WEBINAR MODERATOR

Chris Owen
Director of Water and Reuse Innovations
Hazen and Sawyer

Chris is the Director of Water and Reuse Innovations for Hazen and Sawyer. She has 29 years of experience in water quality, research, treatment and regulatory compliance. Her utility roles have included regulatory compliance, research, laboratory management, source water assessment and protection, and distribution system issues. Research work included investigations of UF/MF/RO membranes, online monitoring, total coliform occurrence, enhanced coagulation, biofiltration, distribution system, corrosion, biostability, ion exchange, chloramine chemistry and stability, contaminants of emerging concern, and algal toxins. She is active in regulatory issues at the state and federal levels, promoting utility concerns and science-based decisions. She served on the USEPA SAB for Drinking Water and the USEPA NACEPT.

She is an active member of the American Water Works Association (AWWA), serving as a Trustee and the current Chair of the Water Science and Research Division. She is a Trustee for WateReuse FL and the President of the Board of Directors for the American Membrane Technology Association. She has been active in the Water Research Foundation (WRF) and the WateReuse Foundation for more than 20 years.

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PANEL OF EXPERTS

Theresa Slifko, PhD
Water Quality Manager: Chemistry Unit
Metropolitan Water District of Southern California

Jeff Biggs
Source Water Administrator
Tucson Water

Erik Rosenfeldt, PE, PhD
Director of Drinking Water Process Technologies
Hazen and Sawyer

AGENDA

I. Microplastics Analytical Results: What Do They Mean? Theresa Slifko, PhD

II. Transformation of Tucson Water’s CERCLA-to-Drinking Water Program After 25 Years Jeff Biggs

III. Addressing Multiple CECs at an East Coast Surface Water Erik Rosenfeldt, PE, PhD
ASK THE EXPERTS

Theresa Slifko, PhD
Metropolitan Water District
of Southern California

Jeff Biggs
Tucson Water

Erik Rosenfeldt, PE, PhD
Hazen and Sawyer

Enter your question into the question pane on the right-hand side of the screen.

Please specify to whom you are addressing the question.

MICROPLASTICS ANALYTICAL RESULTS: WHAT DO THEY MEAN?

October 28, 2020

AWWA Webinar

“A Closer Look at New and Not so New CEC’s: PFAS, Microplastics and Solvents”
“PLASTIC”

- Polyoxybenzylmethylenglycolanhydride
- First plastic was “Bakelite”
- Invented by Dr. Leo H. Baekeland in 1907
- Mixture of phenol and formaldehyde mixed with wood or asbestos fillers under controlled conditions for pressure and temperature
- At Baekeland’s death in 1944, the world production of Bakelite was ca. 175,000 tons, and it was used in over 15,000 different products

https://en.wikipedia.org/wiki/Leo_Baekeland

ABOUT ONE BILLION ELEPHANTS

Today: 100 BILLION plastic bags are used by Americans every year.

Tied together, they would circle the Earth’s 773 times!


WHAT A WASTE.

Defining Microplastics
Detecting Microplastics
Interpreting Microplastics Monitoring Data
Water Treatment Efficacy

LEARNING OBJECTIVES
WHAT ARE “MICROPLASTICS”?  
Small pieces of plastic between 1 and 5,000 µm in size (less than the size of a sesame seed)

- Fibers
- Pellets
- Films
- Fragments
- Foam
- Spheres

Mini-microplastics: 1 µm to 1,000 µm
Nanoplastics: less than 1 µm

Definition source: The Microplastics Toolbox by A Rocha International; Images: inch calculator.com (ruler); cleanpng.com (salt); dlpng.com (sesame seed)

California SWRCB Microplastics Definition (June 2020):

“Solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least two dimensions that are greater than 1 and less than 5,000 micrometers (µm). Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded.”
SOME SOURCES OF MICROPLASTICS IN WATER

- Surface runoff
- Wastewater discharges
- Industrial discharges
- Atmospheric deposition


DETECTING MICROPLASTICS IN DRINKING WATER

➢ 9 reliable water studies (of 50)
  • Bottled > Surface Tap > Ground Tap

➢ Challenges with analytical methods
  • No unified definitions
  • No standard sampling, extraction, and identification methods
  • Pervasive analytical errors

➢ Water treatment processes have shown ~92% removal

Sources: Citation: WHO 2019. Microplastics in drinking-water.
Isobe et al., 2019. An interlaboratory comparison exercise for the determination of microplastics in standard sample bottles.
MICROPLASTICS ANALYTICAL METHODS FOR SOURCE AND TREATED DRINKING WATER

