FALL 2008

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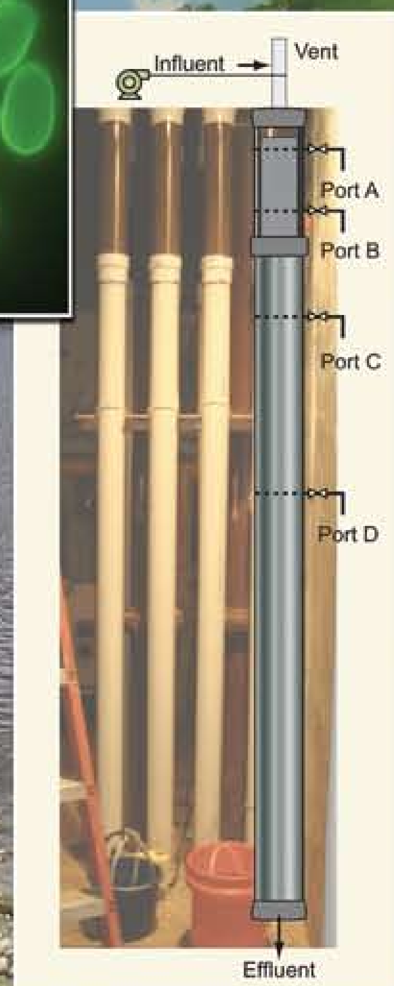
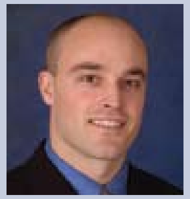
A Publication of the Carollo Research Group



In this Issue

Bridging the Gap



Jess Brown, Ph.D., P.E.
CRG Manager

Welcome to the Fall 2008 issue of *Research Solutions*, a quarterly publication of the Carollo Research Group (CRG). CRG, a diverse team of engineers, scientists, and researchers located throughout the country, is focused on ***bridging the gap*** between fundamental research and practical, innovative, and reliable solutions for those we serve. *Research Solutions* features articles that demonstrate Carollo's capabilities to develop and implement advanced processes, technologies, and tools for the treatment and management of water, wastewater, and reuse water. You'll also find commentary about industry developments and announcements about recent publications, awards, and new staff. The Fall 2008 issue discusses:

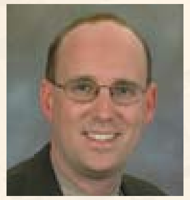
- How to improve activated sludge treatment efficiency by optimizing aeration.
- A new method to assess the influence of surface water on groundwater sources.
- The expansion of the San Antonio Water System brackish groundwater desalination pilot study to accommodate a design-build RO procurement approach.
- An AwwaRF Tailored Collaboration project with the City of Arlington, TX, applying enhanced biofiltration for the simultaneous removal of multiple contaminants.
- A desktop evaluation of plastic pipe compatibility with various disinfectants.

Research Solutions reflects our belief that creativity, science, and technology must be integrated with sound engineering to meet the complex challenges facing our industry. Challenges like aging infrastructure, increasingly stringent water quality and discharge requirements, the movement toward sustainability, and growing water supply shortages require innovative thinking to bridge the gap from R&D to real-world solutions.

We hope that *Research Solutions* provides new ideas and case studies that help you address your water and wastewater needs. Do not hesitate to contact the authors or me directly to discuss any of these articles.

COMMENTARY

Optimizing Aeration System Design



By Garrett Sheehan, P.E. (gsheehan@carollo.com), Randal Samstag, P.E., Coenraad Pretorius, P.E.

The energy requirements for a modern activated sludge wastewater treatment plant can represent 50 to 90 percent of the total plant energy requirements (USEPA, 1989). There are a number of considerations in properly designing an aeration system/basin to optimize power use and to provide efficient operation. Figure 1 shows the key elements discussed here.

(1) DO Control Strategies

With constantly changing wastewater flow and strength, accurately reacting to these fluctuations is key in optimizing aeration system design. Improving dissolved oxygen (DO) control can result in aeration energy savings of 25 to 40 percent, depending on the existing control strategy being used (USEPA, 1989). A number of different control strategies, each with different complexities, can be used to adjust airflow and provide reliable DO control.

The simplest (low-complexity) control strategy involves adjusting blower output to maintain a desired DO concentration in the aeration basins.

