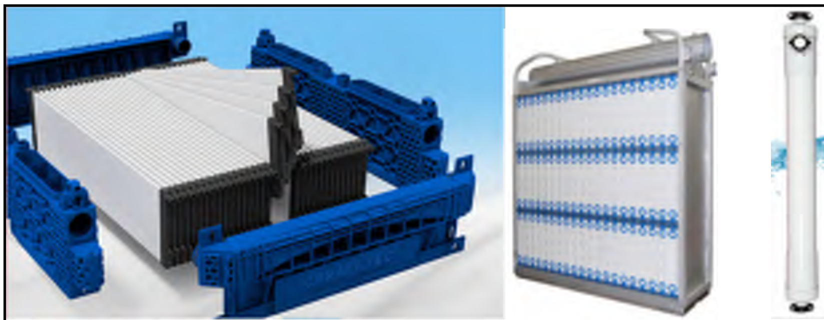


Bismarck WTP Expansion: MF/UF Piloting Program Overview

2025 AWWA Surface Water Treatment Workshop

HDR

4-23-25

1

Bismarck

HDR would like to thank all City of Bismarck Utilities Operations, Water Treatment Plant, and Lab staff, including Michelle Klose, Jim Kershaw, Ira Williams, Jared Curl, Ryan Spletstoser, Jason Ulland, Sandy Young, and many others for their support throughout the piloting process.

HDR

2

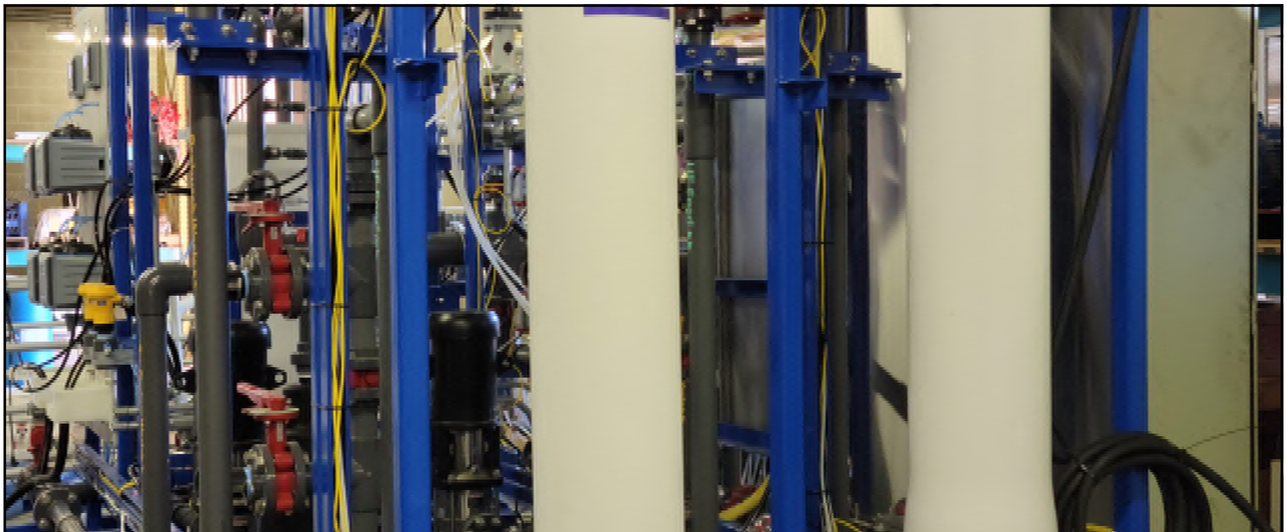
HDR would also like to thank the PKG Contracting, Inc. team for their support during the piloting program. Russ Sorenson, Jeremy Johnson, Seth Nutt, and Darin's entire CMAR team were instrumental in the procurement, installation, and tear down processes.

HDR would also like to thank the ND DEQ Drinking Water Program team for their open communication and availability during the piloting program. Bryan Schmitt was an excellent resource to help guide the process and support timely decision making during operations.

