contaminants from water. Little did he realize then that this experience would start him on a path to pilot testing 17 conventional and advanced technologies and pipe loop systems, and ultimately to develop a program to enhance Carollo’s companywide pilot-testing services.

In addition to the pilot-testing experience, Justin has had many opportunities to work with clients to solve distribution system water quality and desalination challenges. In the last 10 years, he has helped clients with nitrification, blending, iron corrosion, disinfection byproducts, and contaminant accumulation issues in their distribution systems. His desalination work in the past several years, with both Texas municipal/industrial clients and the Texas Water Development Board, has provided great opportunities to solve technical problems (e.g., managing RO concentrate containing sodium) and examine regulatory challenges (i.e., evaluating various state regulatory approaches for approval of RO/NF systems).

Prior to Carollo, Justin spent several years at the Missouri University of Science and Technology (formerly the University of Missouri at Rolla) in Rolla, MO, earning a BS in Chemical Engineering, an MS in Environmental Engineering, and a PhD in Civil Engineering. Even though he had started working with process technology and developing models for their performance as an undergraduate, it was not until graduate school that Justin began applying these concepts to remove
**Fingerprinting Your Organics: Treatability Assessment Using Advanced Characterization Technologies**

By Charlie He, Ph.D. (che@carollo.com), Chao-An Chiu, Ph.D., Jun Wang, and Mark Gross, Ph.D.

**INTRODUCTION**

Disolved organic matter (DOM) present in groundwater, surface water, and wastewater is a complex heterogeneous mixture composed of terrestrial, autochthonous organics, low molecular weight (MW) organic acids, carbohydrates, proteins, etc. Total organic carbon (TOC), dissolved organic carbon (DOC), and ultrafiltrate absorbance at 254 nm (UVA254) are typically measured to quantify this type of organic matter, providing insufficient information on DOM properties. DOM characterization plays an important role in water and wastewater treatment systems. Its selection drives the selection of treatment regimes, helps identify treatment challenges that must be mitigated, and provides critical insights for troubleshooting and for process optimization. For example, aliphatic and aromatic compounds have functional groups that react with different oxidants, which act as scavengers of oxidants like chlorine or ozone, resulting in differences in disinfection byproduct (DBP) formation potential and treatment efficiencies.

Traditional organic characterization procedures use physical fractionation techniques with resin, membranes, or dialysis sieves. These procedures are often time-consuming and costly. Enhancements in advanced analytical techniques, such as size exclusion chromatography (SEC) and fluorescence excitation-emission matrix (EEM) analyzes allows researchers and engineers to understand the characteristics of organic compounds in a more prompt, meaningful, and cost-effective way.

**CASE STUDIES**

Two recent studies were selected to demonstrate the usefulness of these organic fractionation tools for source water identification, treatability assessments, and treatment strategy optimization.

**Source Water Identification**

A surface water treatment facility in Arizona, designed to remove moderate- to high turbidity Colorado River water via the Central Arizona Project (CAP) canal, has experienced high turbidity (>100 NTU) and high TOC (>7 mg/L) spikes in its raw water. Such water quality upsets the existing treatment processes (i.e., dissolved air flotation [DAF] and granular activated carbon [GAC] filter) and caused several temporary shutdowns. Pretreatment improvement needs were evaluated through water quality sampling and bench- and pilot-scale testing. SEC and EEM were used as treatability assessment tools throughout the project. Interestingly, the EEM results (Figure 2) validated an important hypothesis for the operations staff regarding the source water: the plant selected for processing water from a different source during the high-turbidity high-TOC events, when normal CAP water is not available due to canal outages or maintenance activities. This backup source is a lake downstream of the main reservoir. The water in this lake is stagnant, with relatively high organic content (7-12 mg/L) compared to CAP water (3-4 mg/L). When water is occasionally released from this lake, sediments are stirred up, causing high turbidity and TOC spikes.