Four microplastics analytical methods
- Microscopy
- FTIR (with or without microscopy)
- Raman spectrometry
- Pyrolysis-Gas Chromatography/Mass Spectrometry (GC/MS)

Microplastics Measurement Methods Evaluation Study (2019-2021)
- Multi-laboratory evaluation
- International team of investigators
- Metropolitan is participating

FTIR = Fourier-transform infrared spectroscopy
http://www.sccwrp.org/news/international-microplastics-measurement-study

METHODS USED IN 49 MICROPLASTICS ID STUDIES*

Visual FTIR Raman SEM Dyes

Water

40%

Fig. 1. Details from sampling methods reviewed from the literature for microplastics in sediment (top row, N = 20) and water (bottom row, N = 20) regarding collection, density separation, digestion, and identification.

SOP FOR MICROPLASTIC EXTRACTION FROM CLEAN WATER

Figure from SWRCB/SCCWRP "Microplastics Measurement Methods Evaluation Study (2019-2020)" Study Plan; Photo credit: MWD staff

MICROPLASTICS MICROSCOPIC IDENTIFICATION

a) Identification of microplastics extracted from water samples

b) Close up of 1 mm size microplastic sphere extracted from water samples

c) Fiber
d) Fragments

Images a-b: Tiffany Lee & Lucy Li, MWD Laboratories 2020.
Images c-d: Rochman 2019. Microplastics workshop presentation. SCCWRP.
### MICROPLASTICS ANALYTICAL METHOD OPTIONS, PROS & CONS

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Minimum Detectable Size</th>
<th>Description</th>
<th>Polymer Composite ID</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscope</td>
<td>&gt;500µm</td>
<td>Visual ID &amp; quantification; Microscopic counting method with or without dye stain to confirm plastic</td>
<td>No</td>
<td>Lower cost; Simple concept; High availability</td>
<td>Expensive; Extensive sample prep; Slow and time consuming; Prone to false positives</td>
</tr>
<tr>
<td>FTIR with microscope</td>
<td>&gt;500µm or ~20µm</td>
<td>Chemical ID, quantification, &amp; characterization; Infrared (IR) absorption spectroscopy</td>
<td>Limited</td>
<td>Non-destructive to samples; Most used for marine studies. Can automate; Can use as a screening tool</td>
<td>Expensive; Some sample prep; &lt;20µm cannot be detected</td>
</tr>
<tr>
<td>Raman</td>
<td>~1 - 20µm</td>
<td>Chemical ID, quantification, &amp; characterization; IR absorption spectroscopy</td>
<td>Yes</td>
<td>ID some polymer type and very small size range; Less sample preparation; Less matrix interference; Can automate</td>
<td>Expensive; Not well proven and tested; Complex instrumentation; Prone to interference; Can overestimate</td>
</tr>
<tr>
<td>Pyrolysis-GC/MS</td>
<td>~150µm</td>
<td>Chemical ID, quantification, &amp; characterization; Gas chromatography – mass spectrometry</td>
<td>Yes</td>
<td>Fastest &amp; most reliable; IDs many polymers; IDs small particle sizes</td>
<td>Cannot measure PVC; Destroys the sample; Requires larger particle masses</td>
</tr>
</tbody>
</table>

23 Tanaka, K. and Takada, H. 2016. Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. Sci. Rep. 6, 34351; doi: 10.1038/srep34351

24 Wu et al., 2020. Microplastics in waters and soils: Occurrence, analytical methods and ecotoxicological effects. Ecotoxicology and Environmental Safety 202 (2020) 110910

### MICROPLASTICS ANALYTICAL METHOD OPTIONS, SCOPE, & ESTIMATED COST

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Quantitative</th>
<th>Minimum Detectable Particle Size</th>
<th>Est. Equipment Cost</th>
<th>Approximate Analysis Time (Hrs./Sample)</th>
<th>Est. Labor Cost per sample*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscope With or without dye stains</td>
<td>Manual Particle counts</td>
<td>&gt;500µm</td>
<td>$1,000-10,000</td>
<td>24</td>
<td>$881</td>
</tr>
<tr>
<td>FTIR without microscope</td>
<td>Manual Polymer type</td>
<td>~200µm</td>
<td>$50,000</td>
<td>32</td>
<td>$1,175</td>
</tr>
<tr>
<td>FTIR with microscope</td>
<td>Automated Counts and Polymer type</td>
<td>~20µm</td>
<td>$250,000</td>
<td>32</td>
<td>$1,175</td>
</tr>
<tr>
<td>Raman</td>
<td>Automated Polymer type</td>
<td>~1µm</td>
<td>$250,000</td>
<td>40</td>
<td>$1,467</td>
</tr>
<tr>
<td>Pyrolysis-GC/MS</td>
<td>Manual Polymer mass</td>
<td>~150µm</td>
<td>$250,000</td>
<td>24</td>
<td>$881</td>
</tr>
</tbody>
</table>

