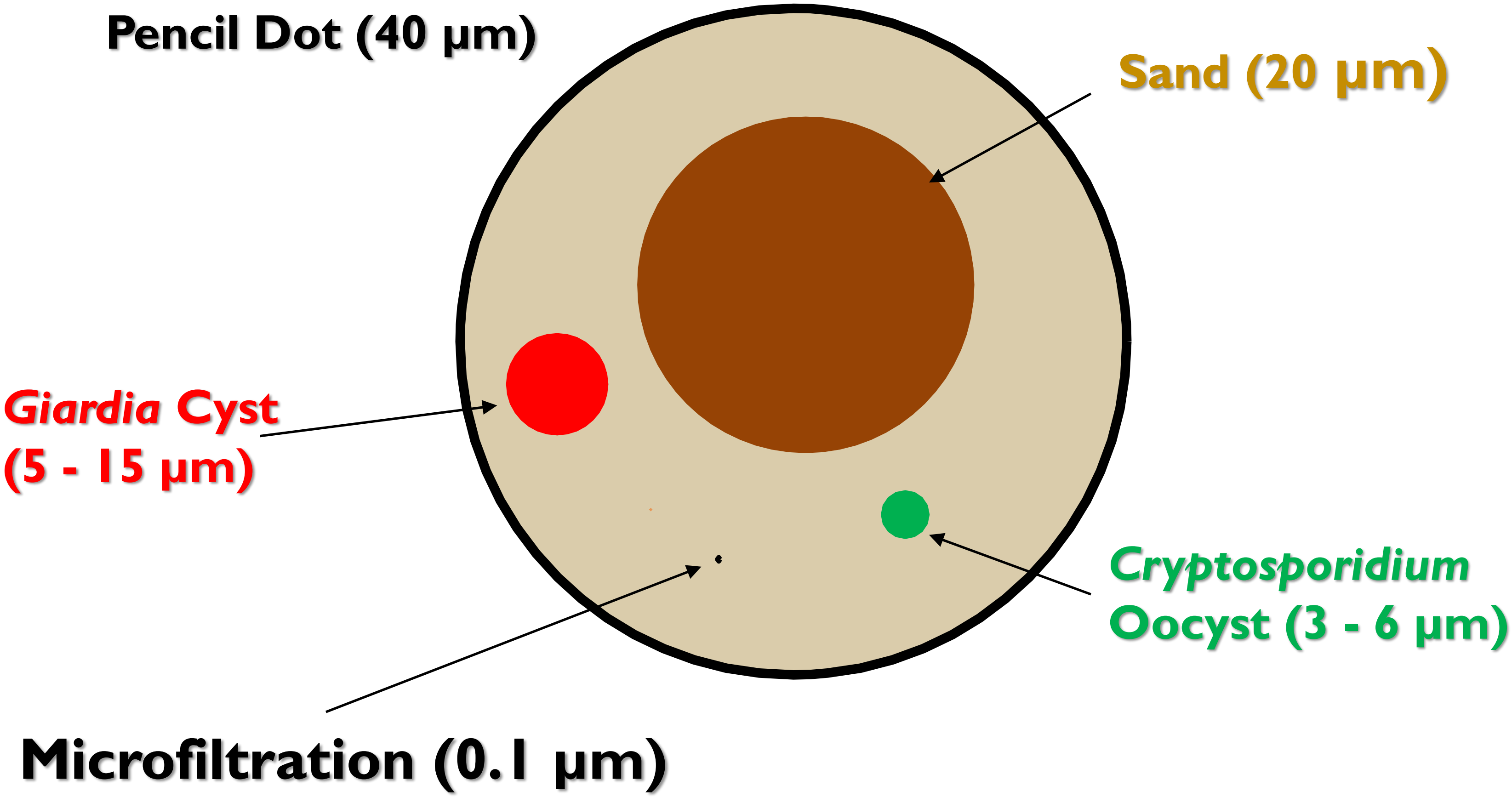
MBR – Filtration Terminology



MBR - Membrane Technology Relative Particle Sizes



MBR - Membrane Technology
Relative Particle Sizes