3

AGENDA

4



01

Introduction

5

Bismarck Water Treatment

Source Waters

- Missouri River surface water
  - Used in peak months (May/June-October)
- Horizontal Collector Well
  - Bank filtration on the east bank of Missouri River
  - Used in low flow months through spring runoff period (November-May)
  - Groundwater Influenced Quality
    - Iron and Manganese present

6

Bismarck Water Treatment

Existing Process

1. Screening
2. Lime Softening
3. Filtration
4. Disinfection
5. Residuals Handling

Capacity (MGD)

1. Current – 30

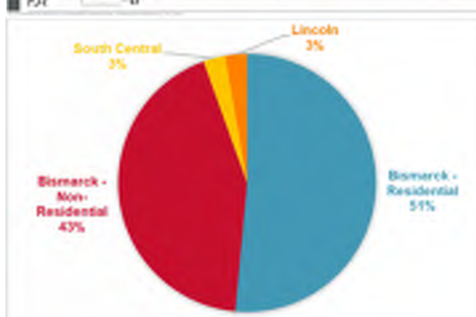
	Actuals	Projections	
Year	2020	2030	2040
Average Demand - MGD	10.1	12.3	14.2
Peak Demand - MGD	27.5	32.5	40.2

Importance of Planning

City of Bismarck Water Treatment Plant Master Plan

- Expected user increase of 30,000+ people
- Expected capacity requirement of 40+ MGD
  - 20-year projection
- Prepared City to take advantage of Funding Opportunities and phasing of improvements

	Actuals	Projections	
Year	2020	2030	2040
Average Demand - MGD	10.1	12.3	14.2
Peak Demand - MGD	27.5	32.5	40.2



Bismarck Water Treatment

Planned 10 MGD Expansion

1. Source Water Blending
   - Missouri River Intake
   - Collector Well
2. Pretreatment
   - Oxidation
   - Sedimentation/Sand Removal
3. Microfiltration-Ultrafiltration (MF/UF)
4. Reverse Osmosis (RO)
5. Disinfection
6. Residuals Handling Improvements

9

HDR

10

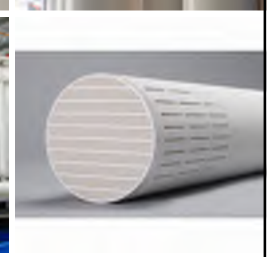
02

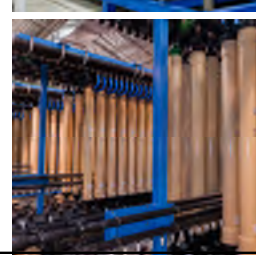
MF/UF Piloting Program

12

Ceramic vs Polymeric

- City of Bismarck interest in possible advantages of ceramics compared to PVDF lead to decision to development a pilot program with multiple MF-UF Modules
- Number Possible Ceramic Advantages
  - Longer membrane life
  - Typical higher flux rates
  - Potential for fewer fouling issues
  - Ability to handle higher strength of cleaning chemicals
  - High thermal stability





13

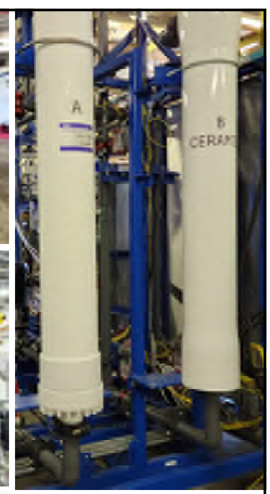
MF/UF Pilot Program Objectives and Goals

1. Obtain sufficient data required for ND DEQ review process for ceramic membrane systems for both City of Bismarck raw source waters (surface water and collector well), minimum of 2 cleaning cycles total.
2. Determine optimum flux, coagulant feed rates, backwash and cleaning frequency on each raw water source to provide basis of design for full-scale membrane system procurement
3. Optimize cleaning chemical cleaning strategy - run continuously for 30 days on each Bismarck source water without requiring a CIP.
4. Meet turbidity reduction and recovery goals for each raw water source

