SCMA Annual Conference & Expo

"Membranes: Basics, Barriers, and Breakthroughs"

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Lessons Learned from a Decade of Experience of Membrane Filtration in Texas

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Presentation Topics

- Discuss fundamentals of membrane filtration
- Discuss types of membrane filtration
- Compare membrane operation to existing filters
- Discuss piloting requirements
- Discuss lessons learned from membrane use

Fundamentals of Membrane Filtration

- Regulatory Requirements
  - Water Treatment
  - Reviewed under §290.42(g) as innovative treatment techniques and exceptions to the Rules
  - Must meet site-specific performance requirements when used at surface treatment facilities, in lieu of granular media filters, per §290.111(b)(1)(B)
    - Requires piloting of proposed system(s)

Fundamentals of Membrane Filtration

- Differences in Terminology for Membranes
  - Membrane – Material where the lateral dimensions (length, width) are much greater than the material thickness
    - Conventional Filtration – Uses granular media
  - Module – A housing for membrane fibers
    - Conventional Filtration – No similar concept
  - Filtrate – Filtered water from a membrane system
    - Conventional Filtration - Filter effluent
  - Concentrate – The waste stream from a membrane system
    - Conventional Filtration – Similar to backwash waste

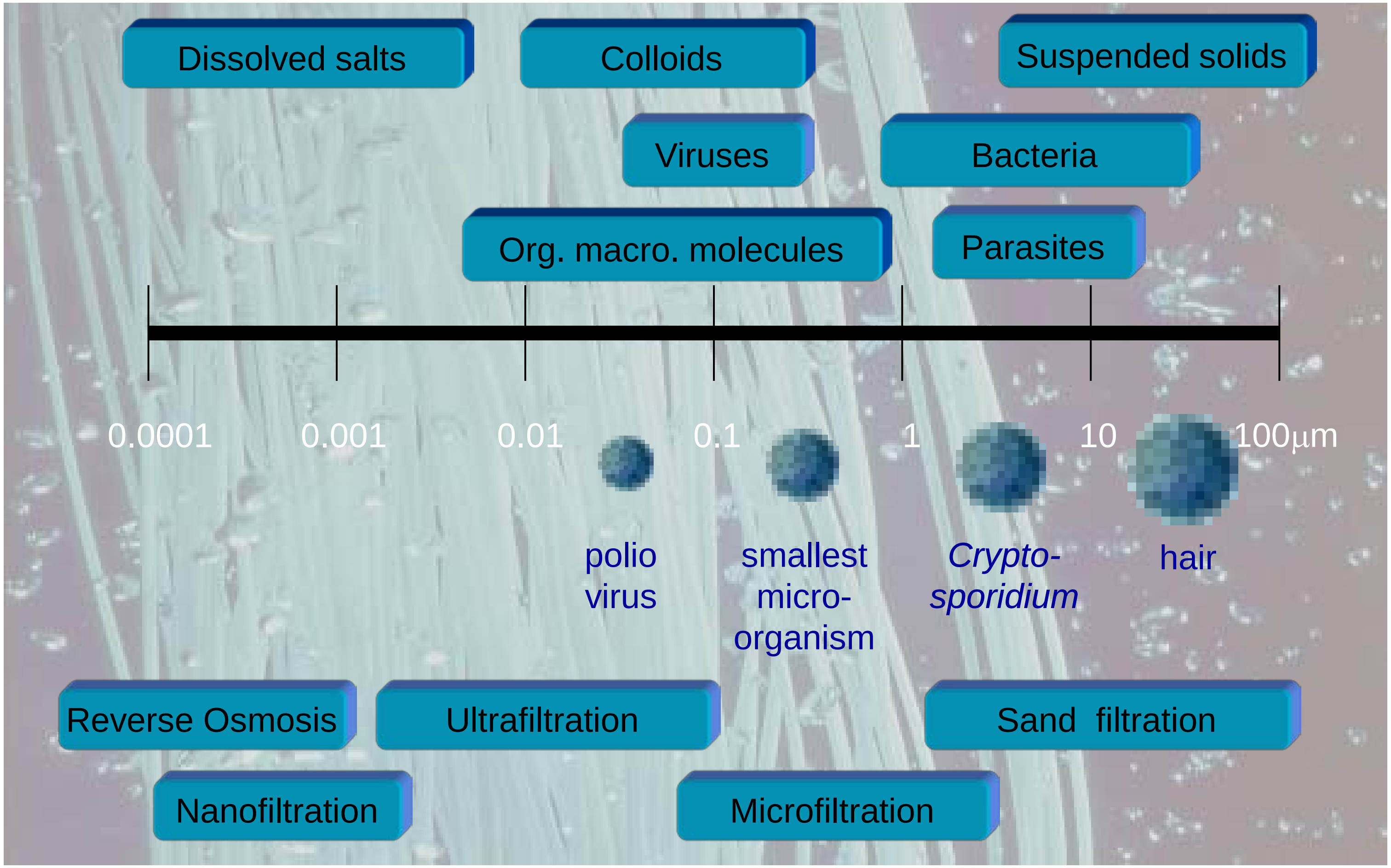
Fundamentals of Membrane Filtration

- Differences in Terminology for Membranes
  - Flux – A measure of the rate at which the filtrate passes through the membrane per unit of membrane surface area, expressed as gallons per square foot per day (gfd)
    - Conventional Filtration - Surface loading rate (gpm/sf)
  - Transmembrane Pressure (TMP) – Measurement of the force required to push/pull filtrate across a membrane surface
