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Bring Wastewater Treatment into the 21st Century - A Review of MBR in the Past, Present and Future

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Acknowledgements

- Texas Commission on Environmental Quality
  - Design Criteria for Conventional and MBR WWTPs in Texas
- MBR Suppliers
  - A3
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  - Kubota
  - H2O Innovations
  - Ovivo
  - Suez Water Technologies (previously GE and Zenon)
- The MBR Site (www.thembrsite.com)

Agenda

- Introduction
- Regulatory Requirements
- MBR Technology Overview
- Conventional and MBR Process Comparison
- MBR Design Considerations
- Summary

Introduction

Why are we discussing membrane bioreactors as an option?

- 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 can be more competitive than conventional treatment under certain requirements
- Site space availability for expansions/upgrades

Regulatory Requirements

- What are typical current permit limits in Texas?

  - 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

MBR Technology 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 0.1-0.3 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.

MBR Technology Overview

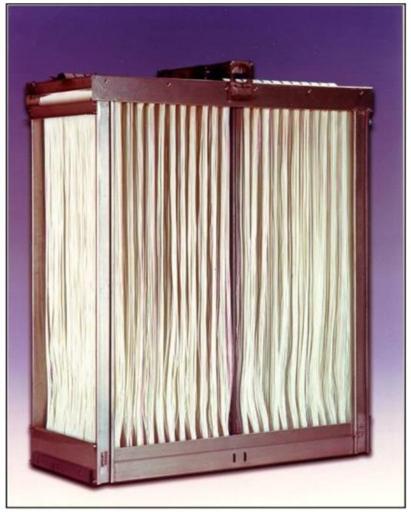
- History of MBR

  - 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 Technology Overview

- System Type – Hollow Fiber

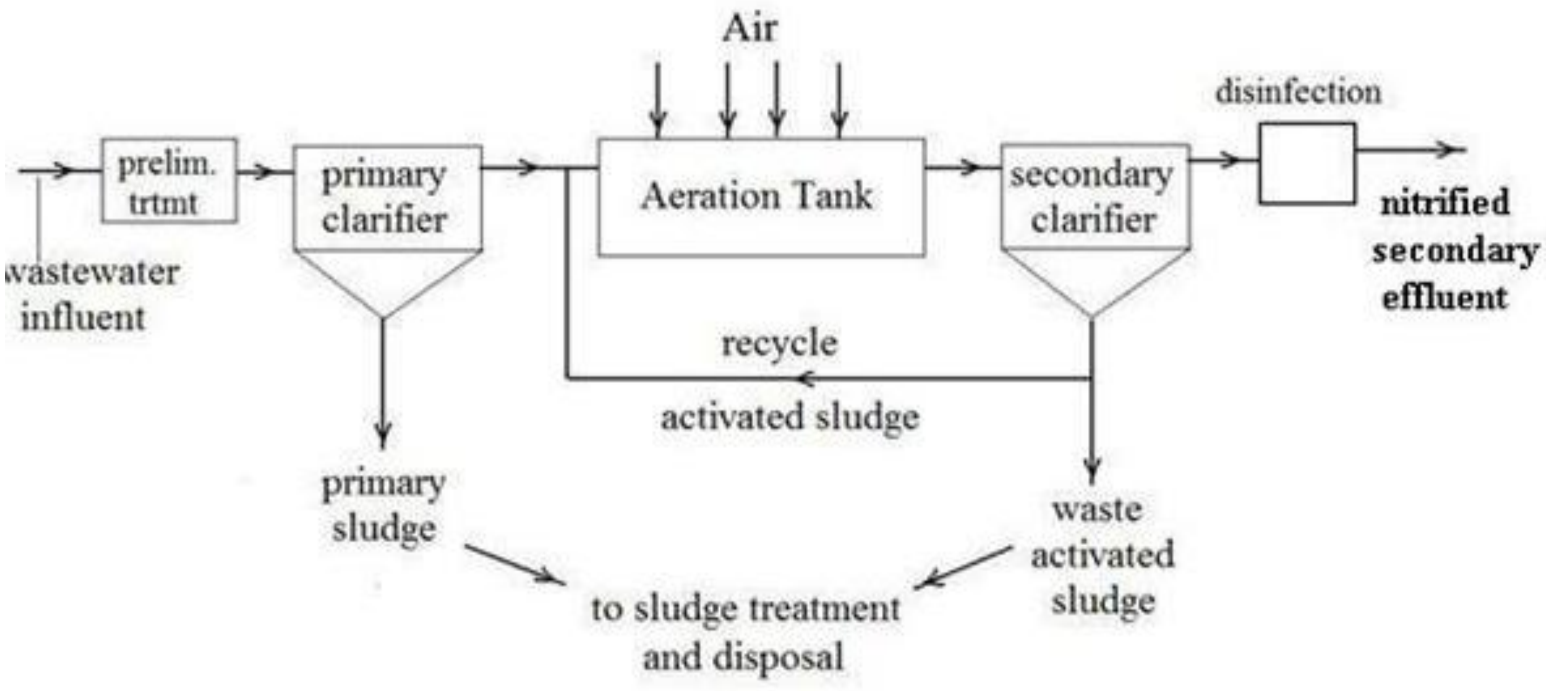


MBR Technology Overview

- System Type – Flat Sheet

Conventional and MBR Process Comparison

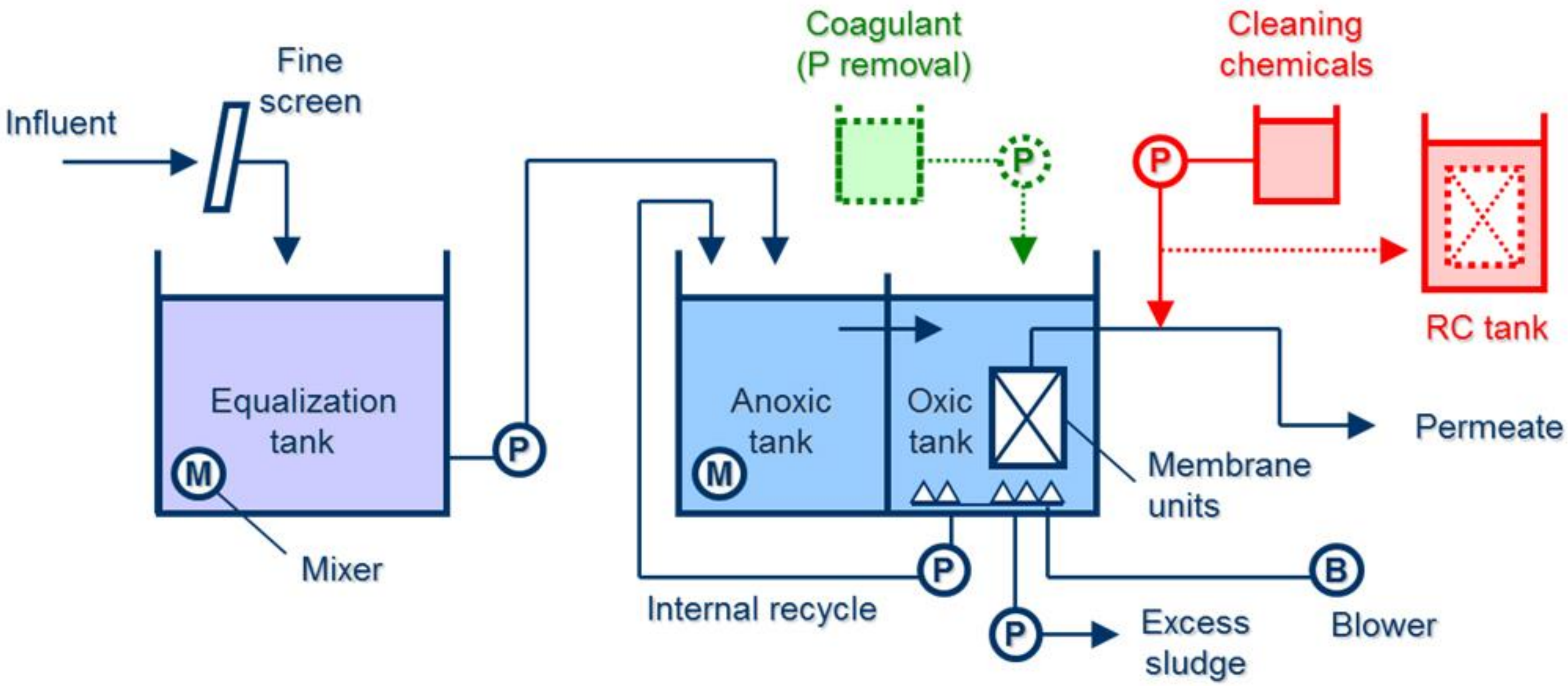
- Typical Conventional Process Diagram



Activated Sludge Wastewater Treatment Flow Diagram

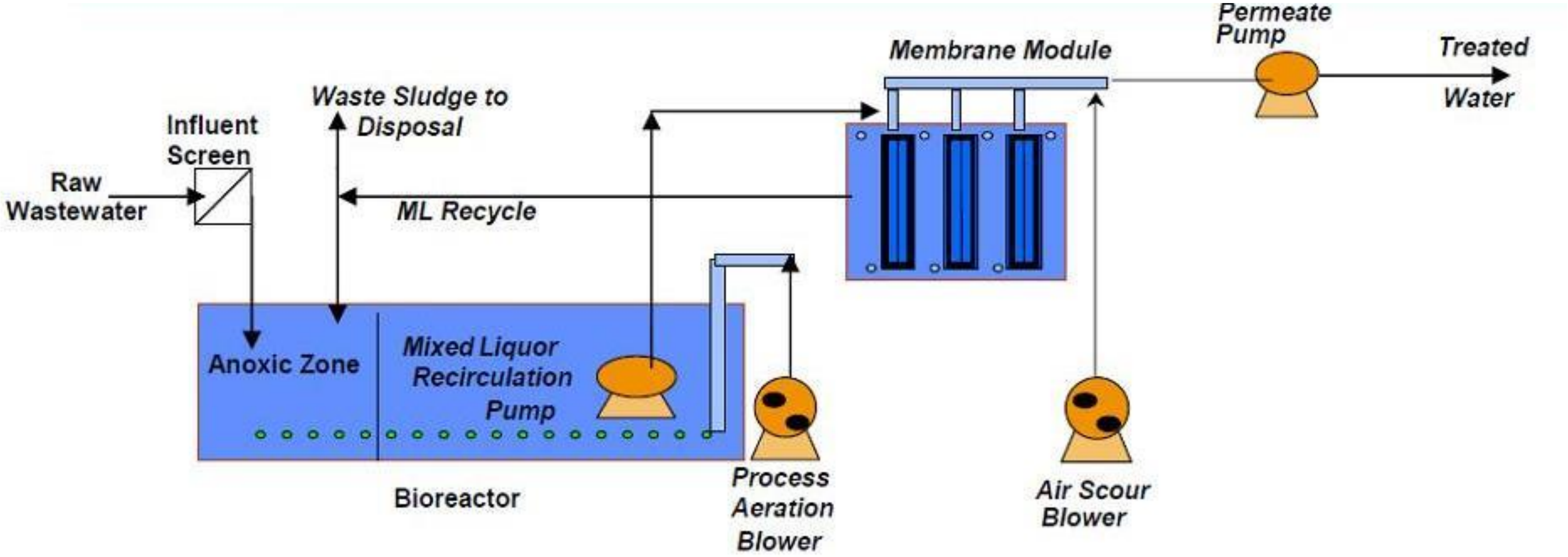
Conventional and MBR Process Comparison

- Historical Compact MBR Design



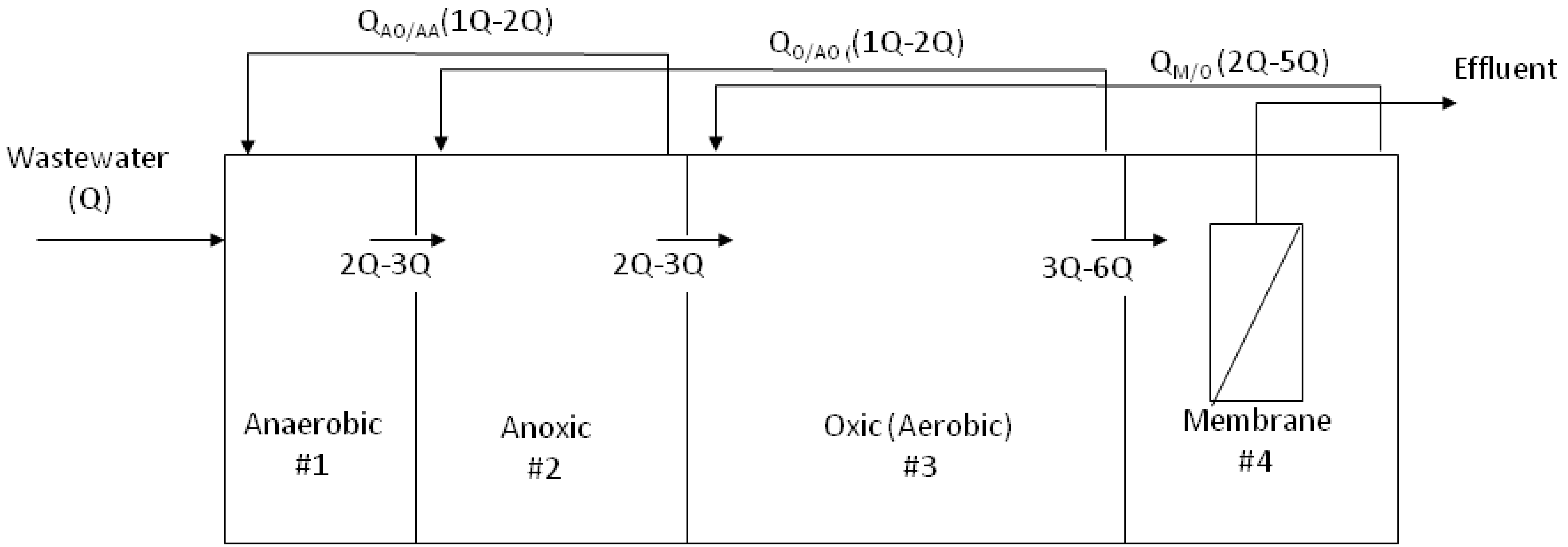
Conventional and MBR Process Comparison

- Historical Custom MBR Design



Conventional and MBR Process Comparison

- Current MBR Design Approach (w/ BNR)

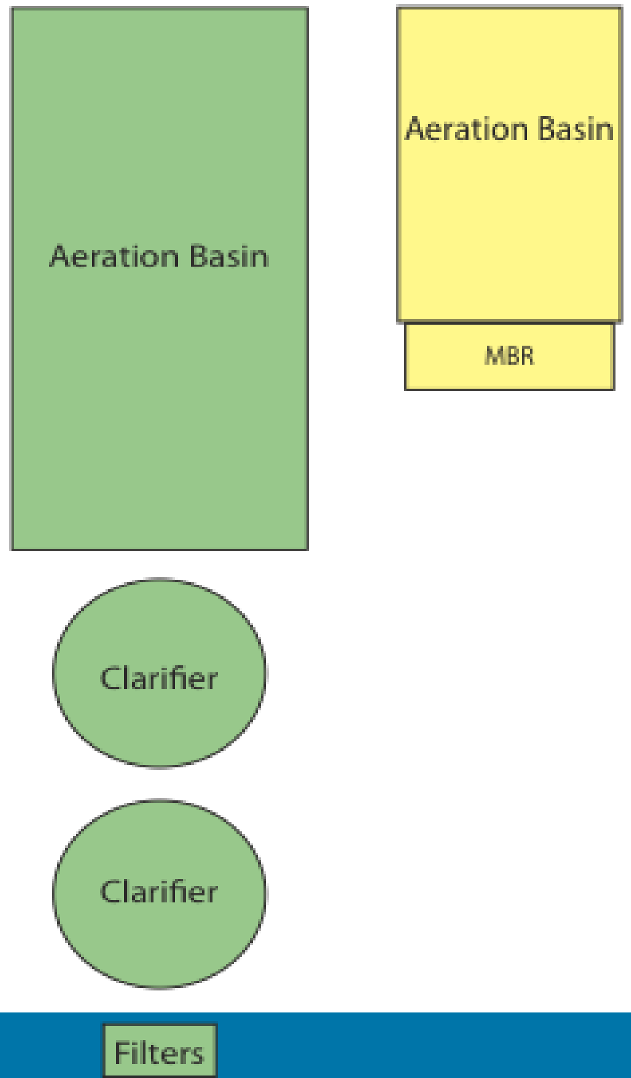


Conventional and MBR Process Comparison

- 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 !**