14

Piloted Systems

- Submerged PVDF (Top Left)
  - Surface Water Only
- Pressurized PVDF (Module A - Right)
- Pressurized Ceramic I (Module B - Right)
- Pressurized Ceramic II (Middle Left)
- Submerged Ceramic (Bottom Left)



15

Submerged PVDF

- PVDF - Polyvinylidene Fluoride
- Cassettes that can be stacked and submerged in a basin
- Cassette Dimensions:
  - 27” height, 27.2” width, 4.2” length
  - 3,084.5 cubic inch volume
- 0.02 micron nominal pore size (UF)
- Fiber OD – 0.95mm
- Membrane Module Surface Area - 550 sf
- Flow path – Outside In

16

Pressurized PVDF

- PVDF - Polyvinylidene Fluoride
- Cylindrical pressurized module
- Dimensions
  - 8.5” diameter, 85” length
  - 4,820.9 cubic inch volume
- 0.01 micron nominal pore size (UF)
- Membrane Module Surface Area - 969 sf

17

Pressurized Ceramic I

- Silicon Carbide (SiC) – Segmented Module
- Cylindrical pressurized module
- 10” diameter, 75” length
  - 5,887.5 cubic inch volume
- 0.04 micron nominal pore size (UF)
- Membrane Surface Area - 244 sf
- Hydrophilic (Attracted to Water)

18

Pressurized Ceramic II

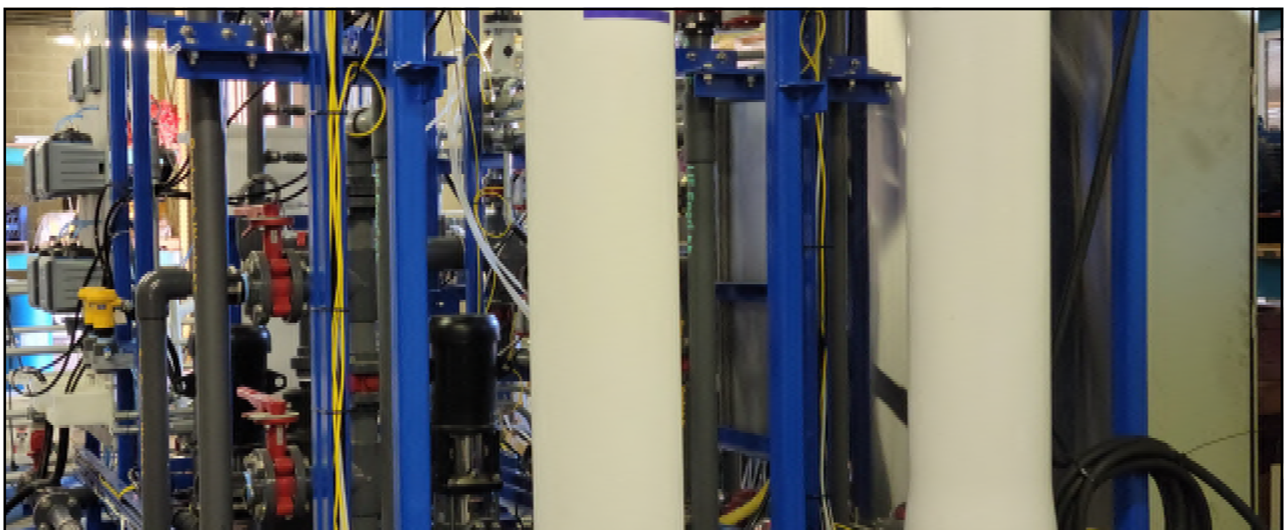
- Alumina – Monolithic Module
- Cylindrical pressurized module
- Inside-out filtration
- Module Dimensions
  - 7.1” diameter, 59.1” length
  - 2,338.7 cubic inch volume
- 0.1 micron nominal pore size (MF)
- Membrane Module Surface Area - 269 sf
- Hydrophilic (Attracted to Water)

