Asset Management

Miami-Dade knows information is key
Since their discovery in the 1970s, disinfection byproducts have been a major concern for regulators, drinking water utilities, and the public due to their carcinogenicity and other potential health effects.

Several iterations of disinfection byproduct (DBP) regulations have been implemented over the past three decades. The latest regulation, the Stage 2 Disinfectant / Disinfection Byproduct Rule (D/DBPR), maintains existing maximum contaminant levels (MCLs) of 80 μg/L for total THMs and 60 μg/L for the sum of five HAAs from the Stage 1 D/DBPR, but focuses on a locational running annual average (LRAA) instead of a system-wide annual average, resulting in stricter limits for many utilities of all sizes.

While most large systems are generally well prepared for Stage 2

In collaboration with the Water Research Foundation, Hazen and Sawyer developed a definitive, understandable, and results-oriented guidance manual and associated web tool to help small- and medium-sized utilities cost-effectively comply with the new Stage 2 D/DBPR.

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DBP Reduction Strategies from Source to Tap
THMs and HAAs form when chlorine reacts with natural organic matter (NOM) during drinking water treatment and distribution. Many different strategies can be applied at different stages of the supply, treatment, and distribution process to reduce DBP formation.

<table>
<thead>
<tr>
<th>SOURCE WATER</th>
<th>TREATMENT</th>
<th>DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Change source water seasonally</td>
<td>• Optimize free chlorine disinfection</td>
<td>• Reduce chlorine levels into the distribution system</td>
</tr>
<tr>
<td>• Blend water sources</td>
<td>• Implement enhanced coagulation</td>
<td>• Convert secondary disinfectant to chloramine</td>
</tr>
<tr>
<td>• Modify reservoir filling operations</td>
<td>• Change coagulant or primary disinfectant</td>
<td>• Reduce water storage or undergo periodic flushing</td>
</tr>
<tr>
<td></td>
<td>• Use MIEX® or post-filter GAC contactors or membranes</td>
<td>• Introduce localized treatment</td>
</tr>
</tbody>
</table>
D/DBPR compliance, many small and medium systems have yet to fully address the various changes in treatment and management practices that may be necessary to meet the new requirements. There are numerous reports and extensive guidance manuals related to dealing with the Stage 2 D/DBPR, but these individual documents do not focus on the needs of small- and medium-sized systems.

The resources developed as part of this project will provide direction for complying with the Stage 2 D/DBPR by offering simple step-by-step approaches that enable utilities to:

- Evaluate their potential compliance status relative to specific compliance goals.
- Assess more than 20 potential DBP reduction strategies.
- Compare DBP reduction strategies by using system-specific information to estimate the DBP reduction percentage from each strategy, as well as the associated cost of implementation.

The online tool provides outputs from calculation results and generates associated plots and charts that can help with visualizing data trends. System-specific data entered by the user - along with questionnaire answers - populate an interactive table of DBP reduction alternatives and their expected result (shown above). The user can select alternatives or combinations of alternatives to tally percent DBP reductions and costs for the selected options. This allows the user to easily compare the possible reduction in DBPs and costs of a variety of different possible combinations of compliance alternatives.

The free online tool is available at: http://stage2dbpcalculator.com.

For more information, contact: Bill Becker, PhD, PE at wbecker@hazenandsawyer.com or Erik Rosenfeldt, PhD, PE at eroosenfeldt@hazenandsawyer.com.
The Miami-Dade Water and Sewer Department in Miami-Dade (FL) serves more than two million customers, oversees three water treatment facilities, and manages a distribution system that encompasses 7,559 miles of pipes.

On March 2, 2010 at approximately 2:00 AM, a Miami-Dade Water and Sewer Department 54-inch diameter concrete water transmission main ruptured, creating a sinkhole 10 feet deep by 40 feet wide in a major intersection and flooding adjacent houses with a foot of water.