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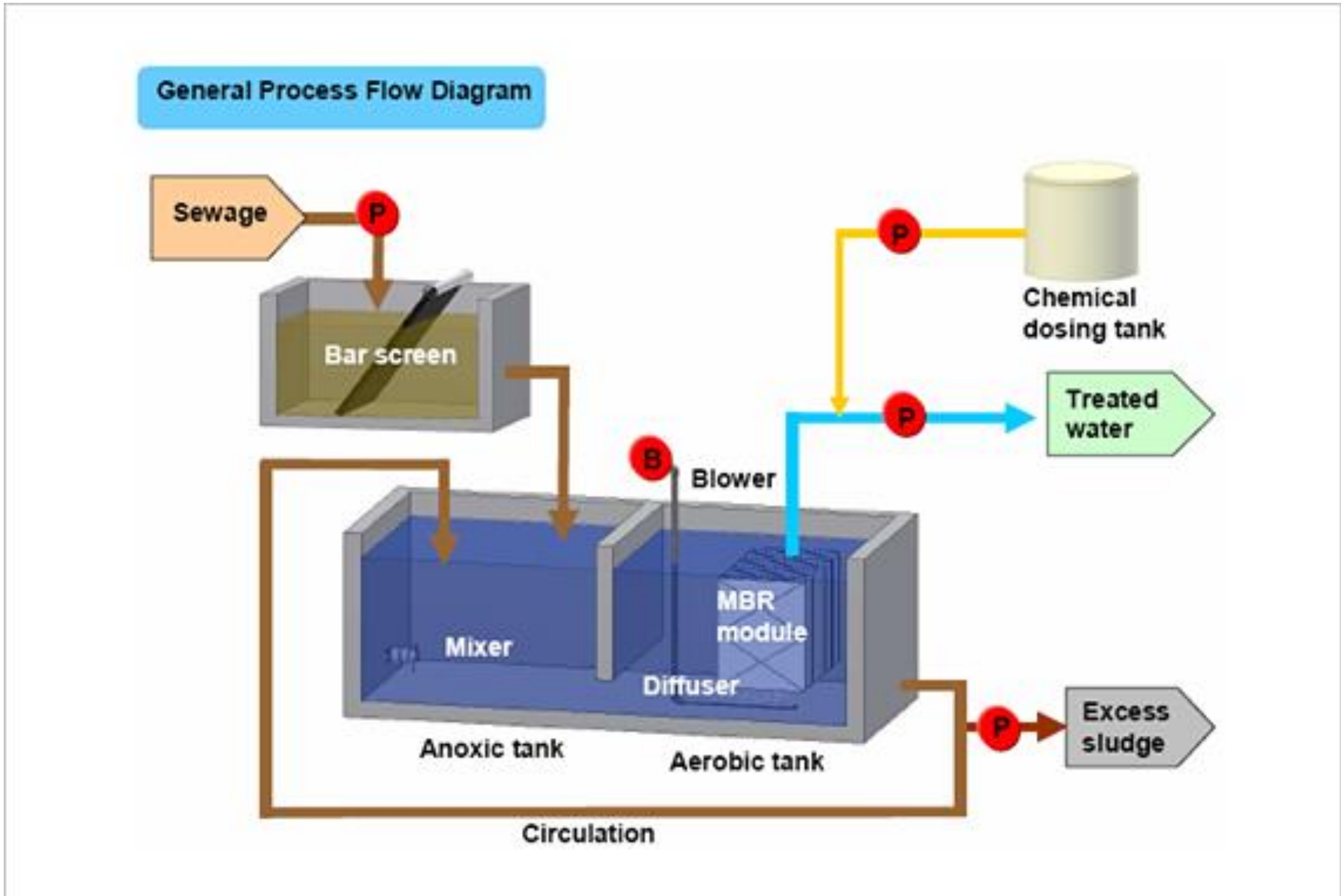
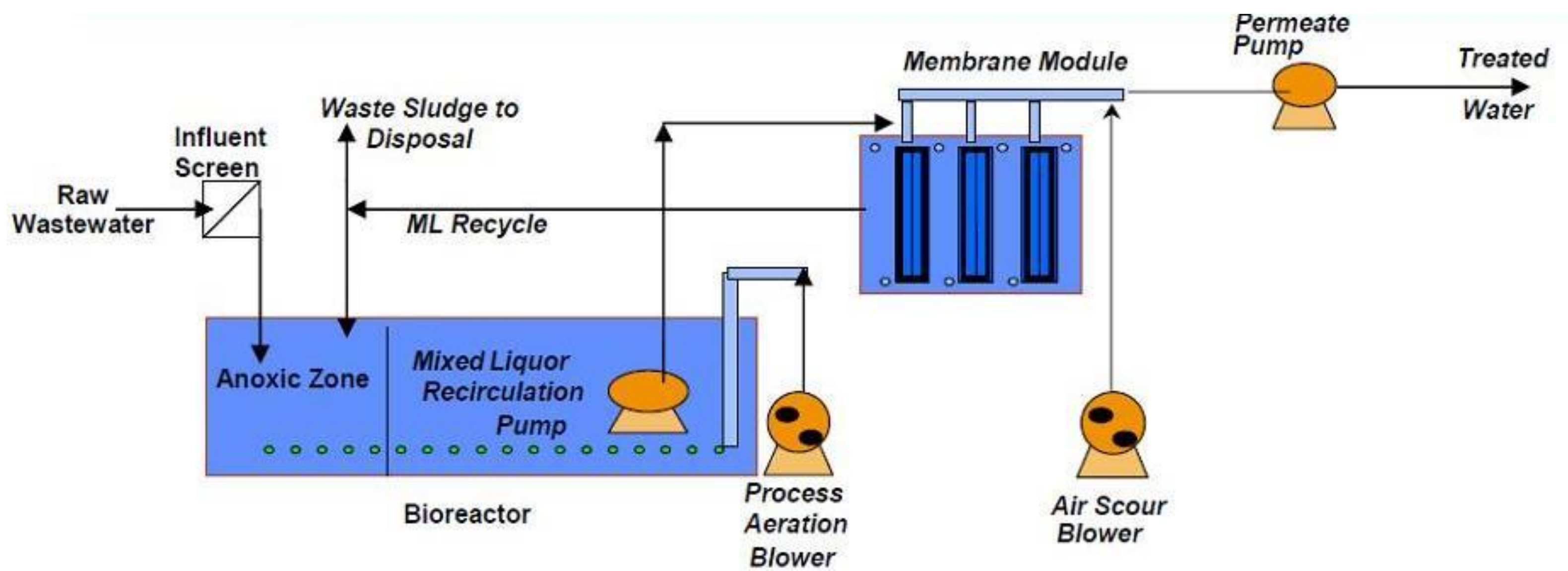
MBR – Process Diagrams