19

Submerged Ceramic

- Alumina - Ceramic
- Plates that are stacked on top of each other
- Outside-in filtration
- Plate Stack
  - 28” length, 22.7” width, 6.3” height
  - 4,004.3 cubic inch volume
- 0.05 micron nominal pore size (UF)
- Membrane Stack Surface Area - 64.6 sf
- Hydrophilic (Attracted to Water)

20



03

UF Piloting - Surface Water

21

Membrane Acronym Refresher

- Flow - GPM – Gallon Per Minute
- Flux – GFD – Gallons per Sq. Foot per Day
  - Normalized Flux – Temperature Correct Flux @ 20 deg C
- Transmembrane Pressure – TMP
- CIP – Clean In Place
- Production Cycle – Length of Time Between Backwashes
- Recovery - % of Total Permeate Volume / Total Feed Volume
- Permeability – Flux/TMP
- HCW – Horizontal Collector Well

22

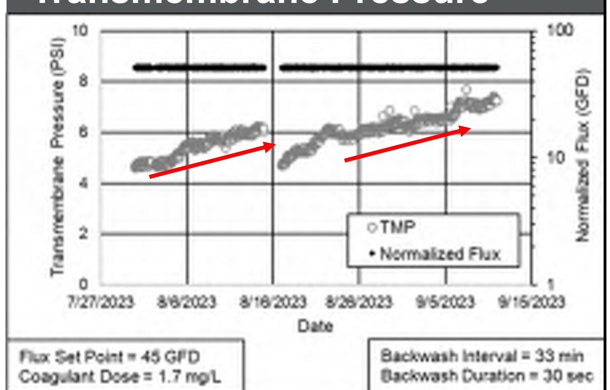
Submerged PVDF

Operating Conditions Table

Description	Units	Submerged PVDF
Flowrate	GPM	17.2
Instantaneous Flux (Normalized)	GFD	45-50 (50-65)
Coagulant Dose	Mg/L	1.7
Production Cycle Time	Min	23-33
Recovery	%	95-96
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	500
50% Citric Acid Dose	Mg/L	2,000
Hypo CIP Permeability Recovery	%	78
Acid CIP Permeability Recovery	%	22
Total CIP Permeability Recovery	%	95.6

Coagulant used was Aquahawk 607 (Aluminum chlorohydrate)

Transmembrane Pressure



- TMP ranged from 5-8 psi throughout the surface water trial.
- The observed linear fouling rate was 0.10 psi/day at the average water temperature of 15.4C.
- 2 Maintenance Cleans per week.

23

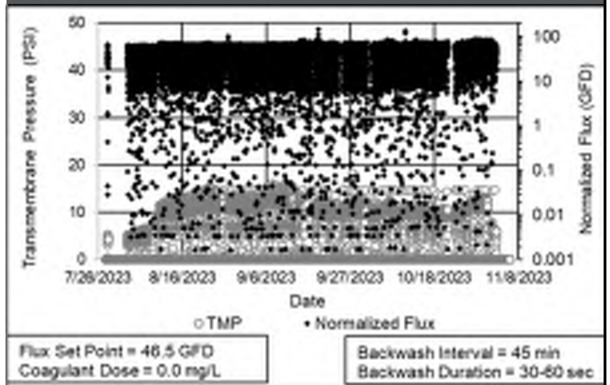
Pressurized PVDF

Operating Conditions Table

Description	Units	Pressurized PVDF
Flowrate	GPM	30
Instantaneous Flux (Normalized)	GFD	44.5-46.5 (50-70)
Coagulant Dose	Mg/L	0
Production Cycle Time	Min	30-45
Recovery	%	>96
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	3,000
50% Citric Acid Dose	Mg/L	5,000
Total CIP Permeability Recovery	%	98.1