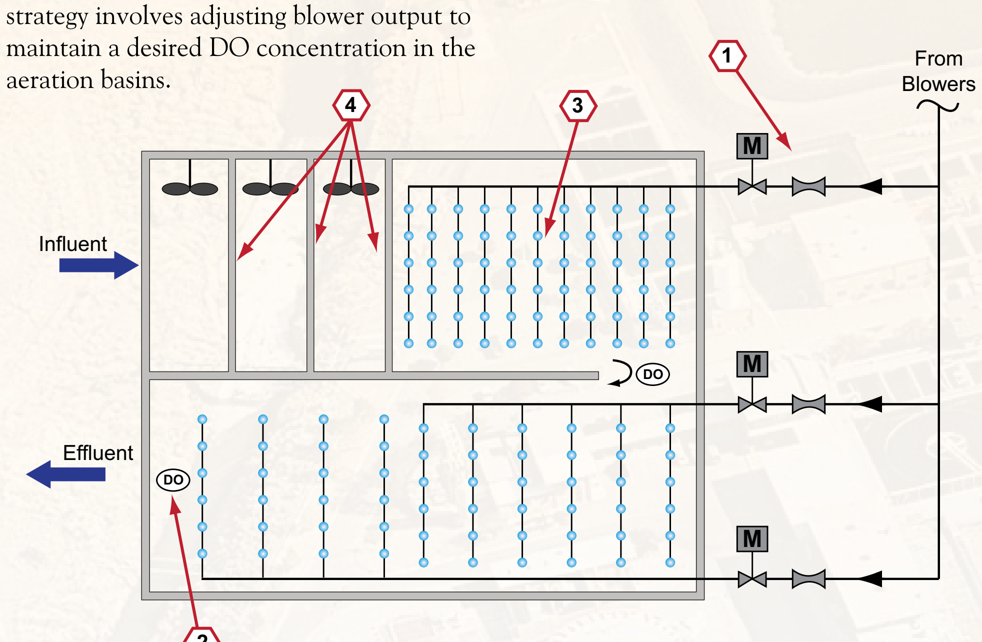


Figure 1. This process schematic shows areas where aeration system design can be optimized.

A more advanced (medium-complexity) control strategy involves the use of individual DO setpoints, controllers, airflow control valves, and air headers at each aeration basin. The major advantage of this method over the low-complexity strategy is that more precise DO control can be maintained across multiple aeration basins because each basin has its own separately controlled air distribution header.

The most complex control strategy involves the adjustment of multiple zones or grids within each basin to closely match oxygen demand. This control strategy has been successfully used at the Truckee Meadows Water Reclamation Facility in Reno, NV. Prior to recent improvements, this 46.5-mgd facility had one control valve per basin and a single DO probe located at the end of each three-pass basin. This limited the efficiency of process control. As part of the upgrades, each pass of each aeration basin was retrofitted with individual air distribution headers having a dedicated control valve and flow meter as well as a DO probe at the end of each pass. Plant staff has observed improved process control and stability along with the reliable production of a high-quality effluent.

When designing DO control systems, the use of a cascade control philosophy should be considered. For example, the simple DO control system illustrated in Figure 2A would be adequate in the absence of external influences. However, if there were a change in the control valve position on an adjacent aeration basin receiving air from the same header, less air would flow to this basin even though the basin's control valve had not changed position. The lack of air would only be detected by the control system once the DO in this basin had dropped. This problem can be solved by using cascade control (Figure 2B). In this system, the output from the DO control loop is used to adjust the setpoint for the airflow control loop. The airflow rate is maintained at a given setpoint until the DO control loop adjusts it based on the basin DO concentration. The advantage of this type of system is that it responds to changes elsewhere in the aeration system and maintains the airflow rate through a given control valve.

(2) DO Probe Location and Type

In many cases, only one DO probe is installed in each aeration basin. Sometimes this probe is located too close to the end of the tank, where changes in load and system oxygen demand may not be detected or may be detected too late to react to changes in DO concentration. In other cases, when this probe is located too close to the inlet of the tank, rapid DO changes that are more likely to occur early in the process may result in undesirable corrections to airflow.

Using dynamic process models, Carollo has explored the impact of placing DO probes at various locations within an aeration basin. The model results showed that by using two DO probes, one located in the middle of the basin and a second at the end of the basin, a better combination of low airflow and relatively even DO distribution can be obtained.