- Historical Compact MBR Design



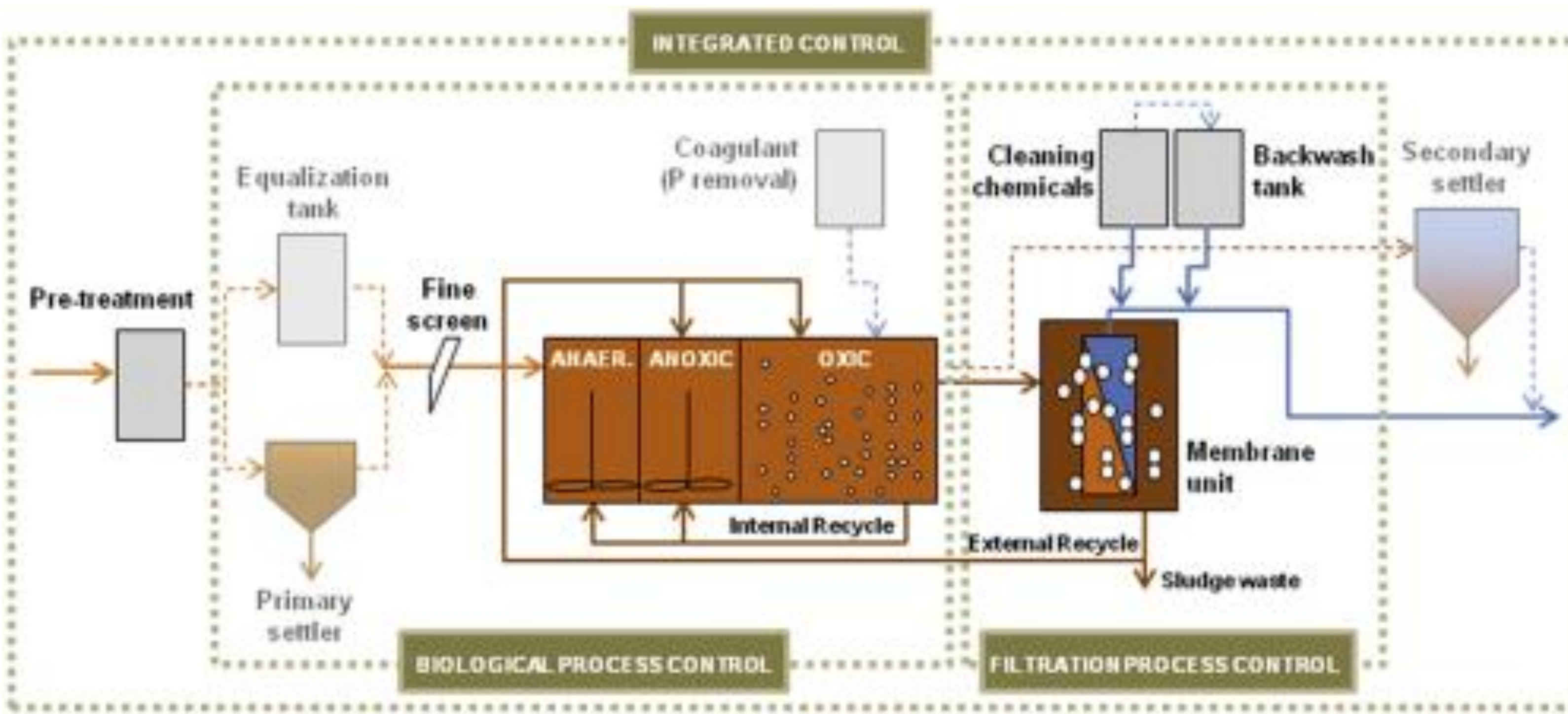
MBR – Process Diagrams

- Historical Custom MBR Design



MBR – Process Diagrams

- Current MBR Design Approach (w/ BNR)



