This presentation premiered at WaterSmart Innovations

watersmartinnovations.com
PUB Water Utility Increases Recovery Rate from 75% to more than 90% using novel Flow Reversal Reverse Osmosis (FR-RO) Technology for Reuse Purposes

Douglas Craver
Western Regional Sales Manager
(480) 243-1824
dcraver@adedgetechnologies.com

October 2, 2019
Agenda Topics

• AdEdge Introduction

• Flow Reversal Reverse Osmosis (FR-RO) Technology Overview

• PUB Case Study – Industrial Reuse Application

• Exciting new Development for FR-RO - First US Based Project Preliminary Update

• Q&A
Approximately 900 system installations
Unprecedented > 37% growth in 2018
99.9% of systems remain in operation
Worker’s Comp (Safety) index of 0.84...lowest in Water Industry
Health & Safety Program Manager
Multiple arsenic projects awarded in Latin America including one of the largest Adsorption projects in the world in 2017 & 2018
No legal disputes, lawsuits or insurance claims in 17 year company history!
Treatment solutions for > 20 different contaminants & extensive piloting program
## AdEdge Treatment Matrix

### Technology or Media

<table>
<thead>
<tr>
<th>Process</th>
<th>Biological Filtration</th>
<th>Adsorption</th>
<th>LGF</th>
<th>RO</th>
<th>UF</th>
<th>Oxidation</th>
<th>IX</th>
<th>R0</th>
<th>MF</th>
<th>Clarification</th>
<th>Adsorption</th>
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*High recovery Approach*
AdEdge Innovation History

- **Bayoxide E33**
  - Adsorption media for arsenic and heavy metals removal

- **MnO2 Catalytic Media**
  - Arsenic, iron, manganese, and hydrogen sulfide removal media

- **WaterPOD**
  - Plug and play containerized treatment solution

- **H2Zero**
  - Backwash recycle system with a 99.7% water recovery rate

- **biottta®**
  - Biological filtration for the removal of nitrate, perchlorate and other contaminants from groundwater

- **NoMonia™**
  - Biological filtration for the removal of ammonia, arsenic, iron, and other contaminants from water

- **911box**
  - Remote programing trouble shooting for immediate response

- **Flow-Reversal RO**
  - Flow-Reversal RO Technology for higher recovery and lower wastewater volume
Flow Reversal RO

A New Approach to
Increasing System recoveries & Facilitating Concentrate management
Buzz words in the Water Industry

- Potable Reuse
- High Recovery Low Waste ZLD, MLD
- Water Ratio Concentration
- Regulation Sustainability
- ROI & Cost Effectiveness
- Circular Water Economy

How can we address these challenges?
75% is Totally 70’s

<table>
<thead>
<tr>
<th>Site</th>
<th>Conventional RO RR</th>
<th>Flow-Reversal RO RR</th>
<th>% Increase (permeate)</th>
<th>% Decrease (concentrate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverage company</td>
<td>65%</td>
<td>85%</td>
<td>20%</td>
<td>57%</td>
</tr>
<tr>
<td>Brewery</td>
<td>75%</td>
<td>92%</td>
<td>27%</td>
<td>68%</td>
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<tr>
<td>Fracking water</td>
<td>70%</td>
<td>89%</td>
<td>19%</td>
<td>63%</td>
</tr>
<tr>
<td>Cooling tower</td>
<td>71%</td>
<td>91%</td>
<td>20%</td>
<td>69%</td>
</tr>
<tr>
<td>SWRO 2nd pass</td>
<td>90%</td>
<td>98%</td>
<td>8%</td>
<td>80%</td>
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<tr>
<td>Reuse</td>
<td>80%</td>
<td>90%</td>
<td>10%</td>
<td>50%</td>
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</table>
Ultra-High Recovery Flow-Reversal RO

A conventional RO with a (patented) twist

Innovative, but not new
Voted “The Most Valuable Technology”
Singapore International Water Week July 2018

Voted “The Most Important Desal Technology”
TX Desal Sep 2018
AdEdge was selected as the U.S. Partner of Rotec to introduce, establish, market, manufacture & sell this disruptive RO technology to North America.

Rotec owns the IP for the Flow-Reversal technology.

Why AdEdge?

- Experience with RO Membrane Technology
- Extensive water treatment capabilities
- Integration Capability with pre-treatment and Other Equipment
- Internal manufacturing Facility, U.S. made. US Operation
- Piloting, QA, and Service Departments
What can Flow-Reversal RO do?

Maximize permeate flow by 20%
Optimize feed water use by 20%
Minimize concentrate flow by 60%

Concentrate management $ ZLD
Two Ways to Save

80% RECOVERY (CONVENTIONAL RO)

Feed 1,500 gpm → Permeate 1,200 gpm
Concentrate 300 gpm

92% RECOVERY (FR-RO)

Feed 1,304 gpm → Permeate 1,200 gpm
Concentrate 104 gpm

- 13%
- 65%

CONSTANT PERMEATE

Feed 1,500 gpm → Permeate 1,380 gpm
Concentrate 120 gpm

- 60%

CONSTANT FEED

Cost avoidance of purchased water
Flow Reversal Prevents Scaling

Our solution:
Operate at higher recovery by reducing scaling potential.