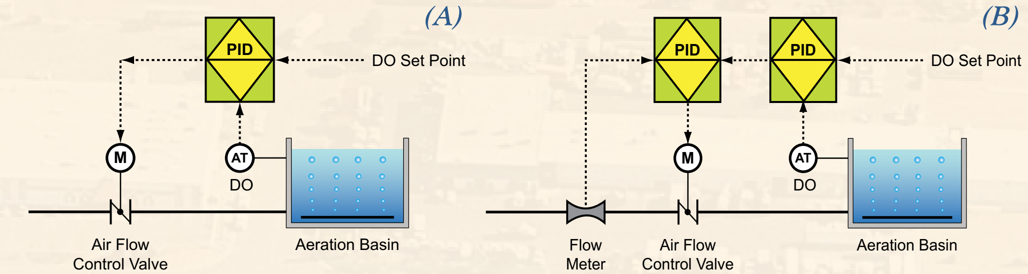


Figure 2. There are two dissolved oxygen (DO) alternatives: simple DO control (A) and cascade DO control (B).

Recently, luminescent DO probes have emerged as the standard in DO measurement. In contrast to traditional membrane electrode DO probes, which are subject to interference from dissolved inorganic salts and reactive gases, the luminescent dyes in these newer probes are highly sensitive to oxygen, are resilient to most interferences associated with the membrane electrodes, and provide high accuracy with reduced maintenance.

(3) Diffuser Layout

Early aeration basin designs incorporating a roll pattern were believed to enhance mixing and improve aeration efficiency. However, experimental testing and operational experience have confirmed that full-floor coverage provides improved process benefits. As an example, at the South Treatment Plant in King County, WA, Carollo conducted dye tests to examine the hydraulic characteristics of the aeration tanks. The results of the dye testing showed that the tanks had highly plug flow-like behavior that could not be accounted for based on geometry alone. It appeared that the small mixing zones created by the fine bubble diffusers in the tanks "held-up" dye in a manner more characteristic of a plug-flow tank than would otherwise be the case. The vertical mixing caused by the rising bubbles also appeared to interrupt the density currents.

This may point to a previously unnoticed benefit of full-floor, fine bubble aeration systems. It appears that the internal mixing created by a full-floor of fine bubble aerators increases the plug-flow character of the tank over aeration systems with larger tank-mixing patterns, like surface aerators or roll pattern configurations. By increasing the plug-flow character of a tank, reactor kinetics for removal of soluble pollutants can be improved and may increase COD and ammonia removal.

(4) Baffle Wall Configuration

As more treatment plants incorporate biological nutrient removal into the activated sludge process, the need for discrete anaerobic and/or anoxic selector zones to provide the necessary environment for biological nutrient removal within aeration basins increases. However, simply providing a baffle wall is typically insufficient to create these zones.

Baffle wall design must provide for the movement of surface scum through the aeration basin and into the secondary clarifier. Consideration must also be given to the density difference between the anaerobic and/or anoxic selector zones and the downstream aerated zones. A baffle wall design that doesn't consider these density differences will not only tend to trap scum in unaerated zones but can cause undesirable back-mixing, so neither zone is fully anoxic/anaerobic or aerobic, as intended. The process implications of this back-mixing include reduced nutrient removal efficiency and reduced treatment capacity.

There are a number of ways to optimize baffle wall design so that scum is removed. Serpentine flow maximizes the plug flow effect and eliminates the potential for back-mixing. Also, in many installations, oversized openings in the bottom of the baffle walls are the main cause of back-mixing. By simply minimizing the size of these submerged openings, back-mixing can be eliminated and the process benefits of the "forward flow" concept can be realized.

References

USEPA. 1989. *Design Manual - Fine Pore Aeration Systems*. United States Environmental Protection Agency (U.S. EPA) EPA-625-1-89-023.

Assessing the Risk of Riverbank Filtration Wells for Pathogen Intrusion

By Tanja Rauch-Williams, Ph.D. (trauch-williams@carollo.com), Morteza Abbaszadegan, Ph.D. [Arizona State University], William Johnson, Ph.D. [University of Utah], Stephen Hubbs, P.E. [Water Advice Associates]

GWUDI Assessments

The Groundwater Under Direct Influence (GWUDI) assessment is a critical tool in the water industry for operators of groundwater wells. This test identifies whether a well may be at risk from microbial pathogen intrusion from a nearby surface water (*i.e.*, whether it is groundwater or GWUDI). In the case of a GWUDI categorization, the well must meet Surface Water Treatment Rule (SWTR) requirements to provide additional above-ground drinking water treatment. Therefore, a GWUDI categorization triggers significant additional treatment costs.