When faced with a significant pipe failure, Miami-Dade Water and Sewer Department turned to Hazen and Sawyer to examine its infrastructure and prioritize potential repairs.
The ruptured main provided the water supply for the City of Hialeah and north Miami-Dade County, but the Department was able to maintain distribution system pressures. The ruptured portion of the main was isolated and subsequently dewatered and repaired by removing two damaged pipe sections and replacing them with adapters, a pipe length, a short, and a closure piece.

In the aftermath of the repair, the Department retained Hazen and Sawyer to validate inspections of the failed pipe and assist in planning relative to condition assessment and repair/replacement options for other prestressed concrete cylinder pipe (PCCP) in operation throughout the Miami-Dade County system.

Pipe Inspections

During the initial repair, while a one-mile section of the pipeline was isolated and dewatered, the Department had contracted with a specialty inspection company to obtain an electromagnetic survey of the isolated section of pipe that included the failed pipe segments. This survey involved sending an electromagnetic signal transmitter through pipe and recording the return signal as influenced by prestressing wires, and provided data on the approximate number and location of wire breaks. Of 256 pipe segments inspected, 46 were characterized as having broken prestressing wires and 17 of the 46 damaged pipes appeared to have broken wires throughout the pipe segment. In total, 24 pipes were recommended for immediate repair.

The same intersection after pipe failure created a 10 foot deep by 40 foot long sinkhole in the four lane highway and flooded adjacent residences.
This initial electromagnetic inspection was followed by a second electromagnetic inspection of a 16.3-mile section of pipe, after the section that ruptured was placed back into service. Once completed, this second inspection revealed that 126 of the 4,505 pipe segments had at least five wire breaks and 40 of 126 damaged pipes had broken wires throughout the pipe segment. Seventy-three pipes were recommended for immediate repair, including the 24 identified during the first round of testing.

Once the pipeline had again been isolated and dewatered for repair of the most severely distressed pipe segments, Hazen and Sawyer conducted a visual and sounding inspection of the pipeline interior to confirm the electromagnetic survey results and verify that the correct segments had been identified for repair. The visual inspection included looking for cracks in the inner or outer coating of the pipes and tapping the inner core with a hammer to detect delamination of the concrete core from the steel cylinder.

Longitudinal cracks and audible delamination were encountered on two of three pipes characterized as most severely distressed, and Hazen and Sawyer confirmed the condition of the third most severely distressed pipe by wire continuity testing. For the wire continuity testing, the pipes characterized as severely distressed were identified from above ground using a measuring wheel and a receiver to locate a sonde placed inside the pipe; the tops of the pipes were excavated and exposed; and the outer mortar was carefully removed to expose the wires. The electrical continuity between wire wraps was then checked to identify broken wires and it was found that the actual wire breaks exceeded the numbers predicted by the electromagnetic testing.

Assessing Repair Options

Following verification for repair, we turned our attention to investigating alternatives to prevent future failures and addressing the following questions:

- What is the condition of the remaining PCCP pipe in the system?
- How can these pipelines be inspected to determine their condition?

The secondary electromagnetic inspection confirmed the results of the initial PCCP survey, indicating a total of 73 pipes that required immediate repair.

The bursting of this 54-inch water main in Hialeah (FL) in March 2010 caused service disruptions, traffic problems, and flooding in nearby homes.
• What preventive maintenance program is required to maintain the integrity of the system?
• What cost-effective repair alternatives are available?

In order to answer these questions, Hazen and Sawyer worked with the Department to develop an Infrastructure Assessment and Replacement Program (IAARP). Through this program, 15 miles of pipe are inspected per year via electromagnetic methods that can be conducted while the pipeline remains operational. The prioritization for these inspections is determined by a variety of factors, including operating pressure, diameter, age, land use, operational criticality, repair history, and the date last inspected. Inspections are scheduled for every three years for known distressed pipes, every five years for 48-inch and above, and every 10 years for pipes smaller than 48-inch.