Coagulant used was Aquahawk 607 (Aluminum chlorohydrate)

Transmembrane Pressure



- TMP ranged from 9-13 psi throughout the surface water trial.
- The observed fouling was 4 psi between CIPs at a normalized water temperature of 20C.
- Maintenance Clean Frequency – 50 backwashes

24

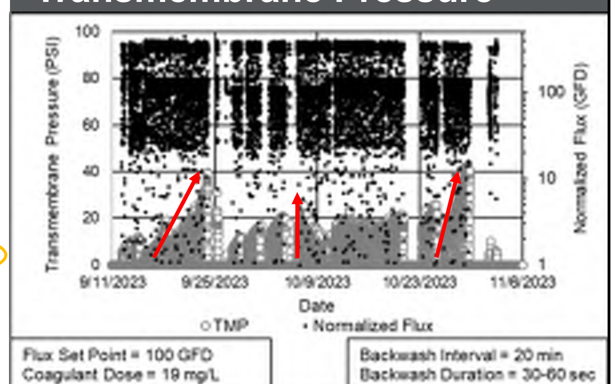
Pressurized Ceramic I

Operating Conditions Table

Description	Units	Pressurized Silicon Carbide
Flowrate	GPM	17-21
Instantaneous Flux (Normalized)	GFD	100-125 (100-175)
Coagulant Dose	Mg/L	15-19
Production Cycle Time	Min	20
Recovery	%	<95
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	3,000
50% Citric Acid Dose	Mg/L	5,000
Total CIP Permeability Recovery	%	96.2

Coagulant used was Aquahawk 607 (Aluminum chlorohydrate)

Transmembrane Pressure



- The observed fouling was extreme during the surface water trial.
- This resulted in multiple shutdowns due to high TMP, and multiple CIPs being performed within a 30 day period.
- Maintenance cleaning schedule was varied greatly during piloting.

25

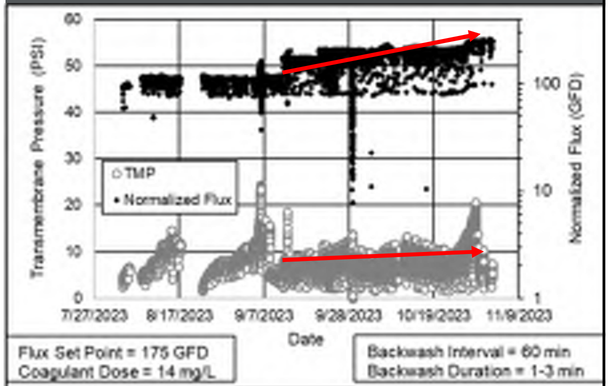
Pressurized Ceramic II

Operating Conditions Table

Description	Units	Pressurized Alumina
Flowrate	GPM	18.7-33
Instantaneous Flux (Normalized)	GFD	100-175 (100-250)
Coagulant Dose	Mg/L	10-14
Production Cycle Time	Min	60
Recovery	%	98.5
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	3,000
50% Citric Acid Dose	Mg/L	10,000
Total CIP Permeability Recovery	%	98.7

Coagulant used was Aquahawk 607 (Aluminum chlorohydrate)

Transmembrane Pressure



- There were 2 spikes caused by low coagulant dose(mechanical issue) seen on 9/2 and 10/29. Neglecting these spikes, TMP ranged from 2-12 psi between CIPs at a normalized water temperature of 20C.
- Maintenance Cleans performed daily.