MBR - Membrane Filtration

- System Type – Submerged Hollow Fiber with Vacuum Pump

MBR - Membrane Filtration

- System Type – Submerged Hollow Fiber with Vacuum Pump

MBR – Hollow Fiber MBR System (Memcor)

MBR – Hollow Fiber MBR Basin (Memcor)

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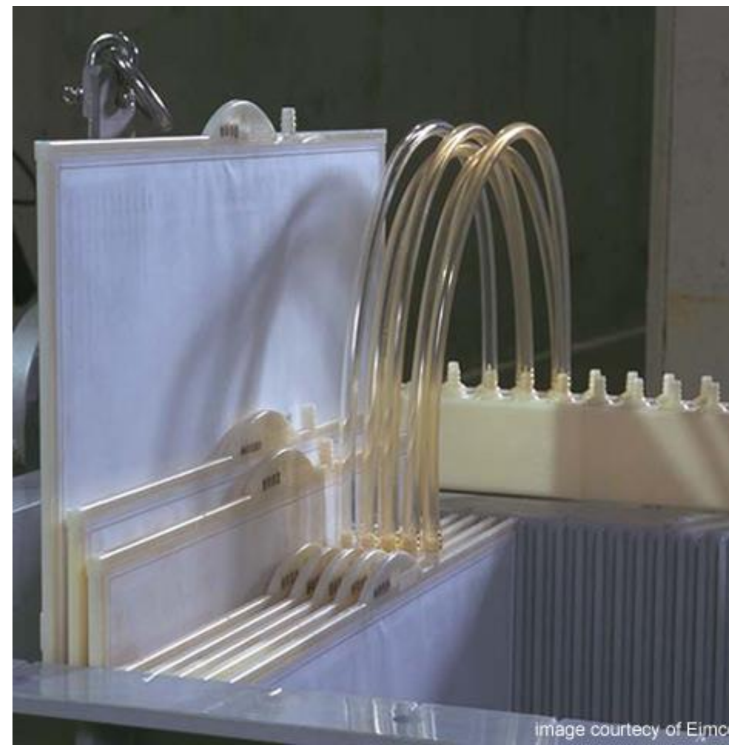
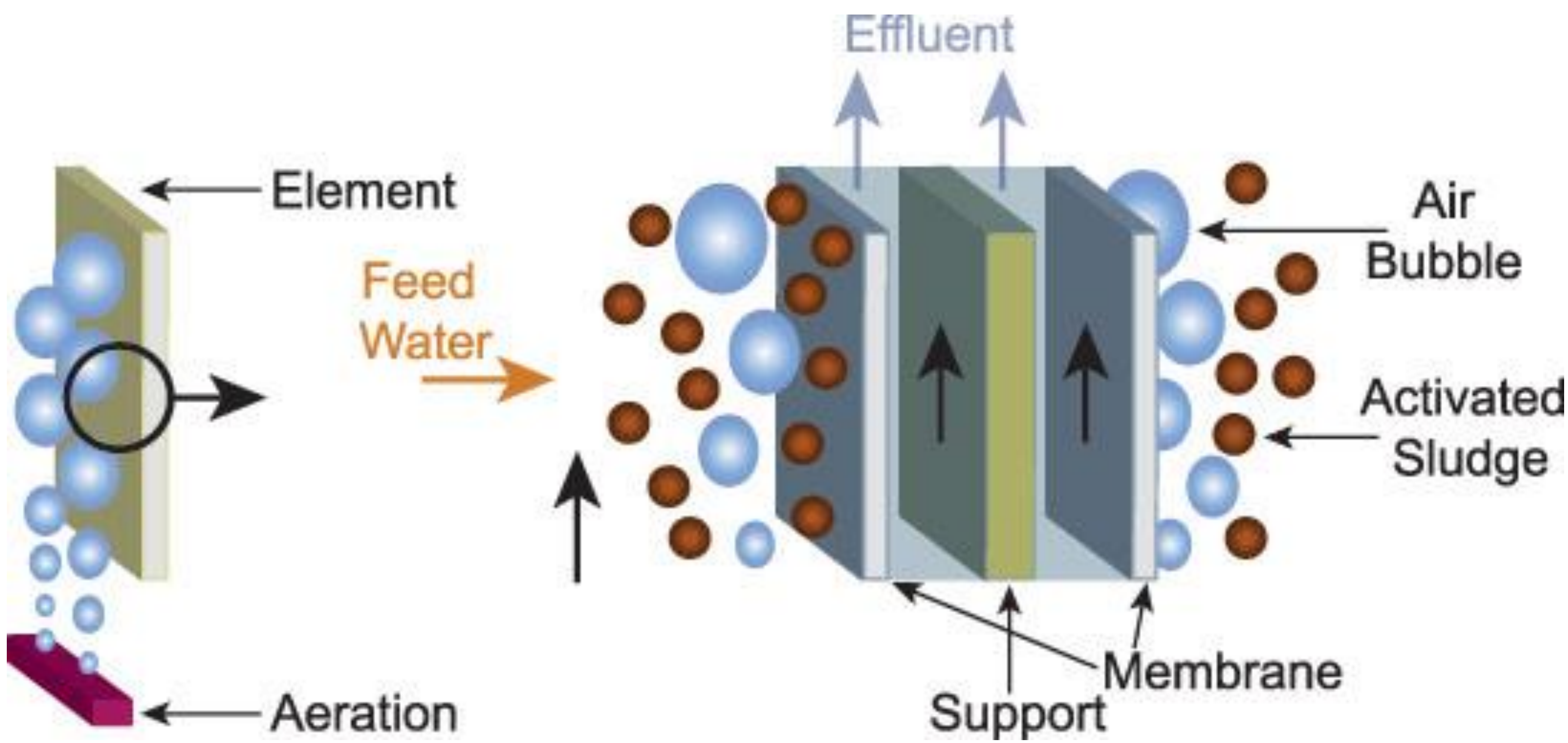
MBR - Membrane Filtration