    - Conventional Filtration - Filter head loss
  - Fouling – Loss of performance due to suspended or dissolved material deposition on the membrane surface
    - Conventional Filtration – No similar concept

Fundamentals of Membrane Filtration

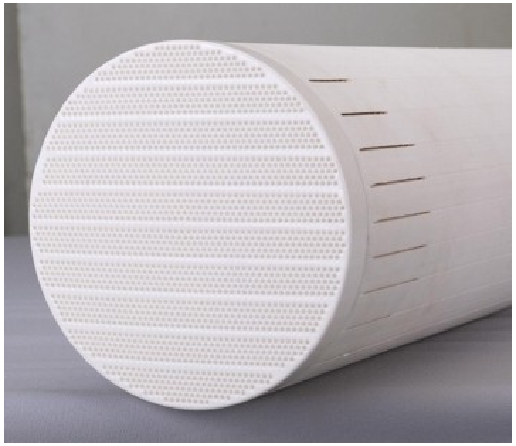
- Differences in Terminology for Membranes
  - Recovery – Ratio of filtrate produced compared to the original feed water flow rate, expresses as a percentage
    - Conventional Filtration – Net water production
  - Reverse Filtration / Backpulse – Forcing filtrate back through the membrane to clean off the feed side of the membrane
    - Conventional Filtration – Filter backwash
  - Clean-In-Place (CIP) – Cleaning the membranes by soaking in chemical solutions while still inside the pressure vessels
    - Conventional Filtration – No similar concept

Fundamentals of Membrane Filtration



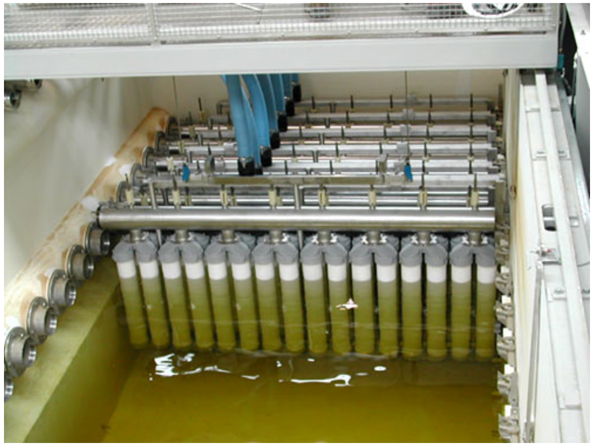
Types of Membrane Filtration

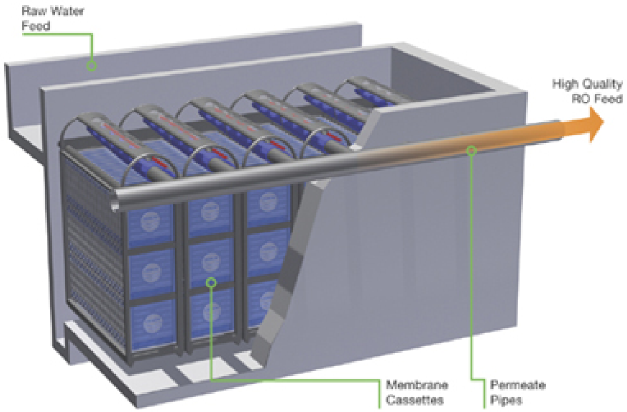
- Examples of Pressure Filters



Types of Membrane Filtration

- Examples of Vacuum Filters





Comparison of Membrane Operation

- Basic differences in operating principles.
  - Conventional plants use coagulants ahead of coagulation / flocculation / sedimentation process to produce settled water of <2 NTU to send to conventional filters. Must regularly produce settled water of about 2 NTU or less to ensure compliance with IFE and CFE limits.
    - Water quality to filters is key for conventional plants and meeting limits.
  - Quality of water to membranes has much less impact on finished water quality. Fixed pore size of membranes dictates finished water quality.
    - Poorer water quality will impact frequency of membrane cleaning but typically not the quality of the finished water.