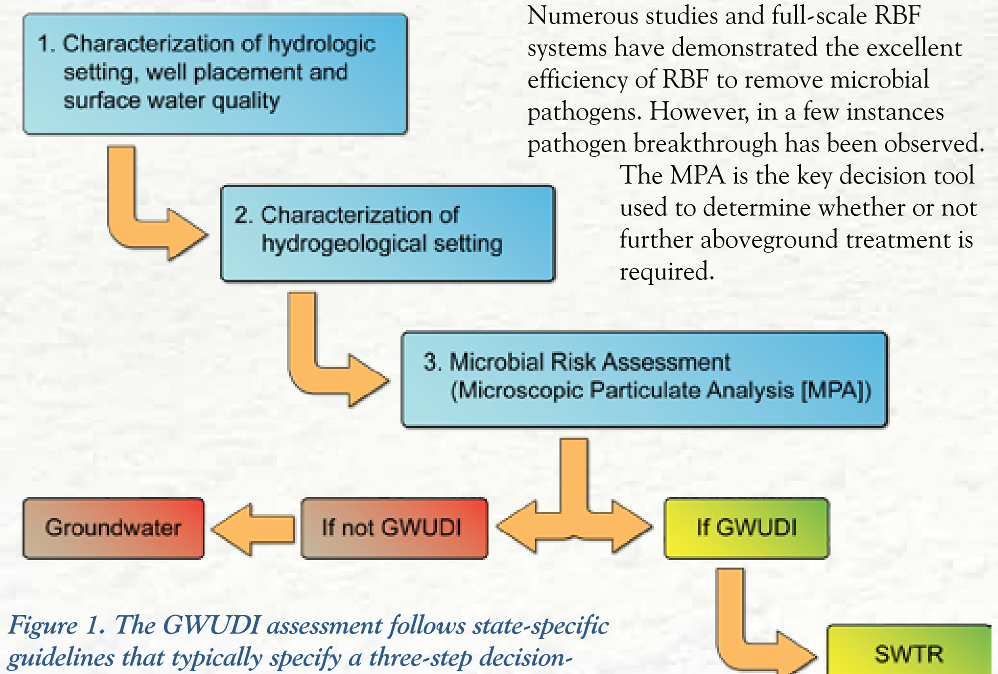


Figure 1. The GWUDI assessment follows state-specific guidelines that typically specify a three-step decision-making approach.

The MPA Tool

The key tool to determine GWUDI status is the Microscopic Particulate Analysis (MPA) test. The MPA Consensus Method was developed by EPA in 1992 and has never been officially revised. For regulatory purposes, a drinking-water well is classified as GWUDI if the MPA indicates the presence of algae, rotifiers, *Giardia*, or other indicator microorganisms in sufficient concentrations. The MPA sets forth the analytical protocol for measuring these microbes and the method for determining the overall risk score of a well. Recently, the MPA tool has also been used to claim site-specific credits for pathogen removal.

Relevance for Riverbank Filtration

GWUDI assessments are critical for riverbank filtration (RBF) systems. RBF wells are designed to recover water from a nearby surface water body, thereby taking advantage of natural filtration as the water moves through the subsurface.

Numerous studies and full-scale RBF systems have demonstrated the excellent efficiency of RBF to remove microbial pathogens. However, in a few instances pathogen breakthrough has been observed. The MPA is the key decision tool used to determine whether or not further aboveground treatment is required.

Limitations of the GWUDI Assessment

Several limitations to the present MPA method have become apparent over the past decade:

- The MPA method and risk scoring system are largely empirical and do not reflect the current understanding of pathogen transport in porous media.
- The analytical MPA method for microbial indicators is time consuming and results in low recovery efficiency and reproducibility.
- The indicator organisms included in the MPA are of a narrow size range and do not provide a comprehensive understanding of the risk of pathogen breakthrough.