As shown in Figure 2, the EEM spectra for the normal and emergent sources are different in both the intensity and the region. Significant amount of fulvic acids present in this water pose a challenge to the existing treatment processes. More protein-like organic matter was found, likely originating from vegetation, algae, and animals. Although physically not connected, the emergency backup source for this facility is more similar to Salt River Project (SRP) water than to CAP water. SRP water (a local Arizona source) and the CAP water (imported source) are two commonly used surface waters in Central Arizona. Based on local SRP water treatment experience, it was expected that a robust enhanced coagulation process would be required to treat the backup water source. The plant’s existing DAF might be ineffective. Subsequent bench- and pilot-studies confirmed this initial assessment.

**Concentration Treatability**

To develop a cost-effective approach for minimizing brine and maximizing recovery, a demonstration test was conducted on reclaimed water tertiary reverse osmosis (RO) concentrate. Based on positive bench-testing results and SEC analysis, chlorination followed by biological activated sludge filters (BAF) were proposed and tested as an organic pretreatment for electrodiialysis reversal (EDR). The testing concluded that this organic pretreatment can effectively manage the organic fouling on EDR membranes and support a recovery rate up to 90 percent.

During the pilot testing, SEC was also used to further characterize the MW distribution, identify changes in organic compounds, and assess the performance. Shown in Figure 3, ozonation reduced DOC responses for this facility more effectively than Salt River Project (SRP) water than to CAP water. The plant’s existing RO concentrate (SRP) water was a local Arizona source and the CAP water (imported source) are two commonly used surface waters in Central Arizona. It was expected that a robust enhanced coagulation process would be required to treat the backup water source. The plant’s existing DAF might be ineffective. Subsequent bench- and pilot-studies confirmed this initial assessment.

**CONCLUSION**

DOM characterization can play an important role in water and wastewater treatability assessments. EEM analyzes enable better understanding of DOM characteristics in both quantitative and qualitative ways. This is directly relevant to water and wastewater utilities because these tools can be readily applied to assist with water treatability assessments. Through identifying the effectiveness or challenges of a unit process in removing target fractions of the organic compounds, such an approach is instrumental in guiding the design and operation of organic treatment processes. Source Water Identification.
By Sandeep Sethi, Ph.D., P.E. (ssethi@carollo.com), Jess Brown, Ph.D., P.E. (FL), Jennifer Stokke Nyffenegger, Ph.D., P.E.

Introduction
 Sarasota County (County) and regional agencies, including Southwest Florida Water Management District (SWFWMD) and Peace River Manatee Regional Water Supply Authority (Authority), have undertaken several studies since the early 2000s to develop the overall Dona Bay project. The objectives of the overall project are to decrease excess freshwater flows to Dona Bay, flood protection, and provide an alternative source of water within the Southern Water Use Caution Area. Previous studies have shown that the diversion of excess freshwater from the Dona Bay Watershed/Cow Pen Slough (CPS) can provide up to 15 mgd of new drinking water capacity, while improving the ecological health of Dona Bay. Carollo is nearing completion on a Treatability Analysis Project that furthers the previous evaluations.

Project Purpose
 The purpose of this treatability project was to determine the most technically feasible and economical options for developing the water supply as part of the larger Dona Bay project. It included a surface water supply as part of the larger Dona Bay project. The project was co-funded by the County and SWFWMD.

Project Components and Objectives
 The major components and objectives of the project included:
 1. Review of pertinent reports and studies related to the overall Dona Bay project.
 2. Evaluation of the CPS and Intermediate Aquifer water sources.

Treatability Analysis for a 15-mgd Water Supply Project

Analysis of water quality from the CPS and the Intermediate Aquifer was performed. The Intermediate Aquifer was included to assess potential blending of the two source waters in the planned reservoir to increase its reliability. Available historical raw water quality data from the CPS and results from additional sampling performed in 2011 (as part of this project) were analyzed. Water quality data from the intermediate aquifer performance tests (APT) performed by the County were also analyzed.