- System Type – Submerged Flat Sheet with Vacuum Pump



MBR - Membrane Filtration

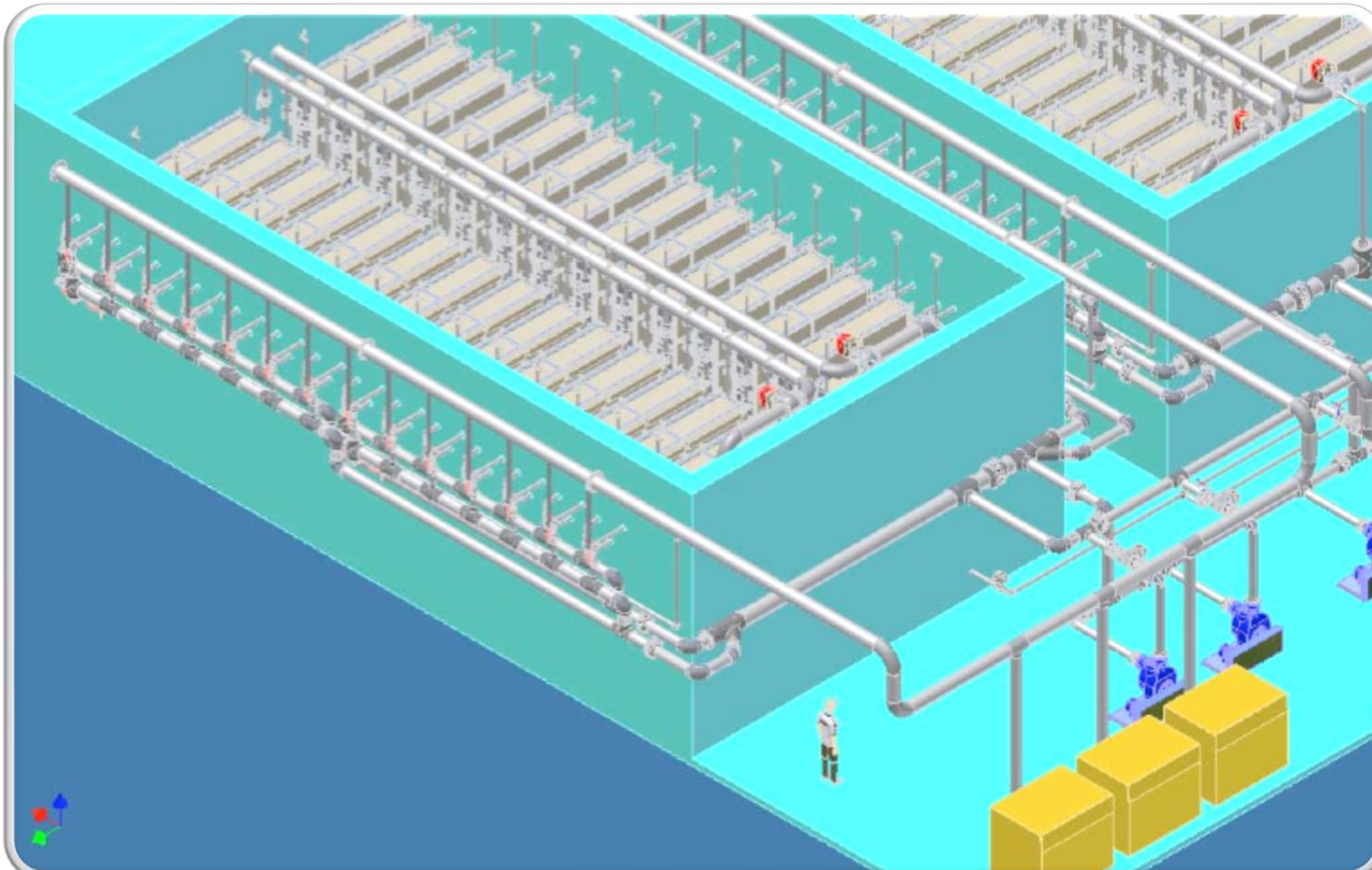
- System Type – Submerged Flat Sheet with Vacuum Pump