Comparison of Membrane Operation

- How are instrumentation requirements different for membrane filtration?
  - Conventional WTPs utilize nephelometric turbidimeters to measure NTU in IFE and CFE.
    - Indirect integrity monitoring
  - Membrane WTPs in Texas must utilize laser turbidimeters to measure turbidity in membrane effluent (in mNTU).
  - Additionally, membrane WTPs must complete DITs on each membrane rack a minimum of once every 7 days (or more frequent, depending on LT2 Bin Classification). Must maintain pressure sensors and instrumentation associated with DIT.
    - DIT – Direct Integrity Testing

Comparison of Membrane Operation

- How are membranes different from conventional filters in cleaning?
  - Membranes are cleaned in several ways. Additional chemicals are used in the cleaning process:
    - Routine short backwashes on regular intervals (every 15-30 minutes) using water and air pulses. Membrane remains in normal service.
    - Weekly mini-CIPs (maintenance cleans) using low pH (acid) and/or chlorine (hypochlorite). Membrane out of service for short period.
    - Long-CIPs using low pH (acid), high pH (caustic) and chlorine (hypochlorite). May also use neutralizing chemicals to neutralize chlorine and low/high pH (monthly). Membrane out of service for 1-2 days.

Comparison of Membrane Operation

- How do membranes change operation of recovery and handling of backwash waste?
  - Due to typically high recovery of membranes through the first pass (95%+), TSS and organics are normally much more concentrated than in conventional filter backwash. Concentration of organics may increase risk of DBP formation potential when recycling back to head of plant.
- How do membranes change operation of solids and waste stream handling?
  - Very little change in how solids are handled. Can either be handled onsite or discharged to sewer for handling at a WWTP.

Comparison of Membrane Operation

- How is equipment operating life different for membrane systems?
  - Membrane life expectancy currently varies between 5 and 15 years. Issues that appear to have the greatest affect on membrane life include:
    - Optimizing frequency and strength of mini- and long-CIPs
    - Maintaining a consistent feed water quality to the membranes
    - Exercise the membranes on a routine basis
  - Dual media filter beds typically last about 10-20 years before needing to be rehabilitated.

Comparison of Membrane Operation

- Monitoring and Reporting - Testing
  - Two methods are required for monitoring and reporting performance and integrity of membrane systems used in potable water production.
    - Direct Integrity Test (DIT)
    - Indirect Integrity Test
  - Monitoring and reporting TOC in membrane treatment of drinking water.

Comparison of Membrane Operation

- Monitoring and Reporting – Direct Integrity Test
  - DIT testing is used to verify there are no breaks or breaches (3 micron) in the membrane capable of allowing pathogens through the membrane barrier (crypto size is 4-6 micron).
  - Purpose of the DIT is to verify the membrane barrier remains intact.
  - Most DIT testing relies on pressurizing the membrane system to minimum required pressures (or vacuum) and measuring the pressure (or vacuum) decay over time. Too much pressure or vacuum decay and the membrane fails the DIT. Too many membrane breaches.

Comparison of Membrane Operation

- Monitoring and Reporting – Indirect Integrity Test
  - Indirect integrity testing uses turbidity levels in the finished water to indirectly establish the integrity of the membrane.
  - Rising turbidity levels indirectly indicate a breach in the membrane.
  - Serves to provide monitoring of membrane integrity between DITs which may only be undertaken once every 7 days.

Pilot Testing

- What is a pilot and why do we do it?
  - Why pilot?
    - Membrane systems are still considered an innovative/alternative treatment technology.
    - 30 TAC 290.42(g) requires that where innovative treatment systems are proposed, the system must be piloted to demonstrate how the system will produce water that meets all State and Federal standards.