*Estimated labor cost based on $18 per hour plus benefits multiplier of 104% for the analyst and QA to process one sample from start to finish. Materials, instrument, and supplies not included.
INTERPRETING MICROPLASTICS WATER QUALITY MONITORING DATA

DO MICROPLASTICS IN DRINKING WATER POSE A RISK TO HUMAN HEALTH?

WHO finds “low or no concern of human health hazards at this time”
- Humans not likely to adsorb >150 µm

Recent human health studies are mixed
- What goes in comes out
- No cytotoxicity in human gut cells
- Additional research needed to fully assess health impacts

WHAT NEXT?

Microplastics are a global concern and the science is still emerging

- SCCWRP Study will standardize & validate analytical methods (35 Labs)
- Monitoring and occurrence evaluations (ambient water, drinking water, animal tissues)
- Water Treatment efficacy
- Health effects including mixtures and chronic exposure studies

Legislative activities to limit environmental loading
- Bans: Plastic bags, single use plastics, & straws
- Restrictions: plastic pellets & personal care products
- Regulations: Trash TMDLs

UPCOMING CALIFORNIA PUBLIC WORKSHOPS

Sources: Coffin 2020. Microplastics in Drinking Water: California’s Regulatory Actions. NEMC Presentation
MANY UNCERTAINTIES AND UNKNOWNS REMAIN

Questions? Theresa Slifko: tslifko@mwdh2o.com
WHAT DO MICROPLASTICS MONITORING DATA MEAN?

“Scientists have made great progress on elucidating the ubiquitous nature of microplastic pollution, but foundational epidemiological and toxicological questions remain, including at what point microplastic concentrations become harmful, rather than just a nuisance.”


Photo credit: www.onegreenplanet.org/environment/plastic-water-bottles-and-the-oceans/
DO WATER TREATMENT PLANTS REMOVE MICROPLASTICS?

<table>
<thead>
<tr>
<th>Location</th>
<th>Microplastic Particle Count/Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary tank skimmings</td>
<td>Highest count*</td>
</tr>
<tr>
<td>Scum in aeration tanks</td>
<td>Some*</td>
</tr>
<tr>
<td>Return activated sludge</td>
<td>1 microplastic/20 mL**</td>
</tr>
<tr>
<td>Secondary effluent</td>
<td>1 microplastic/15,000 gallons</td>
</tr>
<tr>
<td>Gravity filter backwash</td>
<td>None found/12 gallons**</td>
</tr>
<tr>
<td>Final effluent</td>
<td>None found/50,898 gallons</td>
</tr>
</tbody>
</table>

Citation: Carr and Thompson. 2019. Chapter 4 Microplastics: transport and removal at wastewater treatment plants. In Microplastics in Water and Wastewater. IWA Publishing, 1 Gallon≈ c. 3.79 L
* = Could not be associated with an influent volume.
** = Average of 4 replicates.

ASK THE EXPERTS

Theresa Slifko, PhD
Metropolitan Water District of Southern California

Jeff Biggs
Tucson Water

Erik Rosenfeldt, PE, PhD
Hazen and Sawyer

Enter your question into the question pane on the right-hand side of the screen.

Please specify to whom you are addressing the question.
Tucson Water’s AOP Treatment Facility
Transformation of Tucson Water’s
CERCLA-to-Drinking Water Program After 25 Years

Jeff Biggs – Tucson Water

PRESENTATION OUTLINE

• TCE remedy & 1,4-dioxane discovery
• Contingency planning and decisions
• Planning, design, and construction
• O&M experience and improvements
• Enhanced Recovery
• PFAS discovery
• Major results and recognition

TARP = Tucson International Airport Area
Groundwater Remediation Project
TCE REMEDY & 1,4-DIOXANE DISCOVERY

TCE DISCOVERY AND INVESTIGATION

- TCE contamination discovered by EPA and Tucson Water in Tucson Airport area wells. 11 City wells and other private wells shut down.
- CERCLA Remedial Investigation completed. Approx. 4-mile by 1-mile plume delineated.
- EPA adds TAA site to Superfund National Priorities List.
- CERCLA Feasibility Study for north area (TARP) completed; EPA issues Record of Decision.
TCE REMEDY IMPLEMENTED