MBR - Membrane Filtration

- System Type – Submerged Flat Sheet with Vacuum Pump

MBR – Flat Sheet MBR Basin Typical Design Model

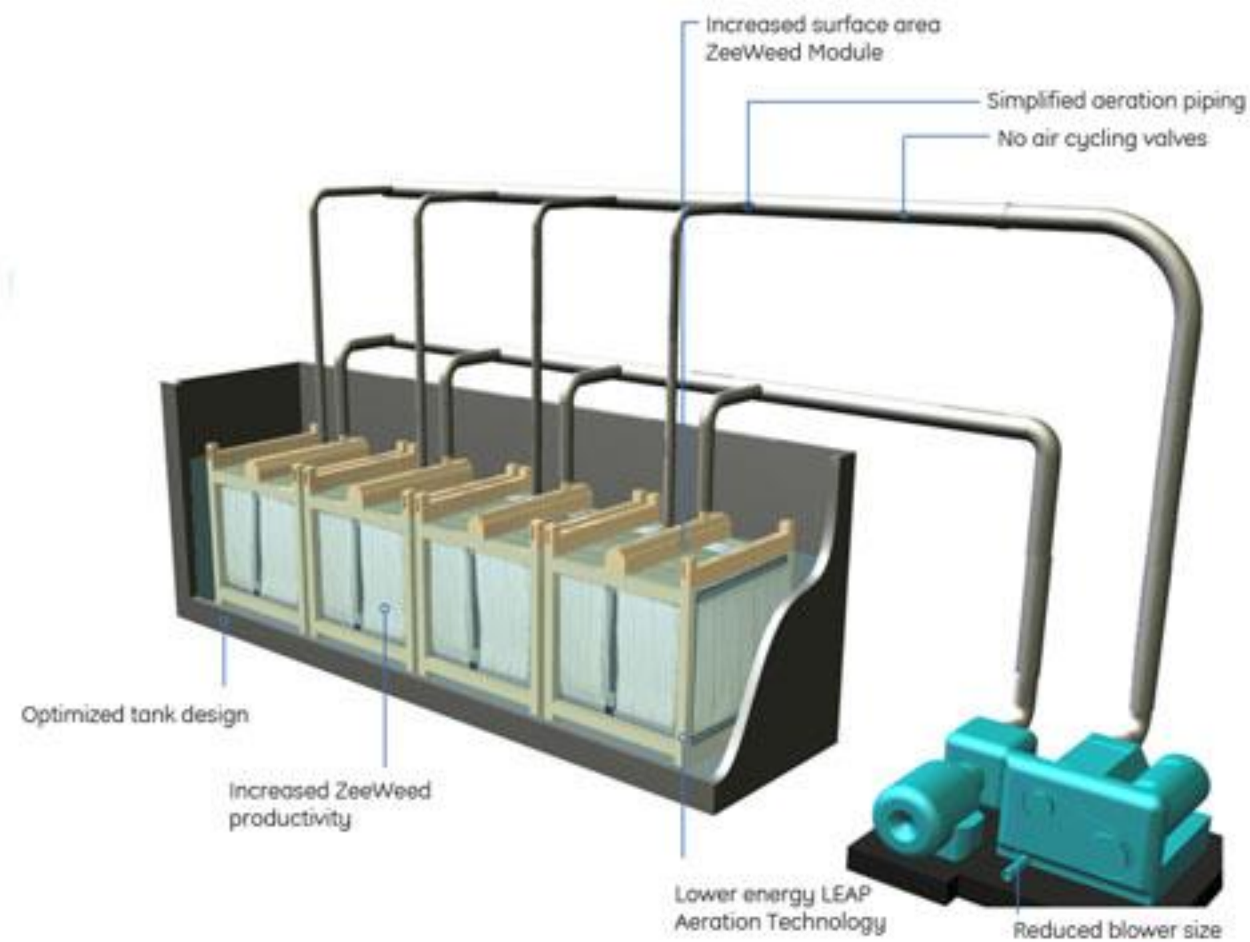


MBR – Flat Sheet MBR Basin (Kubota)