Conventional and MBR Process Comparison

Conventional 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

Conventional and MBR Process Comparison

- 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)

Conventional and MBR Process Comparison

- 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 can be considered to provide aerobic digestion.
        - Ultimate solids handling and disposal method should be reviewed with TCEQ prior to completion of final design!

Conventional and MBR Process Comparison

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

Conventional and MBR Process Comparison

- 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 - $1.00 - $3.00 (installed in aeration basins)
  - Current 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 - $0.50 - $1.50 (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 Design Considerations

MBR

Module

Cassette or Rack

Membrane

MW

CEB

EFM

Hollow Fiber Membrane

Skid or basin or train

Flux rate

CIP

TMP

Flat Sheet Membrane

MBR Design Considerations

- 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 Design Considerations

- 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 Design Considerations

- 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 Design Considerations

- What are typical components?
  - Coarse screen (0.25”), grit removal, fine screen (< 2-3 mm)
  - 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 Design Considerations

- 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 Design Considerations

- 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 flux peaking factor of 1.5:1 or a maximum flow peaking factor of 2.5:1 (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 Design Considerations

- Air Scour – What is it and what is it for?
  - Typical MBR MLSS ranges from 4,000-12,000 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)

Summary

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- Cost of membranes can be more competitive than conventional treatment under certain requirements
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Questions?

Thank you!