1,4-DIOXANE DISCOVERY & EARLY EFFORTS
CONTINGENCY PLANNING AND DECISIONS

CONTINGENCY PREPARATIONS

Contingency Plan developed for TARP operations to manage 1,4-dioxane
AOP Pilot Treatability Testing conducted

Advanced Oxidation Process (AOP) Treatment Evaluation conducted
REGULATORY DEVELOPMENTS & TREATMENT IMPLEMENTATION

EPA publishes revised Toxicological Evaluation for 1,4-dioxane in August

2010 2011 2011 - 2013

EPA publishes new Drinking Water Health Advisory for 1,4-dioxane (0.35 µg/L at 1x10^-6 excess lifetime cancer risk level)

AOP preliminary design

AOP design and construction

PLANNING, DESIGN, AND CONSTRUCTION
LPHO UV-PEROXIDE TECHNOLOGY SELECTED FOR TARP

- Exceeded treatment goals for 1,4-dioxane reduction
- No formation of bromate or unregulated byproducts
- Operational simplicity
- Demonstrated full-scale drinking water installations

PEROXIDE QUENCHING USING GAC SELECTED FOR TARP

- Complete quenching at low contact times and high surface loading rates
- Potential to decrease byproducts
  - Assimilable Organic Carbon (AOC)
  - TTHM precursors
  - Other unregulated contaminants
- Operational and water quality stability advantages over chemical quenching
SCHEMATIC

ADVANCED OXIDATION PROCESS (AOP)
A proven technology that combines ultraviolet (UV) light with hydrogen peroxide to create a strong oxidant that removes 1,4-dioxane from water

New AOP Water Treatment Facility

The UV reactors remove 1,4-dioxane by oxidation

Granular activated carbon (GAC) removes any hydrogen peroxide left in treated water

Remediation Wells

Existing TARP Water Treatment Plant

TECHNICAL IMPLEMENTATION

• Design/CM Services: $3.3M
• Contracting approach
  - Construction manager at risk
  - Separate GMPs for long-lead equipment purchase and general construction
• Schedule
  - Major equipment:
    • GMP-1, $4.3M awarded July 2012
  - Construction:
    • GMP-2, $11.0M awarded Sept. 2012
  - Completion: January 2014

5,800 gpm
Total Capacity

$18.6M
Total CIP
Construction Site Overview

UV Building/Equipment Construction
AOP FOLLOW-UP TO COMPLETE TARP WTP TRANSFORMATION

- EPA coordination with CERCLA process affects timing

- Vapor-phase GAC removed from service August 2017
  - Eliminated natural gas usage for duct heaters
  - Eliminated GAC media replacement
  - Eliminated exhaust air VOC monitoring

- Packed columns to be retired
  - Eliminate power used for blowers
  - Eliminate cost and hazard of sulfuric acid
  - Avoid additional scaling and future rehabilitation
  - Reduce water quality monitoring requirements

O&M EXPERIENCE AND IMPROVEMENTS
FULL-SCALE PERFORMANCE: 1,4-DIOXANE

Average 1,4-Dioxane Concentration (Dec. 2014 - Jun. 2020)

- EPA Health Advisory Guideline (0.35 µg/L)
- Method Reporting Limit (0.1 µg/L)

- **NWF**: 0.7 µg/L
- **SWF**: 4.2 µg/L
- **AOP Raw Water**: 1.2 µg/L
- **AOP Treated**: <0.1 µg/L

FULL-SCALE PERFORMANCE: TCE


- **SDWA MCL = 5 µg/L**
- **Consent Decree Limit = 1.5 µg/L**
- **Method Reporting Limit = 0.5 µg/L**

- **NWF**: 10.1 µg/L
- **SWF**: 9.8 µg/L
- **AOP Raw Water**: 10.3 µg/L
- **AOP Treated**: <0.5 µg/L
UV REACTORS O&M EXPERIENCE

- UV Part Replacement
  - Lamps under warranty 12,000 hours
  - Ballasts under warranty 5 years
  - Staggered lamp replacement spreads cost over several years

- UV Reactor O&M Costs
  - ~$15,000/month electric power
  - ~$10,000/month hydrogen peroxide
  - $330/replacement lamp
  - $724/replacement ballast
  - ~$164,000 for single-train lamp changeout