26

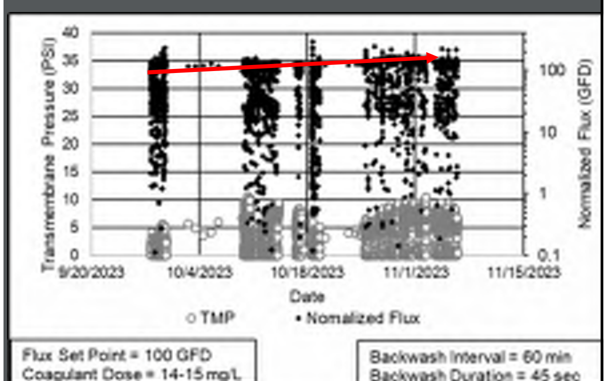
Submerged Ceramic

Operating Conditions Table

Description	Units	Submerged Alumina
Flowrate	GPM	13.7
Instantaneous Flux (Normalized)	GFD	100 (122-146)
Coagulant Dose	Mg/L	14-15
Production Cycle Time	Min	60
Recovery	%	95.6
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	2,655
50% Citric Acid Dose	Mg/L	10,185
Hypo CIP Permeability Recovery	%	89
Acid CIP Permeability Recovery	%	11
Total CIP Permeability Recovery	%	96.7

Coagulant used was Aquahawk 607 (Aluminum chlorohydrate)

Transmembrane Pressure



- TMP ranged from 2-10 psi between CIPs. Operating temperatures ranged from 40-60F throughout the surface water trial.
- Maintenance Cleans were performed once daily.

27

04

UF Piloting - HCW Water

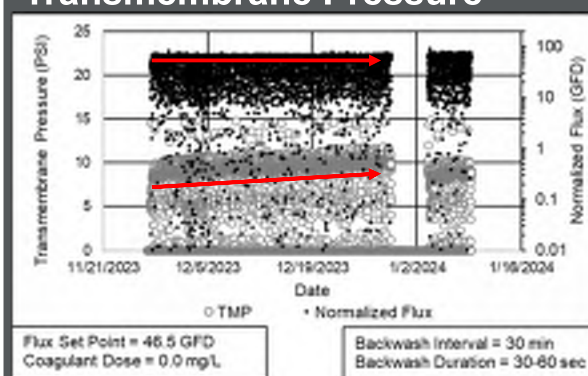
28

Pressurized PVDF

Operating Conditions Table

Description	Units	Pressurized PVDF
Flowrate	GPM	30
Instantaneous Flux (Normalized)	GFD	44.5-46.5 (55-65)
Coagulant Dose	Mg/L	0
Production Cycle Time	Min	30
Recovery	%	>96
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	3,000
50% Citric Acid Dose	Mg/L	5,000
Total CIP Permeability Recovery	%	99.5

Transmembrane Pressure



- TMP ranged from 8-10 psi throughout the HCW water trial.
- The observed fouling was 2 psi at a normalized water temperature of 20C.
- Maintenance Clean Frequency – 50 backwashes

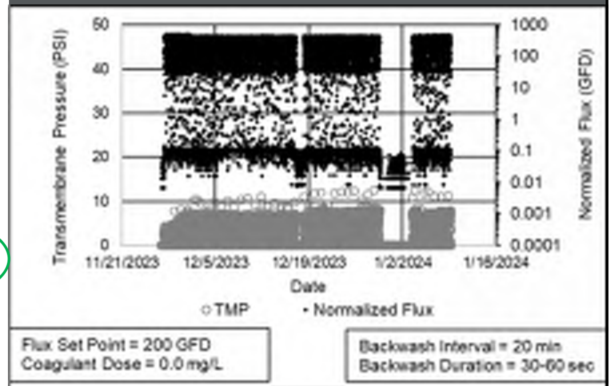
29

Pressurized Ceramic I

Operating Conditions Table

Description	Units	Pressurized Silicon Carbide
Flowrate	GPM	33.9-37.3
Instantaneous Flux (Normalized)	GFD	175-220 (150-275)
Coagulant Dose	Mg/L	19 - 0
Production Cycle Time	Min	20
Recovery	%	>96
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	3,000
50% Citric Acid Dose	Mg/L	5,000
Total CIP Permeability Recovery	%	>95