The CPS surface water is challenging (Table 1) with the following parameters requiring treatment: turbidity, microbial parameters, organics, hardness, total dissolved solids (TDS), iron, and taste and odor (T&O). Organic content, color, and hardness in the CPS source are relatively high, along with excursions of TDS over the secondary regulatory standard. The high levels of hardness and the TDS excursions need a desalting step. Compared to the CPS, the Intermediate Aquifer contains higher concentrations of TDS and sulfate.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>MCL</th>
<th>SMCL</th>
<th>Min.</th>
<th>Max.</th>
<th>Avg.</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalinity CaCO₃</td>
<td>mg/L</td>
<td>11</td>
<td>11</td>
<td>158</td>
<td>110</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>mg/L</td>
<td>500</td>
<td>100</td>
<td>156</td>
<td>500</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>mg/L</td>
<td>11</td>
<td>10.2</td>
<td>25.9</td>
<td>16.9</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Color (Total)</td>
<td>mg/L</td>
<td>15</td>
<td>1.0</td>
<td>43</td>
<td>1.6</td>
<td>0.6</td>
<td>0.53</td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
<td>250</td>
<td>11</td>
<td>37</td>
<td>526</td>
<td>186</td>
<td>136</td>
</tr>
<tr>
<td>Hardness CaCO₃</td>
<td>mg/L</td>
<td>11</td>
<td>82</td>
<td>695</td>
<td>307</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>11</td>
<td>1.1</td>
<td>9.7</td>
<td>4.3</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>FTU</td>
<td>5</td>
<td>3</td>
<td>32</td>
<td>12</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>MBI</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;5</td>
<td>36</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Geosmin</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;3</td>
<td>340</td>
<td>49</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>Radionuclides</td>
<td>Some detected, all below MCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOCs</td>
<td>None detected</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOCs</td>
<td>Glyosphate detected, below MCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDCs/PPCPs</td>
<td>Few detected, 2 w/ MCLs but detected below MCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The analysis resulted in the identification of five top-ranked, promising treatment alternatives for the surface water treatment component (Table 2), which demonstrated similarities in relative costs and benefits. Three desalting alternatives were identified, including RO, NE, and EDR, and carried forward for further evaluation. The EDR design alternative assumes integration with the existing EDR process at the County’s treatment facility (Carlton WFF).

Bench-Scale Testing
 To close data gaps in the conventional pretreatment step in four of the five top-ranked treatment alternatives, five coagulants were jar-tested by the University of Central Florida (UCF) to optimize the removal of organics and color from the CPS source. These included aluminum chloride (ACH), ferric chloride, aluminum sulfate, ferric sulfate, and polyaluminum hydroxide (PAC). ACH demonstrated the best overall performance in terms of organics removal, while providing good alkalinity retention and some turbidity reduction.

Pilot-Scale Testing
 The goals of the pilot study task were to evaluate the performance of one of the top-ranked treatment alternatives, and to further develop and/or verify design criteria for the associated unit processes based on continuous flows. The complete treatment train alternative comprising the combination of Alternative 4A with RO desalting (i.e., BRF – FBIX – UF – RO) was selected for pilot testing to close data gaps for FBIX treatment and to verify/optimize selected parameters for BRF, UF, and RO.

The pilot plant was operated for a period of nine months and treated a maximum raw water flow of 30 gpm. The overall treatment train was effective in addressing the goals of the pilot study and met all water treatment objectives during dry- and wet-season testing. Stable hydraulic performance and water quality were observed for the units. Spikes in instantaneous color/organics loadings during the wet season were addressed by implementing a two-stage FBIX system that enhanced color/organics removal via increased media depth.

Conclusion
 This project showed that the water from the CPS can be treated to provide a new source of water supply. Cost estimates are being developed for the two top-ranked surface water treatment alternatives that were tested (4A and 3E in Table 2).