NUISANCE SEDIMENT PRODUCTION

- Sources of sediment
  - Aging and failing extraction wells produce sediment
  - Deposition in wellfield collection pipelines over time
  - Flow reductions from failing wells and rehabilitation/replacements
O&M IMPACTS OF SEDIMENT

- Periodic rapid loading/damage to basket strainers
- Overloading of cartridge filters
- UV wiper seal/function and lamp sleeve damage
- GAC acts as filter in addition to peroxide quenching

SEDIMENT MITIGATION

- Investigations
- Well rehabilitation and replacement
- WTP sediment removal
GAC PEROXIDE QUENCHING EXPERIENCE

- Robust performance with minimal maintenance by 8 pressure contactors
- Short (2-min) “fluffing” backwash every two weeks
- Periodic peroxide detections in top two of three bed profile sample ports
- Detections not present after backwashing
- No media replacement after 4.5 years of service to date
TARP TREATMENT UPGRADES FOR ENHANCED RECOVERY

- TARP treatment upgrade construction currently in progress:
  - New well being drilled and equipped for enhanced remediation
  - Treatment upgrades for additional well capacity
  - 4 GAC contactors being installed for peroxide quenching
  - Communications upgrades
  - Packed column aeration retirement demonstration
  - Potential addition of 10 – 12 GAC contactors for PFAS removal
SCHEMATIC

AOP Water Treatment Facility

Feed Pumps → Sediment Removal → Hydrogen Peroxide

UV Reactors (typ. for 3 trains) → GAC Contactors (typ. of 8)

North Wellfield

Sediment Removal

South Wellfield

Remediation Wells

Original TARP Water Treatment Plant

Packed Column Aeration Process (typ. of 3)

Air Inlets

Vapor-phase GAC Contactors (typ. of 3)

Decommissioned

Blowers Heaters

Sodium Hypochlorite

Sulfuric Acid Decommissioned

Drinking Water Distribution System

AOP Water Treatment Facility

65

65

65

65

TECHNICAL IMPLEMENTATION

• Design/CM Services
• Contracting approach
  - Construction manager at risk
  - Separate GMPs for long-lead equipment purchase and general construction
• Schedule
  - Major equipment pre-purchase: GMP-1
  - Balance of construction: GMP-2 thru GMP-6

7,200 gpm
Total Capacity

2021
Completion

66

66
**PFAS DISCOVERY**

**PFAS HISTORY**

- **EPA Provisional Health Advisories:**
  - PFOA = 400 ng/L
  - PFOS = 200 ng/L

- **Initial detections of PFOA/PFOS at TARP well below Provisional Health Advisories**
  - 2009
  - 2013 – 2014
  - 2016

- **Continued monitoring indicates concentrations approaching New EPA HA for PFOA + PFOS (70 ppt)**
  - 2016 – 2018
  - *All sample results indicate that water delivered was below the EPA HA*

- **Interim mitigation: Well operations, blending, and GAC change out**

- **GAC & IX bench-scale testing (RSSCT)**
  - Long-term mitigation selection/design

- **Continued GAC changeouts & capacity expansion construction**

- **Continued monitoring indicates concentrations approaching EPA HA**
  - 2016 – 2018

- **2019 → 2019**

- **EPA Provisional Health Advisories:**
  - PFOA = 400 ng/L
  - PFOS = 200 ng/L

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- **Continued monitoring indicates concentrations approaching EPA HA**
  - *All sample results indicate that water delivered was below the EPA HA*
GAC CHANGEOUT

- Carbon used for hydrogen peroxide quenching replaced.
- Three carbons were used in different vessels.
- Additional 4,000 lbs of media (to 18,000 lbs) was installed in each vessel to increase EBCT.
- Weekly sampling of GAC side sample ports for 14 PFAS.
- Shorter chain species are being used as indicators for PFAS migration through carbon bed.
- Currently using bituminous coal based GAC in all vessels.
- GAC changeouts conducted:
  - Dec 2018-Feb 2019
  - Sept 2019-Jan 2020
  - Aug 2020

FULL-SCALE PERFORMANCE: PFAS

Average PFOA + PFOS + PFHxS + PFHpA (Feb. 2019-Jun. 2020)

- EPA SDWA Health Advisory PFOA + PFOS = 70 ppt
- Tucson Water Operational Target = 18 ppt
- Method Reporting Limit (MRL) for each of PFOA, PFOS, PFHxS, and PFHpA is 2.0 ppt
MAJOR RESULTS AND RECOGNITION