**Going Forward**

As part of this program, we developed a PCCP pipe inventory of the Department’s water system including calculated theoretical pipe failure rates during the next 5-, 10- and 100-year periods. We also reviewed the advantages and disadvantages of repair and replacement alternatives, the factors to consider when selecting a rehab method (including structural condition and proximity of distressed pipe, hydraulic adequacy, and surface conditions), and associated costs of each repair option.

The project has enabled the Department to proactively monitor the state of their prestressed concrete cylinder pipes in order to properly prioritize repairs, select the best repair option, extend the useful life of their assets, and save money by avoiding emergency repairs.

<table>
<thead>
<tr>
<th>PRODUCTION YEAR</th>
<th>PIPES INSTALLED</th>
<th>PREDICTED 5 YEAR FAILURES</th>
<th>PROJECTED 5 YEARS</th>
<th>PREDICTED 10 YEAR FAILURES</th>
<th>PROJECTED 10 YEARS</th>
<th>PREDICTED 100 YEAR FAILURES</th>
<th>PROJECTED 100 YEARS</th>
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</thead>
<tbody>
<tr>
<td>64-67</td>
<td>1,243</td>
<td>8.05E-4</td>
<td>1</td>
<td>1.61E-3</td>
<td>2</td>
<td>2.00E-2</td>
<td>25</td>
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<tr>
<td>68-71</td>
<td>1,470</td>
<td>2.24E-3</td>
<td>3</td>
<td>4.47E-3</td>
<td>7</td>
<td>1.30E-1</td>
<td>191</td>
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<tr>
<td>72-78</td>
<td>9,413</td>
<td>4.67E-3</td>
<td>44</td>
<td>9.34E-3</td>
<td>88</td>
<td>1.00E-1</td>
<td>941</td>
</tr>
<tr>
<td>79-91</td>
<td>7,673</td>
<td>1.09E-3</td>
<td>8</td>
<td>2.18E-3</td>
<td>17</td>
<td>7.81E-3</td>
<td>60</td>
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<tr>
<td>92-06</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>Totals</td>
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<td></td>
<td>56</td>
<td></td>
<td>114</td>
<td>1,217</td>
<td></td>
</tr>
</tbody>
</table>

One of the results of the project was a PCCP pipe inventory that calculated theoretical failure rates for the next 5, 10 and 100 years. \(^{(1)}\) Estimated at ½ of 10-year failures.

Wire continuity testing revealed that the number of wire breaks was actually higher than the number predicted by electromagnetic testing.
The City of Garland owns and operates the Duck Creek Wastewater Treatment Plant (WWTP), which is permitted to treat 40 million gallons per day (mgd) on an annual average basis. The Duck Creek WWTP has to comply with seasonal ammonia nitrogen limits, but has periodically experienced periods of high ammonia in the effluent. City staff had long suspected nitrification-inhibitory compounds in the wastewater and had developed operating procedures to minimize the impact to the process.

The City turned to Hazen and Sawyer to provide assistance to confirm the inhibition. The project, currently in its latter stages, required understanding the Duck Creek WWTP operating conditions and its potential for optimization, verification of inhibition of nitrification, and identification of other issues impacting nitrification performance. The City also sought to identify and verify whether inhibition was due to outside sources in the influent and the extent of inhibition occurring.

To gain a better understanding of the factors affecting plant performance, we first analyzed the available historical data (January 2009 to September 2012), which showed that BOD and TSS removal performances...
Samples were taken from several locations throughout the treatment process and analyzed to pinpoint the source of the inhibitory compound. Bench-scale nitrification rate testing in parallel reactors showed that the suspect compound slowed nitrification but didn’t disable it completely.

were consistently good, with no violation of the current operating permit. However, some high ammonia events could not be explained based on the available data and, as suspected by plant staff, were later proven to be the result of nitrification inhibitory compounds in the wastewater.

Next, the team conducted nutrient profile sampling, drawing samples from several locations throughout the biological treatment process and from the influent, primary effluent, and secondary effluent. Samples were measured on-site, with consequent supplemental lab analysis by the City.