Transmembrane Pressure



- TMP stayed around 8 psi throughout the HCW water trial.
- The observed fouling was negligible at normalized water temperature of 20C.
- Maintenance Clean ranged between 34-108 backwashes. Optimized at 108 backwash interval

30

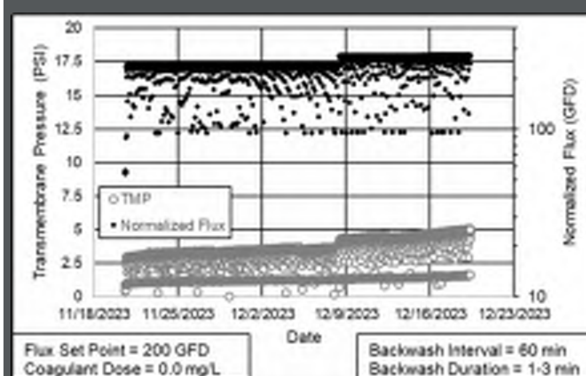
Pressurized Ceramic II

Operating Conditions Table

Description	Units	Pressurized Alumina
Flowrate	GPM	33-37
Instantaneous Flux (Normalized)	GFD	175-200 (240-275)
Coagulant Dose	Mg/L	14 - 0
Production Cycle Time	Min	60
Recovery	%	98.8
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	3,000
50% Citric Acid Dose	Mg/L	10,000
Total CIP Permeability Recovery	%	101[1]

[1] - Values greater than 100% can be caused by variances in flux, water temperature, and other factors during clean membrane permeability calculation and post CIP permeability calculation.

Transmembrane Pressure



- TMP ranged from 3-5 psi throughout the HCW water trial.
- The observed fouling was 1.27 psi at 175 gfd flux and 1.01 psi at 200 gfd at a normalized water temperature of 20C.
- Daily Maintenance cleans were performed.

31

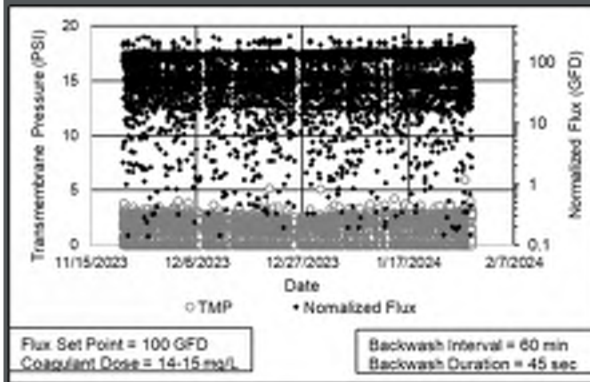
Submerged Ceramic

Operating Conditions Table

Description	Units	Submerged Alumina
Flowrate	GPM	13.7
Instantaneous Flux (Normalized)	GFD	100-101.5 (122-146)
Coagulant Dose	Mg/L	15 - 0
Production Cycle Time	Min	53-60
Recovery	%	95.1
CIP		
12.5% Sodium Hypochlorite Dose	Mg/L	2,243
50% Citric Acid Dose	Mg/L	10,401
Hypo CIP Permeability Recovery	%	0
Acid CIP Permeability Recovery	%	100
Total CIP Permeability Recovery	%	104[1]

[1] - Values greater than 100% can be caused by variances in flux, water temperature, and other factors during clean membrane permeability calculation and post CIP permeability calculation.

Transmembrane Pressure



- TMP ranged from 2-3 psi throughout the HCW water trial. Observed fouling was minimal.
- TMP ranged from 0.5-2 psi at a normalized water temperature of 20C.
- Maintenance Cleans were performed once daily.