CONTINUOUS PUBLIC ENGAGEMENT

• Unified Community Advisory Board (UCAB)
• Neighborhood association meetings
• Customer communications
  - Brochures
  - Newsletters
• Groundbreaking event
• Traditional news media
• Electronic media
AQUIFER REMEDIATION STATISTICS (THROUGH JUNE 2020)

- Remediation of **54.25 billion gallons** of groundwater since 1994
- Removal of **5,848 pounds** of TCE since 1994
- Removal of **135.3 pounds** of 1,4-dioxane since 2014
- Significant decrease of TCE & 1,4-dioxane contamination

NATIONAL AND STATE RECOGNITION FOR ENGINEERING EXCELLENCE

- 2016 Crescordia Award – Technology Innovation
  - Arizona Forward/SRP
- 2015 National Grand Prize - Design
  - American Academy of Environmental Engineers & Scientists (AAEES)
- 2015 National Recognition Award
  - American Council of Engineering Companies (ACEC)
- 2014 Judge’s Choice Award
  - American Council of Engineering Companies of Arizona (ACEC-AZ)
- 2014 Water Treatment Project of the Year
  - AZ Water Association
QUESTIONS!

ASK THE EXPERTS

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Addressing Multiple CECs at an East Coast Surface Water

Erik Rosenfeldt, PhD, PE
Hazen and Sawyer

Agenda

• Defining the challenges
  • System Description - Expansion and Upgrades
  • Cape Fear Today: DBPs, dioxane, forever chemicals
  • Regulatory drivers and Public demands changes project “scope”

• Addressing the Challenges with Treatment
  • Options available
  • Bench Testing Results

• Impacts of the Testing Results
  • Several Potential Paths forward
  • Prioritizing Water Quality and Expansion

• The Path Forward
  • Prioritizing public health protection
  • Considering regulatory uncertainty
Defining the Challenges

Case Study Background

- Surface water system in North Carolina
- System currently considering expansion and/or implementation of advanced treatment
- Multiple Water Quality Concerns
  - Stage 2 Compliance Concerns (infrastructure concerns)
  - Bromide leading to elevated TTHMs
  - 1,4-Dioxane at elevated levels throughout watershed
  - “New Kid” is PFAS (specifically GenX)

WTP 1
Source: Cape Fear River

WTP 2
Source: Reservoir & Cape Fear River

Total Permitted Capacity: 50 mgd

WTP-1
32 mgd (Expandable)

WTP-2
18 mgd (Max)
Case Study Background

The Area is Growing, the Water is Needed

- Reliability concerns – aging infrastructure
- Expansion needs – WTP-1 (design complete)
- Phased approach
- Emerging contaminants discovered in Cape Fear River

The “Cape Fear” is an Iconic Watershed

It has faced Challenges for Decades

Cape Fear in 1962  Cape Fear in 1991  Cape Fear in 2020
The Cape Fear through History

Bromide in the River is impacting THMs and unregulated HAAs

1,4-Dioxane

Hazen
The Cape Fear Through History

Summarizing the Challenges

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Regulatory Perspective</th>
<th>Historical Data Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBPs</td>
<td>- Stage 2 regulates TTHM, HAA5, bromate</td>
<td>- Chloramination to “control” DBPs</td>
</tr>
<tr>
<td></td>
<td>- Recognition that brominated DBPs likely more toxic</td>
<td>- As bromide in Cape fear increases, DBP regs are a challenge to meet</td>
</tr>
<tr>
<td></td>
<td>- UCMR4 (and Stage 3) considering HAA9</td>
<td>- Bromate could impact use of strong oxidants (O₃, AOP)</td>
</tr>
<tr>
<td></td>
<td>- Current ongoing work (WRF 4807) investigating toxic “Modes of Action” for bromate</td>
<td></td>
</tr>
<tr>
<td>1,4-Dioxane</td>
<td>- No national MCL (No Regulatory Determination)</td>
<td>- 1,4-dioxane regularly detected in Cape Fear between 1 and 6 ppb</td>
</tr>
<tr>
<td></td>
<td>- California has 1 ppb notification limit</td>
<td>- No removal across current treatment train</td>
</tr>
<tr>
<td></td>
<td>- New York MCL will be 1 ppb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- North Carolina focusing on 0.35 ppb</td>
<td></td>
</tr>
<tr>
<td>PFOA + PFAS</td>
<td>- EPA Health Advisory: PFOA + PFOS &lt; 70ppt</td>
<td>- PFOA + PFOS have been detected at ~ ½ the Health Advisory</td>
</tr>
<tr>
<td></td>
<td>- No national MCL (Positive RD in Feb 2020)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Many states going beyond Health Advisory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- New York MCL will be 10 ppt PFOA, 10 ppt PFOS</td>
<td></td>
</tr>
<tr>
<td>Short Chain + GenX</td>
<td>- Some states (MA, VT) consider shorter chain PFAS in their rules</td>
<td>- Short chain PFAS found regularly</td>
</tr>
<tr>
<td></td>
<td>- North Carolina Health Guidance Level for GenX of 140 ppt</td>
<td>- GenX not acute concern at this facility</td>
</tr>
</tbody>
</table>
Addressing the Challenges with Treatment