Hazen and Sawyer then conducted bench-scale nitrification rate testing in parallel reactors to develop a baseline condition during non-inhibited nitrification. One reactor was fed with primary effluent collected during an inhibition period; the other reactor was fed with primary effluent collected during normal operation (a control sample). The influent collected during normal operation nitrified immediately at normal rate. The influent collected during an inhibition period showed no significant nitrification activity for approximately 210 minutes. After this initial period, nitrification was observed but at a low rate compared to the control sample, meaning the suspect compound was found to be inhibitory but not toxic.

Hazen and Sawyer then developed a preliminary BioWin™ model of the facility’s process based on the supplemental sampling and the historical data. Two steady state simulations were conducted: one to simulate the special sampling event and the other to simulate historical data. The results of these simulations helped identify preliminary options for further evaluation at the Duck Creek WWTP.

“Thanks to the work of Hazen and Sawyer, we were able to quickly show meaningful progress to address inhibition.”

“Thanks to the work of Hazen and Sawyer, we were able to quickly show meaningful progress to address inhibition,” said Wes Kucera, Director - Wastewater Treatment.

The second phase of the study is currently underway, further evaluating ways to manage the periodic inhibitory compound. City staff is currently working to identify the source of the suspect discharge. This phase will include an intensive sampling protocol and bench-scale testing to predict the plant’s responses to changes in operation or modifications to the process, enabling the City to identify the capital expenditures or operational modifications with the best return on investment.
Managing Groundwater Contaminants: Solutions for our Fastest Growing Source

The City of Glendale (CA) has been managing a major research effort to identify technologies for removing hexavalent chromium, Cr(VI), from drinking water supplies.

When the project began almost a decade ago, the City of Glendale was planning to take delivery of treated groundwater from a new water treatment plant. After delivery of the treated water to Glendale’s residents was approved, the City Council became very concerned with the presence of any Cr(VI) in their water supplies, even though the concentration was far less than federal and state water quality standard maximum contaminant levels (MCLs) for total chromium in water supplies. The City soon realized that there was no proven feasible technology for low-level Cr(VI) removal from water.

A research program led by the City, in partnership with many other agencies and organizations, has identified a handful of effective treatment technology options for removing Cr(VI) in drinking water, including reduction/coagulation/filtration (RCF), weak base anion exchange (WBA), strong base anion exchange (SBA), and reverse osmosis (RO). The test results can help utilities to better understand which processes might work best for their situation, accelerating the design and construction of appropriate treatment facilities.

While Glendale chose to pursue RCF and WBA removal options to treat their groundwater, selection of treatment depends on a number of factors, including treatment goals, residuals disposal options, operational complexity, source water quality, and cost.

Leading Cr(VI) Technologies

Four leading technologies have emerged for Cr(VI) treatment in drinking water. Regenerable SBA is a fairly standard technology used mostly for nitrate or arsenic treatment of drinking water, although an application for Cr(VI) removal may require an additional level of complexity to precipitate Cr(VI) from

About Chromium

Chromium is a naturally occurring element found in rock, soil, and groundwater. It is the 11th most common element found in the Earth’s crust. Chromium is commonly present in the environment in primarily two forms—Cr(III) and Cr(VI).

Cr(III) is an essential human nutrient that is included as an element in food supplements. Cr(VI) can also occur as an industrial byproduct in manufacturing processes for stainless steel, chrome plating, dyes, pigments, leather tanning, and wood preserving. In many cases, it is suspected that these industrial byproducts were discharged to the ground, in rivers, etc. and eventually reached groundwater supplies.
brine used for regeneration. WBA is a new technological ion exchange approach that is characterized by a much higher Cr(VI) capacity arising from the conversion of Cr(VI) to Cr(III) by the resin matrix, compared with SBA where Cr(VI) is exchanged in the hexavalent form. WBA requires upstream and downstream pH adjustment. The RCF process is similar to conventional water treatment with coagulation and filtration, with the addition of upstream reduction using ferrous iron, making this process fairly complex to operate. Reverse osmosis can also be effective at removing Cr(VI) through size and charge exclusion of the Cr(VI) with membranes, although water losses are significant.

