

# research

## SOLUTIONS

A Publication of the Carollo Research Group



### In this Issue

- 2** Bridging the Gap
- 2** Commentary - *Thermal Imaging Is a Cost-Effective Technology for Scaling Detection in Anaerobic Digestion Facilities*
- 4** Feature Story - *Water Quality and Aquatic Impact of Advanced Wastewater Treatment Technologies*
- 6** Project Updates
- 7** What's New

## Bridging the Gap



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

Welcome to the Winter 2011 issue of *Research Solutions*. This issue addresses a variety of important issues and projects, including:

- **Scaling Detection in Anaerobic Digestion Facilities.** Phosphate scaling in digestion facilities can weaken process performance and increase system downtime and costs. Carollo developed an inexpensive thermal imaging technique that can rapidly detect phosphate scaling, thereby allowing the timely implementation of scale mitigation strategies.
- **Performance and Aquatic Impact of AWT.** Pilot testing was performed to evaluate the removal of trace organic compounds (EDCs/PPCPs) across various advanced wastewater treatment processes. The toxicity and hormonal impact of AWT effluent was assessed, and the fate and transport of AWT discharges was modeled.
- **RO Concentrate Minimization Using EDR.** To minimize the costs of thermal brine treatment for achieving zero liquid discharge, an EDR process was used to treat reverse osmosis (RO) concentrate. Pilot testing showed that EDR recoveries were 75-80 percent, performance was stable, and fouling was not a problem. Using the EDR process, overall RO concentrate volumes decreased by 60 percent.
- **Evaluating Radium Removal Technologies.** Modeling, bench-top testing, and cost analyses of lime softening, ion exchange, and RO/NF were performed to select the best process for removing iron and radium from groundwater. Pilot testing is now underway using two iron pre-treatment options (phosphate-based sequestration and oxidation/filtration) and three single-use radium-selective IX media.
- **Comparing Duel Distribution to Indirect Potable Reuse.** This article describes the development of a decision support tool (DST) that will help utilities evaluate factors to consider when choosing how to implement or expand a beneficial water reuse program. The project involves 12 utilities from the U.S., Europe, and Australia to ensure broad applicability of the DST.

## COMMENTARY



Dallas Water Utilities detected scaling in sludge heating and recirculation piping and heat exchangers at their Southside Wastewater Treatment Plant. Carollo's study of scale formation and mitigation led to the development of a thermal imaging technique for monitoring scaling in heated sludge piping.

## Thermal Imaging Is a Cost-Effective Technology for Scaling Detection in Anaerobic Digestion Facilities



By Toshio Shimada, Ph.D., P.E. (tshimada@carollo.com), Jeff Sober, P.E., Rudy Kilian, P.E., and Chris Kaakaty, P.E. [Dallas Water Utilities]

### Background

Facing stricter phosphorus discharge limits, many utilities are retrofitting their wastewater treatment facilities to include phosphorus removal processes. To achieve liquid stream phosphorus removal, phosphate is biologically accumulated as poly-phosphate within the biomass or chemically precipitated with cations like calcium, iron, and aluminum. Phosphorus is also removed biologically in activated sludge processes that operate with anaerobic selectors, and chemically in facilities that practice iron addition for odor control. Chemically and biologically removed phosphorus is carried with the waste sludge,

considerably increasing the phosphorus load to the solids handling facilities. A large fraction of the phosphorus that is sequestered to the solids is released back to the liquid during anaerobic digestion due to poly-phosphate degradation or reduction of ferric iron to ferrous iron. This release of phosphorus leads to phosphate precipitation (scaling) in process piping and equipment. Scaling can result in decreased process performance, increased equipment downtime, and higher maintenance costs.