In 2006, AwwaRF and EPA launched the project *Methods to Assess Groundwater Under Direct Influence and Bank Filtration Performance* to address these MPA limitations and to develop a more reliable protocol for assessing GWUDI. Results of this project are the basis for a revision of the current MPA protocol and a new guidance document for the industry.

Integration of *Cryptosporidium* into the MPA Protocol

Even though *Cryptosporidium* is one of the key pathogens of concern, its analysis is not part of the existing MPA protocol. Recent developments in sampling strategies and molecular biological identification technologies make it feasible to integrate *Cryptosporidium* into the revised MPA method. The research team developed and fine-tuned a method for the incorporation of *Cryptosporidium* into the new approach.

A More Robust Tool

Several analytical modifications were tested and demonstrated to improve the overall recovery efficiency, reproducibility, and accuracy of the MPA protocol while reducing the time required for the analysis. The investigations focused on replacing the fiber cartridge filter currently used in the MPA method with Envirocheck filters. Envirocheck filters are commonly used for environmental sampling for microbial analysis and require no pre-assembly. Recovery efficiencies for all target microorganisms from Envirocheck filters consistently outperformed the current MPA fiber cartridge filters.

The new analytical MPA protocol was tested side-by-side with the existing MPA protocol at two full-scale RBF systems. At both RBF sites, Sioux City, IA, and Cedar Rapids, IA, year-round sampling consistently showed that the improved analytical procedure had higher indicator organism recoveries.

Improving Understanding of Pathogen Transport

A good understanding of RBF system operation and pathogen transport in the subsurface is essential for assessing the risk of pathogen intrusion into a well. However, our ability to predict pathogen transport in the subsurface is still progressing. Often, pathogens are not directly detectable in surface or well water samples. Instead, we rely on surrogates that are assumed to be similar in transport behavior properties to the pathogens they represent.

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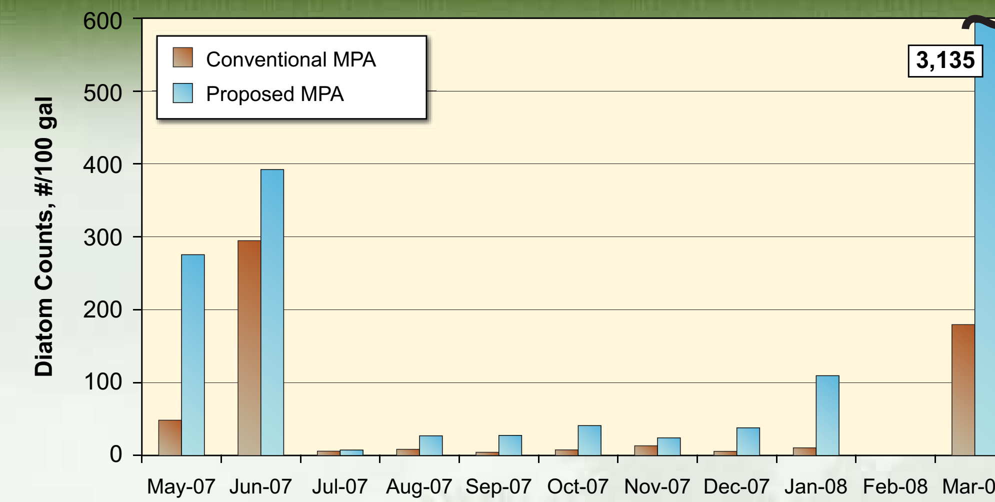

Figure 2. During RBF well testing the improved MPA protocol consistently resulted in higher indicator recoveries than with the existing MPA method.

In this project, pilot-scale column experiments were conducted to monitor and compare the removal of MPA indicator organisms to *Cryptosporidium* along the length of a 3-meter column designed to simulate RBF.

Studies included a wide size range of indicators (virus to protozoa). *Cryptosporidium* was generally completely removed early on in the columns under both normal and stressed conditions (high infiltration rates, shear stress, changes in water saturation). Of all the indicators studied, bacteria (*e.g.*, *Escherechia coli*) behaved most conservatively with regards to *Cryptosporidium* transport, showing the highest breakthrough.

Importance for the Industry

This study developed a more robust analytical MPA method. This updated protocol allows detection of more constituents, should result in a better understanding of RBF systems, and should ultimately offer improved public health protection. The revised MPA protocol will be proposed for adoption by EPA. Further work is needed to revisit the current MPA risk scoring procedure based on our current understanding of the value and transport behavior of target MPA indicator organisms.