Operational implications of scaling:
- Mineral Scaling leads to RO membrane plugging and...
- Decrease in flux >> Increase energy consumption
- Increased: CIP frequencies, Down time, Chemical consumption
- Overall increase in OPEX and decrease in profitability
Why Flow-Reversal RO is so Brilliant?

Continuous process
works just like conventional RO

New & existing
Retrofit

No proprietary equipment
Always adhere to manufacturers’ specs

No special operator training
is needed

Low risk
100% Fallback

Added value
Reduced biofouling & chemical use
How does FR-RO Work?

1. Reversing the flow in the PV
2. Block Rotation
3. Continuous process

The results: Scale prevention
Converting a Conventional RO to FR-RO is Simple

Conventional RO

Flow-Reversal RO

New RO systems
Existing RO systems
Flow-reversal Concentrator
Reversing the Flow in the PV

1. Reversing the flow in the PV
2. Signs of scaling
3. Continuous process
Block Rotation
Flow Reversal adaptation to tapered flow array in a 2-Stage RO System

Block C is 2nd Stage

Block B is 2nd Stage

Block A is 2nd Stage
Impact of Flow-Reversal on Biofouling

- Sheering forces
- Changing water quality
Flow Reversal Products

1. **New RO Systems** *(RNS)*

2. **Retrofit** Existing RO Systems *(RTF)*

3. **Concentrate Management System** *(FR-CONC)*
Case study: Industrial Reuse application

- PUB is the most appreciated water utility in the world
- Innovation hub
- Large scale retrofit
- Perfect setting for a comparison study
- Municipal Reuse application for Industrial use
- Increased revenue & saving
- Led to a 25MGD new FR-RO system
Retrofit Case Study - PUB, Singapore

Pre – Retrofit
49:24 array

Retrofitted System
45:25:10 array
Pre – Retrofit
49:24 array

Retrofitted System
45:25:10 array

- 1st stage
- 2nd stage
- 3rd stage
Flow Reversal & Block Rotation

- 1st stage
- 2nd stage
- 3rd stage
Rotation of blocks - 1\textsuperscript{st} and 3\textsuperscript{rd} Stages

HMI Screen Shot
## Municipal Reuse Retrofit Case Study

### Retrofit Results Summary

<table>
<thead>
<tr>
<th>Unit</th>
<th>Conventional RO</th>
<th>Flow Reversal RO</th>
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<tbody>
<tr>
<td>Recovery Rate</td>
<td>%</td>
<td>75%</td>
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<tr>
<td>Array Configuration</td>
<td>N/A</td>
<td>49:24</td>
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<tr>
<td>Feed Flow</td>
<td>GPM</td>
<td>1,955</td>
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<tr>
<td>Permeate Flow</td>
<td>GPM</td>
<td>1,466</td>
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<tr>
<td>Concentrate Flow</td>
<td>GPM</td>
<td>489</td>
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<tr>
<td>Total Number of PVs</td>
<td>#</td>
<td>73</td>
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<tr>
<td>Total Average Flux</td>
<td>gfd</td>
<td>10.4</td>
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<tr>
<td>Feed Pressure Stage 1</td>
<td>PSI</td>
<td>100</td>
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<tr>
<td>3rd Stage Booster Pump</td>
<td>PSI</td>
<td>N/A</td>
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<tr>
<td>Specific Energy*</td>
<td>kWh/m³</td>
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<td>kWh/ 1000 gal</td>
<td>1.21</td>
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</table>
The CIP was triggered by a) 10% increase PD or b) 10% drop in specific flux (Lp)
CIP was done when recovery on the FR train was increased in order to have the same starting baseline each time which explains why there is overall a larger total of CIP’s in FR than in control.

Fewer CIP’s were done with FR than with control for the same amount of total produced water, means fouling was slower for the FR unit.
## Economic Comparison (95% utilization)

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<tr>
<th></th>
<th>% RR</th>
<th>Permeate Million m³/y</th>
<th>Permeate MG/y</th>
<th>Conc. Million m³/y</th>
<th>Conc. MG/y</th>
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<tbody>
<tr>
<td>Conventional RO</td>
<td>76</td>
<td>2.8</td>
<td>740</td>
<td>0.92</td>
<td>243</td>
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<tr>
<td>Flow Reversal RO</td>
<td>90</td>
<td>3.3</td>
<td>872</td>
<td>0.37</td>
<td>98</td>
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<td>(+) 0.5</td>
<td>(+) 132</td>
<td>(-) 0.55</td>
<td>(-) 145</td>
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</table>

- **Permeate**: $1.22 USD/m³ Permeate
- **Concentrate removal**: $0.10 USD/m³ Concentrate removal

**Total increased income / Year**: $665,000 / Year
First US Based FR-RO Project
Preliminary Overview
Case Study: Native American Community in Arizona

Diversified Economy:
- Agriculture
- Casino
- Transportation
- Golf Club
- Entertainment complex