32

05

UF Piloting Conclusions

33

Submerged PVDF

- Take Aways
  - Performed as expected with surface water piloting – Recovery, chemical usage, cleaning rates, low coagulant usage
  - Known Missouri River water performance and pilot results indicated no significant deviation at the Bismarck location
  - Small basin area requirements; potentially allowing for future expansion within existing footprint
  - Lower flux rates (40-45 GFD) and recovery (95-96%)
  - Hands-on operating experience for Operations staff

34

Pressurized Polymeric

- Take Aways
  - Performed as expected with surface water and HCW sources
  - Slightly higher recovery than submerged PVDF
  - Lowest coagulant usage among piloted modules
  - More maintenance typically compared to ceramic pressurized module, but no pinning required during piloting
  - Lower flux rates (46 GFD), slightly higher than submerged PVDF

35

Pressurized Ceramic I

- Trends and Takeaways
  - Performed well on HCW
    - Reached 200 GFD with stable operation
  - Pilot did not demonstrate stable treatment of Missouri River surface water
  - Did not meet ND DEQ requirement of 30 days run time without conducting CIP on surface water

36

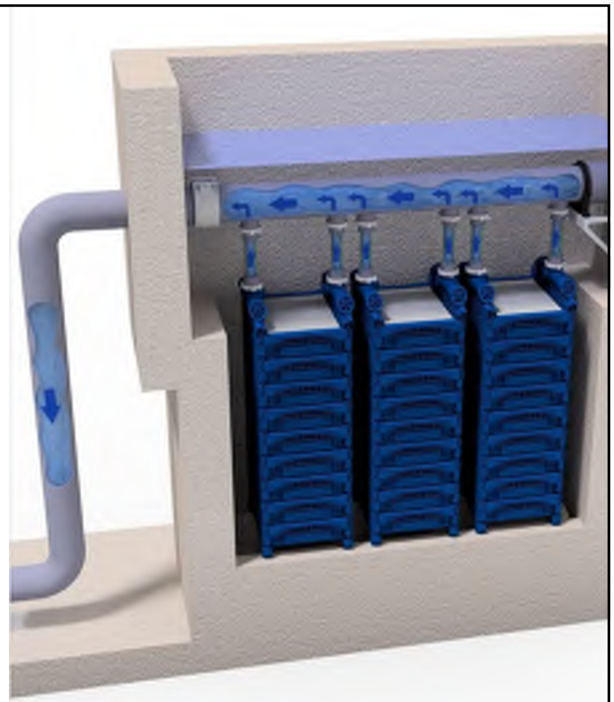
Pressurized Ceramic II

- Trends and Takeaways
  - Performed extremely well on both Surface and HCW source waters; long run times, relatively low chemical usage, extremely high recovery (~98-99%)
  - Highest stable flux rates (200 GFD) of the membranes piloted
  - Higher coagulant dosage required for surface water compared to PVDF
  - Long warranty, and lower O&M costs likely compared to pressurized PVDF

37

Submerged Ceramic

- Trends and Takeaways
  - Performed well on both Surface and HCW; long run times, relatively low CEB-CIP chemical usage
  - Long warranty, and lower O&M costs likely compared to PVDF submerged
  - Higher flux rates than comparable PVDF but significantly lower than the alumina pressurized module
  - Limited US installations
  - Large basin requirement, little to no room for expansion
  - Higher coagulant dosage required for surface water compared to PVDF



38

06

10 MGD WTP Expansion – Project Overview & Status

39

Membrane Selection Status

- Early coordination with ND DEQ lead to confidence in bidding UF Ceramics directly against PVDF
- City of Bismarck recently completed their Membrane procurement process with HDR – Design Engineer and PKG – CMAR.
- Pressurized Ceramic – Selected
  - Aqua-Aerobics System, Inc.
    - MultiBore C-Series Ceramic UF Membrane Modules
    - Toray RO Membrane Elements

40

10 MGD Expansion Overview

41

07

City of Bismarck CMAR Program Overview

42

WTP and WWTP Improvements CMAR Program

- Multiple facilities, locations, schedules, subcontractors, funding sources
- 9 total GMPs
- Projects ranging from new structures, forcemain, control structures, HVAC systems, SCADA network backbone, UF piloting, regional CO2 storage

43

Thank You

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44