Acknowledgements

This study was jointly funded by AwwaRF and EPA. The authors would like to thank AwwaRF Project Manager Linda Reekie, the Project Advisory Committee, Monika Emelko, Phil Berger, Ray Diaz, Scott Bradford, and Jay Jasperse, and the participating utilities, the City of Sioux City Water Department and the City of Cedar Rapids Water Department. The final report is currently under preparation.

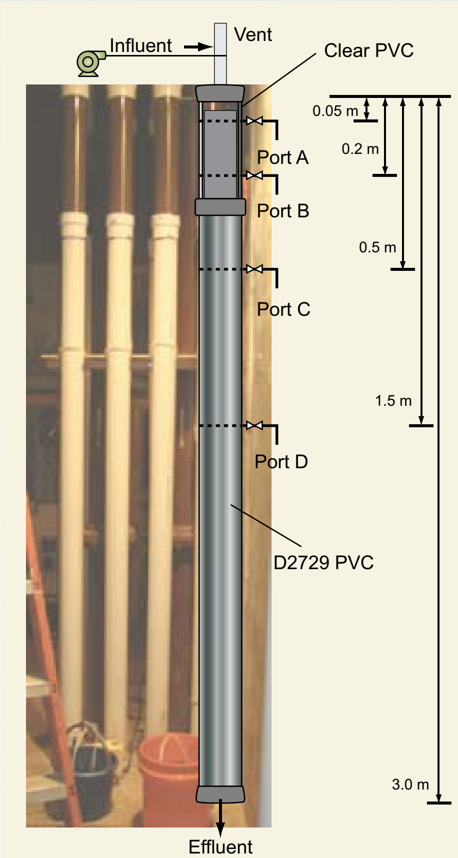

Figure 3. Controlled tests were conducted to simulate the transport of MPA target indicators in relation to Cryptosporidium under simulated RBF operation.

SAWS Brackish Groundwater Desalination: *Pilot Testing for Design-Build*

Multiple RO recoveries and treatment options will be evaluated.

The San Antonio Water System (SAWS) recently approved an amendment to Carollo's contract for their Brackish Groundwater Desalination (BGD) Pilot Study. The BGD project serves to enhance the water supply options available to SAWS to help them meet growing water demands. The goals of the pilot study are to define the appropriate process for a full-scale reverse osmosis (RO) treatment facility and to begin the Texas Commission on Environmental Quality (TCEQ) permitting process.

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Under the original contract, the scope of work was based on the regulatory standard 3-month evaluation and a conventional project delivery method. However, in Spring 2008 SAWS elected to deliver the plant using design-build procurement to take advantage of the potential time savings and flexibility that this process allows. In light of this change, the original protocol was inadequate to meet the pilot study goals and needed to be revised to:

- Evaluate the water quality impacts of multiple treatment and pre-treatment process configurations.
- Provide TCEQ the required data for rating the full-scale facility under multiple scenarios.

Under the amended contract, the pilot study was expanded to 9 months. The testing will be conducted in four phases to evaluate multiple RO recoveries and pre-treatment options. Permitting a RO membrane facility under these conditions is a significant departure from TCEQ's standard procedure. SAWS and Carollo worked with the agency to develop a protocol that satisfies both SAWS and TCEQ requirements.

In using this expanded approach to their RO membrane pilot study for a design-build procurement, SAWS can:

- Evaluate the impact of multiple process scenarios on permeate and concentrate water quality using relevant data.
- Evaluate the appropriate concentrate disposal options, potential locations, and costs for a given scenario earlier in the design-build process.

By having access to this data during the initial stage of project development, SAWS will maintain the flexibility and time savings they seek by:

- Better defining the full-scale design early in the design-build process.
- Minimizing or eliminating the need for further pilot testing.
- Initiating permitting early in the design-build process.

The anticipated completion date for the pilot study is Spring 2009.

Disinfectants and Plastic Pipe Material: A Desktop Study to Evaluate Their Compatibility in Distribution Systems

Carollo recently completed a review of the compatibility of disinfectants with polyethylene (PE) and polyvinyl chloride (PVC) pipes. This review sheds new light on the performance of PE and PVC pipes in drinking water distribution systems.