Fighting Back

Our approach may be a little less “confrontational”

1962 1991 2020

Oxidation/Disinfection
Ozone, chlorine, chloramine, UV, AOP

Forms/Adds:
Brackish (O3), NDMA (O3), THMs
Fixes (O3, AOP, GAC):
NDMA (O3), THMs

Biology
Baf

Forms/Adds (BAF):
Nitrite, Nitrate
Fixes (BAF):
EDCs/PPCPs (BAF)
Microbial, NO3

Physical Separation
Coag/Floc/sed, Filtration, GAC, IX

Forms/Adds:
Baf

Fixes:
THMs/HAAs (BAF, CFS, GAC)
DOC (CFS, GAC, BAF)
EDCs/PPCPs (GAC)

1,4-Dioxane (GAC, limited)

NDMA (GAC, CFS)

1,4-Dioxane (AOP, GAC)

Physical Separation
Coag/Floc/sed, Filtration, GAC, IX
Advanced Treatment Options

Unfortunately Best Treatment Options do not Overlap

Treatment Options for 1,4-dioxane

- GAC and PAC: Not effective
- Ion exchange: Not effective
- Ozone
  - Not effective in groundwater
  - Potentially effective in surface water
- AOPs (O_3/H_2O_2, UV/H_2O_2)
  - Effective in groundwater
  - Potentially effective in surface water
- High pressure membranes (NF, RO): Partially effective

Treatment Options for PFAS

- GAC and PAC
  - Effective for long-chain PFASs (PAC is somewhat effective)
  - Poor performance for short-chain PFASs (PFBA and PFPeA)
  - Higher organic matter levels in raw water impair PAC performance
- Ion Exchange
  - Can be effective for short-chain PFASs
  - Experience only in groundwater
- Ozone: No oxidation
- AOPs (O_3/H_2O_2, UV/H_2O_2): No oxidation
- High pressure membranes (NF, RO): Effective for PFAS removal

1,4-dioxane Treatment Options

Ozone / Ozone Peroxide severely hampered by bromate formation

UV AOP needs high doses of UV and peroxide for significant removal
PFAS Treatment Options

Short-Chain PFAS provide treatment challenges

GenX rapid breakthrough

Impact of Chain length on GAC breakthrough

Reagglomerated subbituminous coal-based GACs
Average TOC = 2.15 mg/L

Carbon: F400
Average TOC = 2.15 mg/L
Impact of Water Quality on PFAS Breakthrough
Comparing Surface Water with Groundwater

- Carbon: F400
  - Open symbol TOC = 2.15 mg/L
  - Closed Symbol TOC = 1.3 mg/L
- Significant impact of TOC at high breakthrough (~80%)
- Hypothesis – is TOC ultimately "kicking off" adsorbed PFAS?

Evaluating DBPs

Question – Could GAC facilitate a conversion to Free Chlorine?

- GAC did not facilitate a conversion to free chlorine
  - (3 to 3.5-month GAC regeneration for 10 minute EBCT)
- Also, did not observe a "bromination" of THMs with GAC
Evaluating DBPs

Question – Could GAC facilitate a conversion to Free Chlorine?

Take Home Messages
- GAC was OK with free chlorine
- A little bit of tribromoacetic acid showed up after GAC

Summarizing the Bench Testing Results

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Oxidation</th>
<th>GAC</th>
<th>Adsorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBPs</td>
<td>Possibly, w/ BAF</td>
<td>Yes, 3-4 months regen. (Cl₂)</td>
<td>MIEX yes Alts. in Testing</td>
</tr>
<tr>
<td>1,4-Dioxane</td>
<td>50 – 60%</td>
<td>&gt; 90%</td>
<td>No</td>
</tr>
<tr>
<td>PFOA + PFAS</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Short Chain + GenX</td>
<td>No</td>
<td>No</td>
<td>In testing</td>
</tr>
</tbody>
</table>