MBR – Flat Sheet MBR Basin (Kubota)

MBR – Flat Sheet MBR Effluent Piping (Kubota)

MBR – Hollow Fiber Membrane Equipment (GE)



MBR - Air Piping for GE MBR

MBR - Manufacturer Summary

Equipment Manufacturer	Membrane Manufacturer	Membrane			U.S. Experience		
		Type	Pore Size (um)	Material	No.	Largest MGD	Longest Years
GE	Zenon 500C and 500D	Hollow Fiber	0.04	PVDF	100+	18	19
Kubota	Kubota	Flat Sheet	0.4	CPE	100+	6	11
AEA	Memcor	Hollow Fiber	0.1	PVDF	30+	3.5	8.5
Kruger	Toray	Flat Sheet	0.08	PVDF	10+	1	6
Koch	Koch	Hollow Fiber	0.04	PVDF	10+	3.4	2.5

Other manufacturers with limited U.S. experience:

- NoritXFlow
- Westech – Partnered with Alta Laval Membrane

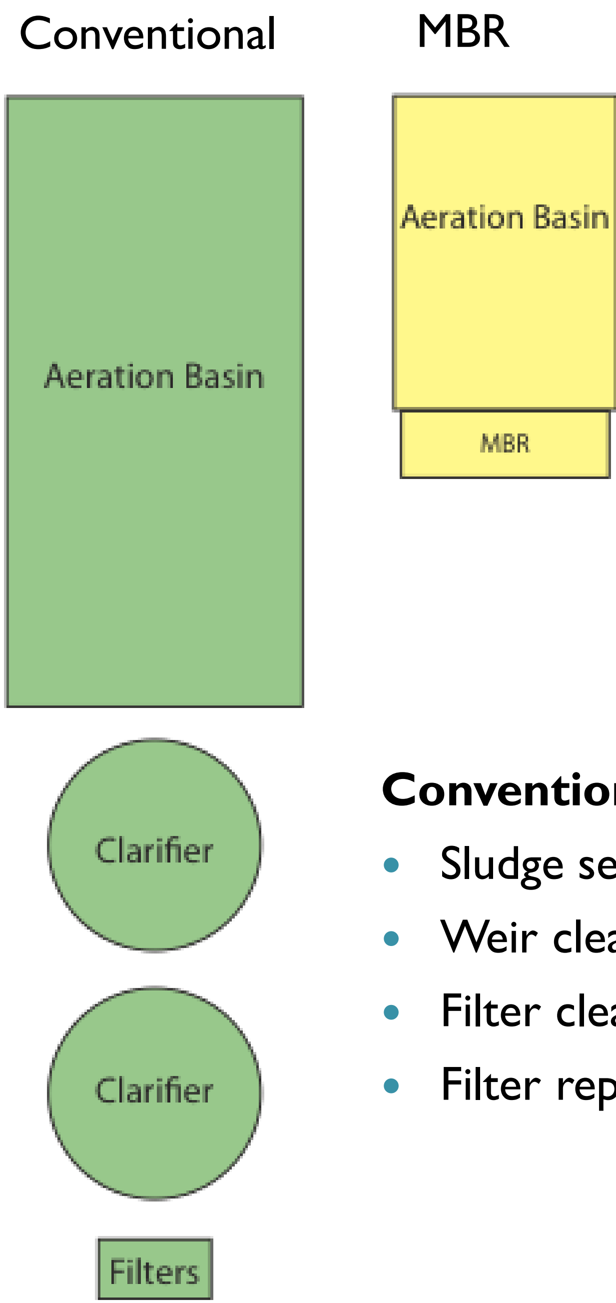
**Other

- Ovivo – Previously partnered with Kubota, now using MicroDyne

MBR - Typical System Summary

- Coarse screen (0.25-inch), grit removal, fine screen (<2 mm for hollow fiber systems, <3 mm for flat sheet systems)
- Anoxic/aerobic basins with recycle and air supply (anoxic reduces process air requirements)
- Membrane basins or skids (basins more common)
- Chlorine or UV Disinfection (minimal disinfection)
- Peak flow storage and equalization (maximum PF=2)

MBR - Comparison to Conventional



MBR Issues

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

Conventional Issues

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

MBR - Operational Differences

- Basic differences in operating principles.
- How are instrumentation requirements different for membrane treatment?
- How are membranes different from traditional filters in cleaning?
- How do membranes change operation of solids and waste stream handling?
- How is equipment operating life different for membrane systems?