**Successful Results**

The City of Glendale tested two of the technologies, RCF and WBA, for more than two years at demonstration-scale - 100 gpm (RCF) and 425 gpm (WBA) - serving water to City customers. In summary, these tests showed:

- Both granular media filtration and microfiltration (MF) were effective in the RCF process for achieving less than 1 ppb Cr(VI). Use of MF allows for less than 1 ppb total Cr; Cr(III) + Cr(VI), compared to less than 5 ppb total Cr for granular media filtration. Total Cr is of interest because disinfectants can convert Cr(III) back to Cr(VI).
- WBA can reach less than 1 ppb Cr(VI) and costs significantly decrease as treatment targets increase since resin can be used longer.
- Pilot testing at Glendale and full-scale SBA treatment at other utilities for other contaminants have been shown to yield Cr(VI) removal to less than 1 ppb.

Residuals Can Drive Selection

Waste products from treatment processes can be significant drivers in technology selection for Cr(VI) - particularly in volumes generated, classification of waste (hazardous, accumulation of other constituents like uranium), and local disposal restrictions - due to cost and labor.

Three of these processes – RCF, WBA, and SBA - can generate a waste that is classified as hazardous in the State of California by the Waste
Extraction Test (WET) but often non-hazardous according to the Federal Toxicity Characteristic Leaching Procedure (TCLP). RCF, if operated with disposal to the sewer without dewatering, might not be considered hazardous in some cities but water losses must be considered and compared with the costs of backwash water treatment and recycle. Due to its high capacity and long life, WBA resin can also accumulate other anions, including uranium, which can trigger additional disposal considerations. The brine resulting from SBA regeneration is not allowed into the sewer system in many cities and would require further treatment or hauling off-site.

Water recovery rates also vary, with the RCF process having a water loss of about 3% for granular filtration and 5% for MF, compared with less than 1% for WBA and SBA. Reverse osmosis can lose 15-25% of the water volume treated, and hence was not considered for demonstration-testing at Glendale.

Cost Considerations
A detailed cost evaluation of treatment options was prepared as part of this work, including generation of cost curves for different flow rates, influent concentrations, and potential MCL treatment goals. The City of Glendale, together with our staff, worked closely with the California Department of Public Health to provide rigorous cost information intended for use in developing a Cr(VI) regulation.

Going Forward
The State of California intends to regulate hexavalent chromium with a new primary MCL expected in draft form in summer 2013. The MCL will take into consideration the Public Health Goal of 0.020 ppb, technological feasibility of treatment, and a cost-benefit analysis.

“The Department of Water and Power of the City of Glendale, working with Hazen and Sawyer engineers, developed solutions for hexavalent chromium treatment to low parts-per-billion levels. The solutions and costs are defined in the report submitted to the State.
of California. The results of this partnership will benefit the water industry in deciding what method of treatment to use to meet the new MCL,” said Ramon Abueg, City of Glendale Department of Water and Power.

The research program led by the City of Glendale and sponsored and supported by the Water Research Foundation, federal agencies, the State of California, and local municipalities, provides the foundation for identifying effective technologies. Follow-up studies are needed to test their application for other utilities, to identify the next generation of technological approaches to overcome limitations of existing technologies, and to develop optimized processes to reduce costs. Studies are underway to investigate the improved chromium removals that can be achieved with adsorptive media and additional ion exchange resins.

For more information contact: Nicole Blute, PhD, PE at nblute@hazenandsawyer.com or Ying Wu, DEnv, PE at ywu@hazenandsawyer.com

Reduction/Coagulation/Filtration (RCF) treatment process showing the pressure filters in the background and rapid mix tank for coagulation (100gpm). Components not shown include reduction tanks and aeration.
Tools for REUSE MASTER PLANNING

Two recently developed tools can simplify analysis, facilitate planning, and improve the efficiency and effectiveness of master planning.