Please consider the environment before printing.
## Impacts of the Testing Results

### Implications on Potential Treatment Trains

<table>
<thead>
<tr>
<th>Treatment Scenario</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Expansion of Conventional Train | • Meets Demand Needs  
• Budget Available | • Does not address Water Quality |
| GAC in lieu of expansion | • Addresses regulated DBPs  
• Addresses "Health Advisory" PFAS  
• Budget Available | • Does not meet demand needs  
• Does not effectively address 1,4-dioxane  
• Difficulty with "unregulated" PFAS |
| UV or O₃ AOP in lieu of expansion | • May address THMs and HAA₉  
• Addresses 1,4-dioxane  
• Budget Available | • Bromate  
• Does not meet demand needs  
• Does not effectively address PFAS |
| GAC + AOP in lieu of expansion | • Addresses regulated DBPs  
• Addresses "Health Advisory" PFAS  
• Addresses 1,4-dioxane  
• Budget Available  
• Bromate | • Does not meet demand needs  
• Difficulty with "unregulated" PFAS  
• Budget not available |
What’s next?

Moving Forward with Testing and Prioritizing Public Health

• Piloting GAC for PFAS and DBP compliance
• Modeling and expanded bench-testing of ozone and UV AOP
  • Impacts of GAC on UV AOP performance
  • Bromate mitigation measures for O₃/H₂O₂ (and for UV/H₂O₂)
• Likely a Phased Approach
  • GAC to improve water quality today
    • Focus on REGULATED DBPs
    • Address PFAS of Concern
  • Expand when Water Quality under control
    • Holistic approach
• AOP if required
  • North Carolina working aggressively to address 1,4-dioxane dischargers into the Cape Fear

Questions?

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Hazen and Sawyer
Director of Drinking Water Process Technologies
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ASK THE EXPERTS

Theresa Slifko, PhD  
Metropolitan Water District of Southern California

Jeff Biggs  
Tucson Water

Erik Rosenfeldt, PE, PhD  
Hazen and Sawyer

Enter your question into the question pane on the right-hand side of the screen.

Please specify to whom you are addressing the question.

ADDITIONAL RESOURCES

• AWWA PFAS Resource Community
• Water Quality & Infrastructure Virtual Summit  
  - The new AWWA Virtual Summit focusing on Water Quality and Infrastructure solutions is a 2 1/2-day, fully interactive online event that delivers premier learning and networking opportunities around the latest in water quality, managing aging infrastructure, utility risk and resilience and much more.
• M68 Water Quality in Distribution Systems  
  - AWWA catalog no: 30068
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– Kenneth Mercer, Ph.D., EDITOR-IN-CHIEF

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• The Joint Section Resource Committee is always accepting new members! If you are interested in volunteering with AWWA please email cbertoia@awwa.org.

• For more information on volunteering and other volunteer opportunities, visit our website.
PRESENTER BIOGRAPHY INFORMATION

Theresa Slifko is the Chemistry Unit Manager at Metropolitan’s Water Quality Laboratory in La Verne, California. Terri has spent over 26 years investigating a wide range of water quality issues including the development and evaluation of analytical tools for the detection of emerging microbial and chemical contaminants in drinking water, recycled water, and recreational water. Terri and her staff are currently supporting an international effort to develop reliable testing methods to study microplastics in source and treated drinking water. Their work helps support Metropolitan’s consortium of 26 cities and water districts that provide drinking water to nearly 19 million people in southern California.

Jeff Biggs has nearly 40 years of experience in the water profession, including being a certified Water Treatment & Water Distribution Operator. Jeff’s experience includes water treatment and quality, water resource management, public outreach, intergovernmental affairs, and research. Jeff also has extensive management experience, is a member of numerous Boards and committees and is an AWWA Life Member and a recipient of the Water for People Kenneth J. Miller Founder’s Award. Jeff is an avid golfer and was the Chair of the Southern Arizona Golf Classic for fifteen years, which raised over $410,000 for Water for People. Water for People is an international 501(c)(3) nonprofit humanitarian organization that focus on long-lasting, safe drinking water and improved sanitation for developing countries.

Erik Rosenfeldt is Hazen’s Director of Drinking Water Process Technologies, and a member of the Firm's Drinking Water, Reuse, and Applied Research groups. Dr. Rosenfeldt’s work focuses on implementing conventional and advanced treatment solutions for addressing emerging water quality challenges. He has lived in Richmond Virginia for 8 years with his wife and 4 kids and has enjoyed getting to know them all better in 2020.

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