Magnetic Ion Exchange (MIEX®) Technology
A Lower Cost Alternative to GAC for DBP control
Outline

- DBP Control Background
- MIEX® Process Overview
- Case Studies - Bench and Pilot Scale Testing Results
  - South Carolina Source Results
  - Tennessee Source Results
  - Pennsylvania Source Results
- MIEX® Benefits/Advantages/Disadvantages
- Conclusions
- Questions
Disinfection Byproducts Control - Background

TOC + \( \text{Cl}_2 \) = DBPs

Natural Organic Matter + Disinfectant = THMs & HAAs
NOM Reduction Approach

- Enhanced/Alternate Coagulation, 10 to 20% DBP Reduction
- Powdered Activated Carbon, 5 to 50% DBP Reduction
- Magnetic Ion Exchange Resin (MIEX®), 70% DBP Reduction
- Granular Activated Carbon, 70 to 80% DBP Reduction
- Membranes (NF), 80% DBP Reduction

Listed in Order of Increasing Cost $
Alternative Disinfectants Approach

- Chloramines as Secondary Disinfectant
- UV Light as Primary Disinfectant
- Ozone as Primary Disinfectant with Biological Filtration

Listed in Order of Increasing Cost $
Distribution System Modifications Approach

- Adjustment of pH, 20 to 30% DBP Reduction (Tradeoff between HAA5 and TTHM – Corrosion control implications)
- Flushing Program
- Reducing Water Age (Looping, Eliminating Major Dead Ends, etc.), Evaluate with Modeling
- Storage Tank Improvements – Mixing, THM Aeration
MIEX® Process Overview – Focus on NOM Removal

NOM + Cl₂ = DBPs

Natural Organic Matter

Disinfectant

THMs & HAAs
MIEX® Process For TOC Removal

- New process developed in Australia
- Developed for waters with high levels of DBP precursor material (NOM)
- Achieves much higher removals than coagulation
- Capital cost: $0.30 to $0.40 per gallon
- Operating costs:
  - Resin
  - Salt
  - Waste Brine disposal
  - Power for resin mixing/transport
- Engineered resin bead is the key
MIEX® Resin Properties

Anion Exchange Resin
- removes negatively charged TOC

Very Fine Particle Size
- very high surface area
- (3-5 times conventional resin)
- rapid exchange kinetics

Magnetic Properties
- aggregation/fast settling

Robust/Tough
- recycled in a continuous process

Magnetic Component

REGENERATION

BRINE

FULVIC/HUMIC ACID

ADSORPTION
Ion Exchange Removes Hydrophobic and Hydrophilic TOC

Charge at pH 8 (meq/g-C)

-50 -40 -30 -20 -10 0 10

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Poorly Removed by Coagulation

Reckhow, et al 1993
TTHM Concentrations in raw, alum, and MIEX + alum treated waters for different source waters

Source of Water
- Durham, NC
- Hackensack, NJ
- Manchester, NH
- Sioux Falls, SD
- MWD, CA
- Austin, TX
- Tampa, FL

TTHM Concentration (ug/L)
- Raw
- Alum
- MIEX + Alum

TTHM for Tampa raw water is 665 ug/L.

MCL – 80 ug/L

Source: P. Singer, 2000, AWWA-WQTC
MIEX® Technology Advancements

First Generation MIEX® System

Advantages
- De-coupled mixing from settling

Disadvantages
- Low resin concentration (rise rate 4 gpm/ft²)
- Recycle (more handling)
- Higher resin loss
- Larger footprint

www.miexresin.com
MIEX® Technology Advancements

- High-Rate MIEX® System

**Advantages**
- Smaller Footprint
- High resin concentration (10 gpm/ft²)
- Less resin handling - simplified
- Much lower resin loss

**Disadvantages**
- Resin fluidization/settling (overcome with good mixing)
Key Design Criteria/Process Parameters

- **Resin Dose (Concentration)**
  - 10 to 30 ml/L – first generation
  - 200 ml/L – high rate

- **Contact Time (Tank Size & Footprint)**
  - 20 to 30 minutes – first generation
  - 10 to 15 minutes – high rate