Hazen and Sawyer has assisted municipalities nationwide with their master planning efforts, utilizing the latest technologies to continuously improve results. As part of a recent master planning effort, we created two tools for the ongoing evaluation of potential reuse projects.

These tools — the GIS Reuse Planning Tool and the Criteria Evaluation Model — originally developed for a county in the Southeastern United States — can be adapted to analyze potential projects around the globe. They also readily identify potential multi-jurisdictional reclaimed water projects with easy-to-use graphical interfaces and enable utilities to plan outside their silo.

Criteria Evaluation Model

The Criteria Evaluation Model performs a quantitative analysis on qualitative data to determine the return on investment of reuse projects and partnerships.

For this initial project, the team established 20 principal criteria (based on project benefits, implementation, reliability, general acceptance, and cost) for use in the evaluation tool. The methodology included establishing a weight for each criterion, which can be tailored to any utility performing the evaluation. Additionally, the team calculated a scaling factor to ensure the criteria are evaluated on similar scales.

Once the user enters scores for each criterion, the model tabulates a total for each project and summarizes the results.

Higher scores are considered higher-ranked alternatives. Since the weighting of the criteria directly affects the scoring of the project, variations in weighting will provide multiple rankings that can reflect the perspectives and the priorities of any number of stakeholders.

Municipalities may also perform this ranking analysis to complete reuse feasibility studies for future permitting efforts. The flexibility of this criteria evaluation model provides a cost savings for future planning updates for all involved municipalities.

<table>
<thead>
<tr>
<th>PROJECT NUMBER</th>
<th>PROJECT NAME</th>
<th>CAPACITY</th>
<th>TOTAL SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Large User Irrigation (Low) - One mile radius from WWTP</td>
<td>1.05 mgd</td>
<td>56.26</td>
</tr>
<tr>
<td>2</td>
<td>Large User Irrigation (High) - Five mile radius from WWTP</td>
<td>3.5 mgd</td>
<td>51.32</td>
</tr>
<tr>
<td>3</td>
<td>Industrial</td>
<td>1 mgd</td>
<td>51.22</td>
</tr>
<tr>
<td>4</td>
<td>Irrigation - Large Scale Residential</td>
<td>1 mgd</td>
<td>47.24</td>
</tr>
<tr>
<td>5</td>
<td>Aquifer Recharge</td>
<td>1 mgd</td>
<td>35.15</td>
</tr>
<tr>
<td>6</td>
<td>Credit Sharing Reuse Partnership with Utility A</td>
<td>1 mgd</td>
<td>27.15</td>
</tr>
</tbody>
</table>
GIS Reuse Planning Tool

The GIS Reuse Planning Tool compiles existing reuse infrastructure, public works projects, and potential large-user customer identification on GIS into a Google Earth platform that anyone, from GIS novice to GIS expert, can manipulate.

For this particular master planning effort, the team worked directly with each of the 28 municipalities in the County to identify large-user reuse projects within one, three, and five miles of the wastewater treatment plants. The tool facilitates the selection of projects both within and crossing jurisdictional boundaries, highlighting the potential partnerships between utilities to foster maximum reuse development.

Blue areas = existing reuse customers
Purple lines = existing reuse lines

Following the input of existing wastewater and reuse infrastructure, the land parcels of potential reuse customers is identified within GIS layers. Keying these parcels by land use code enables the user to view customers by either total potential reuse or by type of reuse.

Blue = industrial  Orange = golf courses
Pink = residential  Green = other green spaces

Given this data, the tool offers the user a comprehensive view of potential reuse projects within a one-, three-, and five-mile radius of each plant across utility service boundaries. Performing this analysis captured the most economically-feasible reuse projects for the County and identified potential strategic utility partnerships.

Red lines = one mile radius from plant
Yellow lines = three mile radius from plant
Blue lines = five mile radius from plant
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