Improvements:
- New fire station
- Water reclamation facility
- Surface water treatment plant

Salt River Project (SRP) Canal
Surface Water Treatment Plant
The Community is Facing a Water Supply Challenge

November 2019:
Shut-down of the only source of water for potable use

The community needs to identify an alternative water source

Must install a new & cost-effective treatment solution in 6 months
Identify an alternative water source

The only readily available water source was groundwater from an idle well (800 gpm) that had never been used due to high concentrations of nitrate, uranium, iron, and total dissolved solids (TDS).
Install a new & cost-effective treatment solution

<table>
<thead>
<tr>
<th></th>
<th>Nitrate</th>
<th>Uranium 238</th>
<th>Iron</th>
<th>TDS</th>
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<tbody>
<tr>
<td><strong>MCL</strong></td>
<td>10 mg/L</td>
<td>30 µg/L</td>
<td>0.3 mg/L</td>
<td>&lt;500 mg/L</td>
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<td><strong>AK Chin WQ</strong></td>
<td>15 mg/L</td>
<td>30 µg/L</td>
<td>1.0 mg/L</td>
<td>1897 mg/L</td>
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</table>

**Treatment approach & efficacy**

- **Biological - biottta**: Yes, No, No, No
- **Biological - NoMonia**: No, No, Yes, No
- **IX – NO₃, U**: Yes *, Yes *, No, No
- **O/F**: No, No, Yes, No
- **RO (High Recovery Flow-Reversal RO)**: Yes, Yes, No, Yes

**Hardness, alkalinity, silica**
Pick one....

1

More water - 88% RR vs. 75% RR
Less concentrate by 50% compared to conventional RO

Design considerations:

• Footprint
• Complexity
• CAPEX & OPEX (competitive compared to IX)
• Concentrate management
• TDS reduction + Multiple contaminants treatment
Also Good to Know...

- At the end of October 2019 when the canal is drained, FR-RO will be the primary water source for approximately 3 months.
- Phase 1 goal is to get the treatment system online for this 3-month downtime period.
- Phase 1 includes installation of the AD26, FR-RO, Chemical Feed Systems and a temporary shade structure.
- During Phase 1 the community will use their existing WWTP to dispose of the concentrate. The WWTP is not sized for long-term operation.
- This was one of the incentives for the higher recovery RO since it minimized the impact to the existing WWTP.
- Once the Surface Water Treatment plants are back online the RO will go to reduced operation (4 hr. / day).
- Phase 2 includes the permanent building, evaporation ponds, etc.
- **Once Phase 2 is completed, they will alternate usage between the Surface Water Treatment plant and the FR-RO system providing them full redundancy if one of the surface water plants goes down in the future.**
Native American Community Project - Timeline

April
- Wilson Engineers reached out to AdEdge that provided proposals for biotitta & RO. IX was also considered.
- Discussion expanded to include PCL, site visit, and the community decides to proceed with FR-RO

May
- LOI was issued to AdEdge
- WQ test confirmed 1mg/L Fe
- AD26 system is added

June
- Formal PO issued
- Submittals begin
- Layout drawings finalized
- Wilson & PCL – permit
- Long lead time items approved

July
- Submittals completed
- AD26 system assembly begins

August
- Submittals updates
- All key items for fabrication ordered
- Permits received
- AD26 system completed

September
- FR-RO delivered to project site 9/27/2019

October
- Startup
PROCESS FLOW SCHEMATIC
AK CHIN COMMUNITIES FR-RO SYSTEM

Notes:

- STREAM 0 - WELL WATER FLOW 800 GPM
- STREAM 1 - RAW WATER FLOW 800 GPM
- STREAM 2 - FEED FLOW TO STAGE 1 550 GPM
- STREAM 3 - FEED FLOW TO STAGE 2 550 GPM
- STREAM 4 - RECYCLING FLOW 0 GPM TBD
- STREAM 5 - CONCENTRATE FLOW 66 GPM
- STREAM 6 - REJECT FLOW 66 GPM
- STREAM 7 - PERMEATE FLOW 484 GPM
- BYPASS / BLEND FLOW 250 GPM
- STREAM 8 - BLENDED PRODUCT FLOW 734 GPM

WELL PUMP
Packaged APU26 Skid Mounted Oxidation / Filtration Module for Fe removal

Notes:
- NUMBER OF NF TRAINS 1
- MASS BALANCE / FLOW - PROCESS STREAMS

TANK STORAGE AND BOOSTER PUMP (BY OTHERS)
PRESSURIZED DISTRIBUTION
TREATED WATER
PRE-CHLORINE
F-RO
BLEND VALVE
BLEND
PACKAGED
APU26
SKID
MOUNTED
OXIDATION
/FILTRATION
MODULE
FOR Fe REMOVAL
WELL PUMP
PACKAGED
APU26
SKID
MOUNTED
OXIDATION
/FILTRATION
MODULE
FOR Fe REMOVAL
WELL PUMP
“It simply doesn’t make sense anymore to install conventional RO”

Questions?