- **Waste Volumes**
  - 0.05 to 0.1% - first generation
  - 0.035% - high rate

- **Resin Loss (Makeup Resin Cost)**
  - 1 to 3% - first generation
  - <<<<1% - high rate (1/2 L/1,000,000 L)
Case Studies – Bench and Pilot Scale Testing Results

Before MIEX®

After MIEX®

Photos Courtesy of Carollo Engineers
Raw Water Quality Summary

- pH – 7.3 to 7.6
- Alkalinity – 30 to 50 mg/L as CaCO3
- Turbidity – 3 to 5 NTU
- UV-254 – 0.15 to 0.19 cm$^{-1}$
- TOC – 4.8 to 5.5 mg/L
- SUVA – 2.7 to 4.0 L/mg-m
Summary of Organic Analyses

- Existing Treatment (Alum with Pre-Chlorine)
  - TOC Removal – 42% (Stage 1 Required = 45%)
  - Remaining UV-254 – 0.052 cm^-1

- MIEX® Treatment (MIEX®, Alum with Pre-Chlorine)
  - TOC Removal – 78%
  - Remaining UV-254 - 0.014 cm^-1
96-hr TTHM and HAA5 Concentrations

Stage 1 D/DBP Rule TTHM MCL = 80 μg/L
Stage 1 D/DBP Rule HAA5 MCL = 60 μg/L

TTHM and HAA5 Concentrations (μg/L)

- Raw
- Plant Filtered
- Plant Finished
- Distribution System No. 1
- Distribution System No. 2

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NOM Removal Performance

Percent TOC Removal

Alum
- Coagulant Only
- Chlorine Dioxide
- Chlorine
- MIEX
- MIEX + Chlorine

Ferric Chloride
- Coagulant Only
- Chlorine Dioxide
- Chlorine
- MIEX
- MIEX + Chlorine

Full-Scale Plant
- Coagulant Only
- Chlorine Dioxide
- Chlorine
- MIEX
- MIEX + Chlorine

Stage 1 D/DBP Rule TOC Removal Requirement = 45%
96-hr SDSTTHM Results

Note: Ammonium chloride was added to form chloramines approximately 2 hours after the post-chlorine was dosed.

Stage 1 D/DBP Rule TTHM MCL = 80μg/L

TTHM Concentration (μg/L)

- Coagulant Only
- Chlorine
- Chlorine Dioxide
- MIEX
- MIEX + Chlorine
- MIEX + Chlorine Dioxide
- Full-Scale Plant
96-hr SDSHAA Results

Note: Ammonium chloride was added to form chloramines approximately 2 hours after the post-chlorine was dosed.

Stage 1 D/DBP Rule HAA5 MCL = 60 µg/L
Tennessee Source Water – Bench and Pilot Scale

- Raw Water Quality Summary
  - pH – 7.7 to 8.0
  - Alkalinity – 140 to 146 mg/L as CaCO3
  - Turbidity – 6 to 17 NTU
  - UV-254 – 0.08 to 0.10 cm$^{-1}$
  - TOC – 2.8 to 3.2 mg/L
  - SUVA – 2.5 to 3.6 L/mg-m
Summary of Organic Analyses

- **Existing Treatment (Alum with Pre-Chlorine)**
  - TOC Removal – 18% (Stage 1 Required = 20%)
  - Remaining UV-254 – 0.048 cm\(^{-1}\)
- **MIEX® Treatment (MIEX® with Alum)**
  - TOC Removal – 59%
  - Remaining UV-254 - 0.013 cm\(^{-1}\)
TTHM Results for Alternatives

MCL = 80 μg/L

- Alum
- Ferric Chloride

Cl2
KMnO4
ClO2
MIEX

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HAA5 Results for Alternatives


HAA5 (µg/L)

MCL = 60 µg/L

Cl₂

Alum

Ferric Chloride

ClO₂

MIEX

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Pilot Plant in Operation
UV-254 and TOC vs. Time - Raw and MIEX®-treated Water