Historically, pipeline designers have focused a majority of their analysis on the physical aspects of pipeline design, such as soil loading, hydraulics, and other physical system constraints. Historically, industry standards such as AWWA and the American Society of Testing and Materials (ASTM) have defined the minimum requirements for users in areas such as dimensions, pressure ratings, and other product performance attributes. However, in the last 6 years there has been an increasing amount of research on accelerated plastic pipe aging from exposure to disinfectants. Some of this work was initiated after premature field failures in Europe were observed where PE pipe was transporting potable water with low concentrations (approximately 0.1 mg/L) of chlorine dioxide. The failures were found to be the result of oxidative attack of the PE pipe by chlorine dioxide, causing what is known as Stage 3 (chemical/oxidative-brittle) failure and shortening the pipe life expectancy to 2-10 years. Further research on both PE and PVC plastic pipes has been conducted using chlorine dioxide, chlorine, and chloramines in drinking water to elucidate the potential risks and mechanisms from disinfectant attack.

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In any case, the existing design standards do not account for the interaction of disinfectants with plastic pipe. They consider only Stage 1 failure (mechanical overload) and Stage 2 failure (slow crack growth). No consideration is given to Stage 3 failure (chemical/oxidative-brittle). There is no guidance in these standards to establish a design factor to account for oxidation-induced degradation in plastic pipes.

Carollo has used this knowledge to improve infrastructure reliability and recommendations on current and future plastic pipeline projects. Nevertheless, more research is needed to provide design guidance for Stage 3 threats.

Carollo and the City of Arlington to Investigate Drinking Water Biofiltration Strategies for the Simultaneous Removal of Multiple Contaminants

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The Awwa Research Foundation (AwwaRF) recently awarded a Tailored Collaboration Project entitled *Enhancing Biofiltration to Achieve Sustained Removal of Multiple Inorganic and Organic Contaminants, Including EDCs, MIB, and Geosmin* to the team of Carollo, the City of Arlington, TX, Water Utilities Department, the University of Texas-Austin, and the University of Florida. The City of Dallas, Ozonia, and the USEPA Office of Research & Development are also participating in the project.

Project Overview and Objectives

The City of Arlington, TX, is faced with both operational and water quality complications at their John Kubala and Pierce-Burch water treatment plants. Both facilities installed ozone and biofiltration in 1999, primarily to help remove taste and odor (*i.e.*, 2-methylisoborneol [MIB] and geosmin), iron and manganese, and turbidity, and to minimize disinfection by-product formation. While the ozone/biofiltration systems performed well for many years, recent operational disruptions and the detection of endocrine disrupting chemicals (EDCs) required that the City evaluate their ozone/biofiltration system to identify potential modifications to enhance process performance.

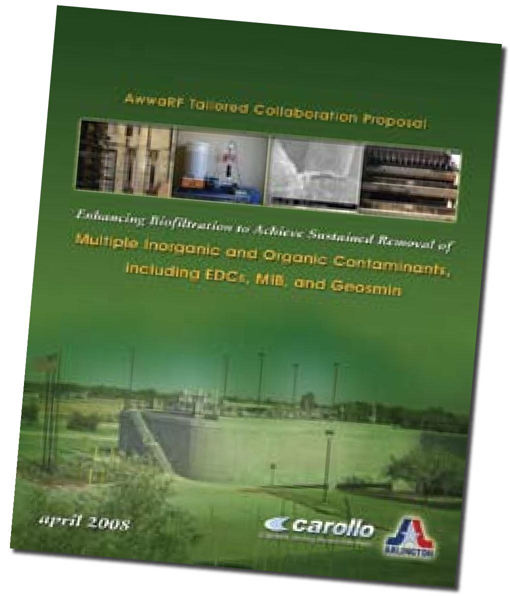
This project will focus on evaluating methods for restoring and enhancing the performance of the existing ozone/biofiltration process, which will entail: 1) characterization, evaluation, and enhancement of the biological activity in the filters, 2) assessment of enzymatic oxidation potential in the treatment system, and 3) examination of inorganic particle formation and filtration. The overall objective of this work is to identify and refine operational modifications to the ozone/biofiltration process that will enable sustained and reliable attainment of the City's multiple water treatment objectives.

Technical Approach

This work will investigate process fundamentals (*e.g.*, microbial ecology, bacterial metabolism, and contaminant removal mechanisms) to understand how:

1. TOC, MIB, geosmin, EDCs, iron, and manganese can be more efficiently removed in a single treatment step.
2. Biological clogging can be minimized.
3. Overall process robustness can be improved.