Table 1. Top Ranked Treatment Alternatives

<table>
<thead>
<tr>
<th>Alternative ID</th>
<th>Description of Water Treatment Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>Conventional Pretreatment - Biological Filter</td>
</tr>
<tr>
<td>1E</td>
<td>BRF - Conventional Pretreatment - Dual Media Filter</td>
</tr>
<tr>
<td>1C</td>
<td>Conventional Pretreatment - Dual Media Filter (w/ GAC)</td>
</tr>
<tr>
<td>3E</td>
<td>BRF – Fixed-Bed Anion Exchange (FBIX) - MF/UF</td>
</tr>
<tr>
<td>3C</td>
<td>BRF - Conventional Pretreatment - MF/UF</td>
</tr>
<tr>
<td>Desalting Component</td>
<td></td>
</tr>
<tr>
<td>RD</td>
<td>Reverse Osmosis (side stream treatment)</td>
</tr>
<tr>
<td>NF</td>
<td>Nanofiltration (full stream treatment)</td>
</tr>
<tr>
<td>EDR</td>
<td>Electrodeionization Reversal (side stream treatment)</td>
</tr>
</tbody>
</table>

Notes:
- Conventional Pretreatment = coagulation/flocculation/sedimentation, BRF = biological filtering, GAC = granular activated carbon, MF/UF = microfiltration/ultrafiltration.
What Can Carollo Do to Improve the Performance of UV Reuse Systems?

Just as any car runs uneconomically without proper maintenance, ultraviolet (UV) systems, which are used for reuse water disinfection all over the world, can operate inefficiently over time. This leads to an increase in O&M costs and may cause indicator microbe concentrations to exceed required levels.

In the several reuse UV system audits that Carollo has conducted, the common issues observed are:

1. **Lamp Aging and Fouling.** The dose-monitoring algorithms used by the UV systems do not include UV sensor intensity as an input. As such, operators have no means to quantify lamp aging and fouling, which can reduce UV dose by as much as an order of magnitude.

2. **Impact of Lamp Failure on UV Dose.** While the NWRI UV Guidelines allow systems to operate with failed lamps, the impact of lamp failure on UV dose delivery is not known. Utilities need tools that quantify the impact of lamp failure on UV dose delivery to maintain efficient UV system operation.

3. **Lack of Quantifying Tools.** Since utilities lack tools for quantifying, troubleshooting, and optimizing UV systems, they operate their UV systems with all lamps on at maximum power or at increased UV dose targets to minimize the risk of indicator microbe excursions.

A UV audit consists of 2 days of fieldwork and laboratory work. Field work consists of:

1. A visual inspection of the lamps and ballast, lamp aging, sleeve fouling, biofilm buildup on lamp modules and channel walls.
2. A measurement of lamp aging, sleeve fouling, and UV sensor window fouling using a custom optics bench.
3. An evaluation and comparison of the UV dose-monitoring algorithm in the PLC with the validation report.

Lab work consists of measuring indicator UV dose response using a collimated beam apparatus and log inactivation through the reactor, thus revealing the actual UV dose delivered by the reactor.

Carollo has conducted several reuse UV system audits for clients in North America. These audits can identify improvements for UV system operation, providing cost savings and improved public health protection.

The Custom Optics Bench consists of a low-pressure mercury lamp source, a radiometer to measure light from source and supports to allow precise placement of a lamp and sleeve in the path of the light source. This device allows direct measurement of the transmittance of UV light at 254-nm wavelength through clean and fouled sleeves and new and aged UV lamps.

As part of the audit, Carollo provides a detailed report that identifies any performance issues with the UV system and recommends corrective actions. In addition, Carollo presents the findings to plant staff and works with them to implement corrective actions.

The analysis of UV audit data can identify improvements to UV system operation and maintenance that provide cost savings for utilities and improved public health protection.