- **UV-254 (cm⁻¹)**

- **TOC (mg/L)**

- **Raw UV-254**
- **MIEX-treated UV-254**
- **Raw TOC**
- **MIEX-treated TOC**

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SDSTTHM & SDSHAA5 vs. Time

Stage 1 HAA5 limit = 60 ug/L
Stage 1 TTHM limit = 80 ug/L

- SDSTTHM using KMnO4
- SDSTTHM using MIEX
- SDSHAA using KMnO4
- SDSHAA using MIEX

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Pennsylvania* Source Water - TOC Removal

*Pennsylvania Data Courtesy of Carollo Engineers
HAA Reduction

*Pennsylvania Data Courtesy of Carollo Engineers
TTHM Reduction

TTHM control  TTHM MIEX

*Pennsylvania Data Courtesy of Carollo Engineers
MIEX® Benefits for Large Pennsylvania* Plant

- 146 mgd average flow

Costs
- Resin costs - $2.5 million (1 gal/MG loss)
- Power - $328,000 ($0.09/kW-hr)
- Salt - $528,000 ($65/ton)
- Total Costs - $3.35 million

Savings
- PAC - $1.6 million (100% reduction)
- Ferric Chloride - $1.5 million (70% reduction)
- Lime - $350,000 (70% reduction)
- Sodium Hypo - $200,000 (10% reduction)
- Total Savings - $3.65 million

MIEX® offers $300,000 per year savings while substantially reducing DBP levels

*Pennsylvania Data Courtesy of Carollo Engineers
MIEX® Advantages

- Removes NOM that coagulants cannot
  - Achieve lower DBP Standards
  - Costs less than Ozone/GAC and NF
  - Synergies with coagulation
- Reduction in chemical usage
  - Reduced chlorine demand (+40%)
  - Reduced DBP Formation Potential
  - Up to 80% coagulant reduction
  - Lower sludge volumes
- Achieve multiple treatment objectives
  - TOC, sulfide, arsenic removal
Benefits of MIEX vs GAC: Operating Costs

Assumptions:
1. MIEX® and GAC operating costs for lowering treated water TOC by 1 mg/L based on report on AWWARF Project #3075, “DBP Control in High Bromide Water While Using Free Chlorine During Disinfection”, 2006.
2. GAC operating costs for lowering treated water by 4 mg/L extrapolated from AWWARF Project #3075 results.
MIEX® Disadvantages

- Salty, Organic Waste Brine Stream
- Proprietary - Single Resin Supplier – Resin is Expensive
- Limited Large-Scale Installations (> 40 mgd)
Alternatives to Minimize Disadvantages

- **Salty, Organic Waste Brine Stream**
  - Sodium bicarbonate as regenerant in place of sodium chloride – provides alkalinity/organics to wastewater biomass (cost 3x more)
  - Zero Liquid Discharge (vacuum distillation)

- **Proprietary - Single Resin Supplier – Resin is Expensive**
  - Long-term resin purchase contracts available with CPI escalation clauses
  - Leasing avoids sole-source purchase issue

- **Limited Large-Scale Installations (> 40 mgd)**
  - Modular (similar to low-pressure membranes)
  - 10 mgd modules are “base” size
Optimization Opportunities with MIEX®

Partial Side-stream Treatment:
- Achieve Benefits with lower cost
- Flexible Operations schedules
- Tailor TOC removal to just meet objectives

Retrofit in Existing Tankage:
- High-rate system is modular
- Square tankage can fit different geometries
- Head loss is relatively low through units
Conclusions

- Significant removals of NOM and DBP precursors achieved with MIEX® (> DBP reductions compared to NOM)

- Water pretreated with MIEX® uses less coagulant for turbidity (no organic coagulant demand), requires less pH adjustment, uses less final disinfectant and produces lower sludge quantities

- Pretreatment with MIEX® can allow continued use of free chlorine as final disinfectant (avoiding chloramines)

- MIEX® works on very different source waters but pilot testing is essential for optimum process design

- MIEX® is a cost-effective alternative to GAC for DBP control

- Flexible configuration and contracting options allow for ease of retrofit and purchasing
Wanneroo, Western Australia: 30 MGD MIEX® Plant

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Questions?

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