MBR - Operational Differences

- Basic differences in operating principles
  - Conventional plants (those with final clarifiers) rely on final clarifiers to settle the solids from mixed liquor leaving clear effluent to flow from clarifier. Operators of WWTPs with final clarifiers must produce a sludge that will settle leaving behind clear effluent.
  - Membrane WWTPs do not have final clarifiers. Process control related to making sludge settle goes away. No longer care if the sludge will settle. Process control shifts to maintaining nutrient removal treatment. Also now have effluent filtration. Well suited to plants with nutrient removal in their TPDES permit or Type I reuse needs.

MBR - Operational Differences

- How are pretreatment requirements different for membrane treatment?
  - Fine screens are required for MBR plants to protect the membranes.
  - MBR plants are commonly used to provide nutrient removal. Nutrient balance becomes more of an issue if biological nutrient removal is required.

MBR - Operational Differences

- How are instrumentation requirements different for membrane treatment?
    - Instrumentation required to operate the membrane system is more complex than for conventional WWTPs.
    - Very little difference in instrumentation requirements for TPDES compliance verification.
    - Analytical procedures for permit compliance remains bench top analytical with an MBR plant as it does with a conventional WWTP with final clarifiers.

MBR - Operational Differences

- How are membranes different from traditional filters in cleaning?
  - Traditional filters are cleaned through the filter backwash procedure.
  - Treated water is flushed back up through the filter opposite the direction of normal flow.
  - Normal filter runs are 48-96 hours.
  - Additional chemicals are typically not used in traditional filter backwash procedure.

MBR - Operational Differences

- How are membranes different from traditional filters in cleaning?
  - Membranes are cleaned in several ways. Additional chemicals are used in the cleaning process:
    - Routine backpulses (mini-backwash) on regular intervals (every 15-30 minutes) using water and air pulses. (membrane train remains in normal service)
    - Weekly mini-CIPs (maintenance cleans) using low pH (acid) and chlorine (hypochlorite). (membrane train out of service for relatively short period)
    - Comprehensive CIPs (recovery cleans) using low pH (acid) and chlorine (hypochlorite). May also use neutralizing chemicals to neutralize chlorine and low pH (monthly-2/year). (membrane train out of service)

MBR - Operational Differences

- How do membranes change operation of solids and waste stream handling?
  - MBR systems can be capable of meeting Class B treatment requirements.
    - MBR waste solids can be tested to verify compliance with Class B (PSRP) requirements
  - SRT from the biological process is considered aerobic digestion.
  - Ultimate solids handling and disposal method should be reviewed with TCEQ prior to completion of final design

MBR - Operational Differences

- How is equipment operating life different for membrane systems?
  - Conventional WWTP treatment equipment has a long lifespan exceeding that of membranes.
  - Membranes will have to be replaced where conventional WWTP basins remain functional for decades.
  - However, membrane life is comparable to life of aeration basin diffusers, with a replacement approximately every 10 years.

MBR - Monitoring and Reporting

- There are no differences in monitoring and reporting requirements for conventional and MBR plants on the wastewater treatment side.

MBR - Lessons Learned

- There are risks of fouling membranes as a result of inorganic scale buildup.
  - In some cases, highly alkaline waters have a tendency to form scale on the feed side of UF/MF membranes.
    - Rate of scale buildup must be monitored to determine if frequency or dosage of low pH CIP clean needs to be adjusted to combat the scale formation
- There are risks of fouling membranes as a result of upstream chemical use.
  - Membrane vendors are very quick to point out the risks of fouling membranes.
    - Use of polymers upstream are frowned upon. Potential to foul the membranes.
    - Use of metal salts upstream (coagulants) must be carefully controlled. Dissolved metals (aluminum, iron, barium, strontium) and other potential foulants must be carefully controlled or prevented.

MBR - Lessons Learned

- There are risks of damaging membranes as a result of cleaning practices.
  - Some systems have seen damage to membranes as a result of cleaning agents used on membranes.
    - Introduction of some cleaning agents may actually break down the membrane and cause the membranes to become more porous.
    - Caution must be used when altering cleaning procedures from Manufacturer's recommended (Potential warranty issues).

MBR - Lessons Learned

- There are risks of damaging membranes as a result of existing system design.
  - Some systems have seen damage to membranes as a result of debris from upstream piping.
    - Older piping and lower cost piping currently commercially available typically use cement mortar lining. Over time, the mortar breaks down and is passed downstream to the membrane system.
    - When installing new membrane systems, it is best to replace older cement mortar-lined piping with epoxy-coated piping (or PVC, HDPE, etc.) to minimize debris passing to the membranes. The key issue is to minimize the amount of abrasive materials that can reach the membranes.

Membrane Bioreactor

Q&A