WRF Knowledge Base Project: Helping Utilities Make Informed Decisions on the Implementation of Biofiltration

A Carollo/Arcadis Team is leading a Water Research Foundation (WRF) project focused on developing a knowledge base tool for cataloguing and summarizing design, operation, and monitoring strategies of high-rate biofiltration facilities in North America. The knowledge base tool is not intended to identify definitive or prescriptive solutions. Rather, the tool will provide planning/design/operating details and industry-wide case studies that utilities can use to make informed decisions.

The project will widely communicate information and guidance to the user about:

- Benefits of biofiltration for drinking water treatment
- Lessons learned on mitigating negative impacts
- Solutions for improving initial design and operations of biofiltration systems
- Knowledge gaps and need for future research

Important project deliverables include:

- A Biofiltration Knowledge Base tool for organizing and analyzing design, operational, and monitoring data.
- A companion guidance document to inform decisions related to the design, operation, and monitoring of biofiltration systems.

Beginning in Spring 2014, utilities through the North American water industry will be able to contribute data and access case studies in the knowledge base. It is our intent to ultimately collect facility information from the hundreds of high-rate biofiltration facilities for the benefit of the broader industry.

If you have evaluated, designed, or are operating a high-rate biofiltration facility, please join us in building this foundational compendium of lessons learned and best practices. The survey will be rolled out in March, and access will be available through the WRF website (www.waterrf.org). Please contact Jess Brown for more information.
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• Benefits of biofiltration for drinking water treatment.
• Lessons learned on mitigating negative impacts.

High-rate biofiltration can address a wide variety of contaminants.

• An expensive catalog of biofiltration-related terminology and frequently asked questions.
• Multiple workshops and webcasts to expand input to the Knowledge Base tool and to broaden the dissemination of project results.
• A literature review has been completed to collect existing information on factors that influence the selection, design, development, and operational effectiveness of biofiltration. An electronic survey was developed to collect planning, pilot testing, design and operating information from water facilities evaluating or currently practicing high-rate biofiltration for the knowledge base. In late 2015, utilities from across Canada and the United States contributed data to the knowledge base.

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Do you use or are you interested in Biofiltration? We need your help.

Paper vs PDF
If you would like to receive a PDF instead of a printed version of Research Solutions, please send your request to us at researchsolutions@carollo.com. If you do not hear from us, we will continue to send you the printed publication.
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WHAT’S NEW

WRF Publishes Taste and Odor Control Report

Carollo is pleased to announce Water Research Foundation (WRF) Report 3032, “A Decision Tool for Earthy/Musty Taste and Odor Control” has been finalized and is now available through the WRF website.

The central objective of this project was to develop a decision-making tool to help utilities develop reasonable and defensible treatment goals for managing geosmin and MIB (4, 8a-dimethyl-decahydronaphthalene-4a-ol) taste and odor (T&O) events.

Geosmin and MIB are the two most common naturally occurring T&O-causing contaminants in the world. Their control in source water reservoirs and at the treatment plant can be difficult and expensive. Although MIB and geosmin do not pose a health threat, these compounds create a displeasing earthy/musty (E/M) T&O when present above sensory thresholds. Often the public perceives E/M water to be unsafe or unhealthy because it is aesthetically objectionable. This creates a public relations problem for the water utility and can result in loss of consumer confidence.

The Earthy/Musty T&O Decision Tool will help utilities characterize their E/M T&O problems, identify reasonable goals for geosmin and MIB control, and develop alternative scenarios for meeting those goals. The tool is based in Microsoft Excel. Two example scenarios illustrating the use of this tool are also included, one a “high-geosmin odor event” example, and the other a “moderate on-going MIB and geosmin levels” example (Example 1_E-M TnO Mgmt Tool.xls and Example 2_E-M TnO Mgmt Tool.xls, respectively).

This report is available in electronic format through the WRF website (www.waterrf.org).