Pilot Testing

- What is a pilot and how do we do it?
  - New Requirements for the Owner
    - Same as current
    - Also must provide membrane-specific data required under LT2ESWTR (LT2) with each pilot study report
  - New Requirements for the Membrane Vendor
    - Provide challenge study removal efficiency
    - Provide maximum log removal value (LRV), verified by a particular direct integrity test (DIT)
    - Provide non-destructive performance test (NDPT) for verification of membrane modules not challenged
    - Provide a quality control release value (QCRV) for the NDPT

Pilot Testing

- Typical piloting procedures
  - Phase 1 – 10-15 days
    - Intended to establish anticipated operating parameters (starting TMP, operating flux, mini-CIP and long-CIP frequency)
  - Phase 2 – 30+ days
    - Intended to verify operating parameters (daily TMP increase, maintained operating flux, effectiveness of mini-CIP frequency, observed flux and TMP recovery from mini-CIPs)
  - Phase 3 – 10-15 days
    - Intended to verify system recovery from long-CIP event (recovered TMP, recovered operating flux, effectiveness of mini-CIP frequency)

Lessons Learned

- Scaling potential of membranes
  - In some cases, highly alkaline waters have a tendency to form a significant amount of scale on the feed side of membranes.
    - Significant scale buildup requires coordination with the membrane manufacturer and design engineer to develop a modified cleaning program to maintain original operating flux and TMP
  - This tends to be fairly common for direct filtration systems, but can be less for systems using pretreatment ahead of the membranes.

Lessons Learned

- 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. High 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.
      - *Also must monitor for potential for metal impregnation of downstream membranes if the membrane filtration system is followed by an RO system*

Lessons Learned

- 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 membrane manufacturer's recommended cleaning procedures (potential warranty issues)
    - It can frequently be best to try new ideas/procedures on only an element or two to determine if the procedure or chemical is safe before implementing on an entire array
      - *Ongoing communication with the membrane manufacturer and the design engineer is key!*

Lessons Learned

- Risks of damaging membranes as a result of air scour
  - Some systems have seen damage to membranes as a result of excessive air scour flow or pressure to the membranes.
    - Excessive air scour flow or pressure can create a “whip-like” wave through the membrane module, cause fiber breakage or damage at the potting connection to the membranes.
    - It is best to coordinate with the membrane manufacturer before adjusting set points for air scour.
      - *Ongoing communication with the membrane manufacturer and the design engineer is key!*

Lessons Learned

- 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 standard ductile iron piping 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 to minimize debris passing to the membranes. The key issue is to minimize the amount of abrasive materials that can reach the membranes.*

Lessons Learned

- Risks of loss of membrane capacity as a result of changing water conditions
  - Some systems have seen rapid (and sometimes irreversible) fouling of membranes as a result of deteriorating water quality.
    - Increased water temperature due to low reservoir levels, concentrated organics, increased bio-fouling, increased scaling potential, reduced effectiveness of mini- and long-CIPs
      - *Trending membrane operational data is critical to determine patterns of increased fouling and reduced cleaning effectiveness on a daily, weekly, monthly, and annual basis!*
      - *Ongoing communication with the membrane manufacturer and the design engineer is key!*

Lessons Learned

- Risks of loss of membrane capacity as a result of unchecked fouling
  - Some systems have seen rapid (and sometimes irreversible) fouling of membranes as a result of unchecked fouling. CIPs and/or chemically enhanced backwashes were not completed because the TMP did not appear to require cleaning.
    - When running an MF/UF system under capacity, the effective TMP will be artificially low. True foulant testing should be completed when operating the system at net production in order to accurately gauge fouling potential.
      - *Trending membrane operational data (for net production periods, not just under low loading rates) is critical to determine patterns of increased fouling and reduced cleaning effectiveness on a daily, weekly, monthly, and annual basis! Ongoing communication with the membrane manufacturer and the design engineer is key!*

Lessons Learned

- Membrane Life
  - Some systems have seen a membrane life of greater than 10 years, while other systems have seen a membrane life of 5 years or less.
    - Biological fouling does not typically contribute to irreversible fouling. Inorganic scale fouling is frequently the majority of the contributor to irreversible fouling and loss of permeability.
      - *Trending membrane operational data is critical to determine patterns of increased fouling and reduced cleaning effectiveness on a daily, weekly, monthly, and annual basis!*
      - *Ongoing communication with the membrane manufacturer and the design engineer is key!*
      - *While the typical membrane warranty is for 10 years, utilities should budget for the next membrane replacement on a 5-8 year basis.*

Lessons Learned

- Membrane System Service Contracts
  - Several of the major membrane filter manufacturers offer an annual service contract. The intent of the service contract is to provide a quarterly, semi-annual or annual checkup of the membrane system to verify effectiveness of air scour, chemically enhanced backwashes, CIPs, etc.
    - Beneficial use of a service contract can lead to maintaining optimized cleaning and maintenance efforts of the membrane system, which can optimize membrane performance and increase membrane longevity.
      - *Service contracts can range from low to fairly high cost (based on frequency of site visits included in the contract). Discussion of key contract goals with the membrane manufacturer and your design engineer is a must to custom-tailor a contract to your needs.*

Thank you for your time!