The approach will include 10 months of bench- and pilot-scale testing to evaluate ozone/biofiltration enhancement strategies. In addition, microbial tracking will be performed throughout the project to better understand how specific microbial communities impact hydraulics and process performance.



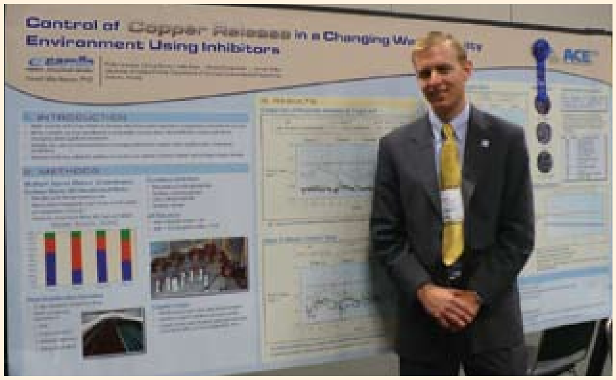
This project will result in a series of operating strategy recommendations that can be implemented at full-scale water treatment facilities to achieve efficient and robust removal of multiple contaminants using ozone and biofiltration.

WHAT'S**NEW**

Clancy Environmental/Carollo Wins Award for Water Science & Research Division Best Paper

Co-authors Kristen Fallon, Tom Hargy, Jen Clancy (of Clancy Environmental Consultants), and Erin Mackey and Harold Wright (of Carollo) were selected for the 2008 AWWA Division Best Paper Award by the Water Science & Research Division for their March 2007 *Journal AWWA* article titled "Development and characterization of nonpathogenic surrogates for UV reactor validation." A portion of work presented in this paper was done as part of the Carollo Tailored Collaboration project *Optimization of UV Disinfection,* published in 2007.

MacNevin Wins ACE's Fresh Ideas Poster Session



Dr. David MacNevin won the Fresh Ideas Poster Session at the June 2008 American Water Works Association (AWWA) Annual Conference and Exposition. He represented the AWWA Florida Section after the poster won at the state level.

The poster, "Control of Copper Release in a Changing Water Quality Environment Using Inhibitors," presented results demonstrating how utilities can use corrosion inhibitors to control copper release in distribution systems receiving seasonally varying blends of groundwater, surface water, and desalinated water. The poster also included electron micrographs showing changes in copper surface characteristics that accompany inhibitor addition and a desktop simulation tool for utilities to use in selecting an appropriate corrosion control treatment based on the water quality entering their distribution system.

As a graduate research assistant at the University of Central Florida, David was part of the Awwa Research Foundation (AwwaRF) study *Control of Distribution System Water Quality in a Changing Water Quality Environment Using Inhibitors*. Since joining the Carollo Research Group, David has continued to troubleshoot distribution system water quality problems for utilities.

Carollo Creates Interactive CD of Previous Issues of Research Solutions Using Flash Software

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Earlier this year Carollo began preparing an interactive cd containing .pdf files of previous issues of *Research Solutions*. The goal was to provide our clients, employees, and other interested parties with a user-friendly reference tool that provides cross-indexed links to all *Research Solutions* articles from 2005 to the present.

Created using Adobe Flash software, the cd allows users to search the disk by Author/Source, Issue, or Subject. The Author/Source and Subject categories are further broken down by names or key words, respectively. The Issue category shows a clickable, chronological index.

The *Research Solutions* cd is packaged with a "sustainable" cd sleeve made of 100 percent recycled material. It will be updated twice a year with new issues of *Research Solutions*.

Interested in a copy of the CD? Contact **Jess Brown** (jbrown@carollo.com) or your regional R&D Lead: **Charlie He** - Southwest (che@carollo.com); **Chris Machado** - Las Vegas (cmachado@carollo.com); **Joon Min** - Southern California (jmin@carollo.com); **Nabanita Modak** - Northwest (nmodak@carollo.com); **Tanja Rauch-Williams** - Central (trauch-williams@carollo.com); **Andy Salveson** - Northern California (asalveson@carollo.com); **Sandeep Sethi** - Southeast (ssethi@carollo.com); **Justin Sutherland** - Texas (jsutherland@carollo.com).

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