Struvite (magnesium ammonium phosphate,  $MgNH_4PO_4$ ) and vivianite (ferrous phosphate,  $Fe_3[PO_4]_2$ ) are the most common types of scaling found in wastewater treatment. The extent and magnitude of scaling is a function of the oxidation/reduction potential, ionic strength, pH, temperature, and the concentrations of ammonium, magnesium, iron, and sulfide in the bulk flow. Struvite is a white crystalline precipitate that typically

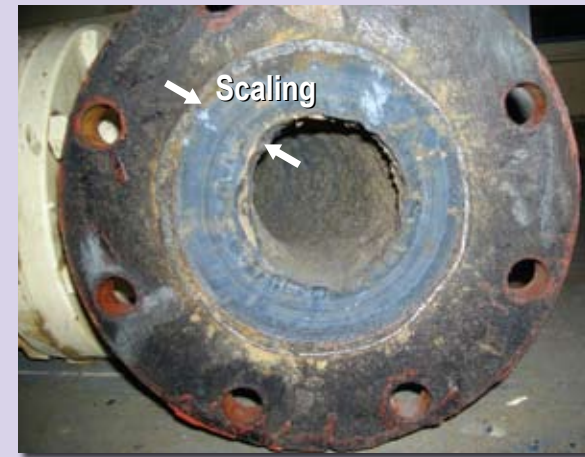


Figure 1. Scaling in digester sludge piping restricts process and control of anaerobic digestion.

occurs in draft tube mixers, pump volutes, dewatering equipment, and centrate/filtrate piping. Vivianite is a clear solid that turns dark blue to blue-green when in contact with the atmosphere. Vivianite typically appears in heat exchangers, sludge heating and recirculation piping, and digesters.

In 2009, Dallas Water Utilities (DWU) Southside Wastewater Treatment Plant (SWWTP) staff detected scaling inside the digester sludge heating and recirculation lines of one of their digesters and suspected that other anaerobic digesters could be affected. DWU retained Carollo to study the extent of scale formation and mitigation at SWWTP. Carollo developed a thermal imaging technique for monitoring scaling in digester sludge pipe. This technique is faster and less costly than conventional inspection methods that involve disassembling and cleaning numerous pipe sections.

### Facility Operation

SWWTP operates as a centralized solids handling facility, treating roughly 130 tons per day of solids generated on-site and transferred from the Central Wastewater Treatment Plant. The solids facilities include rotary screens, gravity belt thickeners, anaerobic digesters, solids holding tanks, and belt filter presses. The facility has eleven 90-ft diameter mesophilic digesters that are configured to operate in two modes: conventional mesophilic anaerobic digestion, and two-phase (acid-gas) anaerobic digestion. SWWTP is not operated as a phosphorus-removal facility, but considerable phosphorus removal occurs due to operation with selectors in the activated sludge process and the addition of iron for odor control.

### Scaling Detection

During routine maintenance on one of the digesters, a thick blue-colored scale was found in sludge heating and recirculation lines (Figure 1). Field observations and laboratory analyses showing high iron and phosphorus levels indicated that vivianite was the major component of this precipitate. Based on a mass balance analysis, approximately 8 percent of the phosphorus in the digester feed may accumulate inside the digesters and sludge heating and recirculation piping.

Thermal imaging was proposed as a tool to identify scaling in the sludge transfer piping because scaling decreases the heat transfer through piping and equipment, resulting in cooler surface temperatures. To validate this hypothesis, fittings that contained significant scaling were replaced with new fittings. Field trials showed that the surface of recently installed fittings was significantly warmer than older adjacent sections of piping, indicating that surface temperature is a good indicator of pipe scaling (Figure 2). The thermal imaging results indicated the presence of vivianite scaling in the sludge heating and recirculation lines of three additional digesters and heat exchangers.

### Large Temperature Changes Decrease Vivianite Solubility

The operation and configuration of the digester feeding and heating and recirculation systems was evaluated to determine the causes for vivianite scaling. Vivianite solubility varies greatly with temperature and peaks at 85 to 95°F, which overlaps with the operating range of mesophilic anaerobic digesters (95 to 100°F). The scaling potential increases when the sludge temperature changes from the optimum vivianite solubility range. The heat exchangers were designed to operate with a relatively high sludge temperature

**Digester mixing and sludge heating and recirculation systems are particularly prone to scaling.**

**Thermal imaging proved quick and cost-effective for monitoring phosphate scaling in digester piping.**

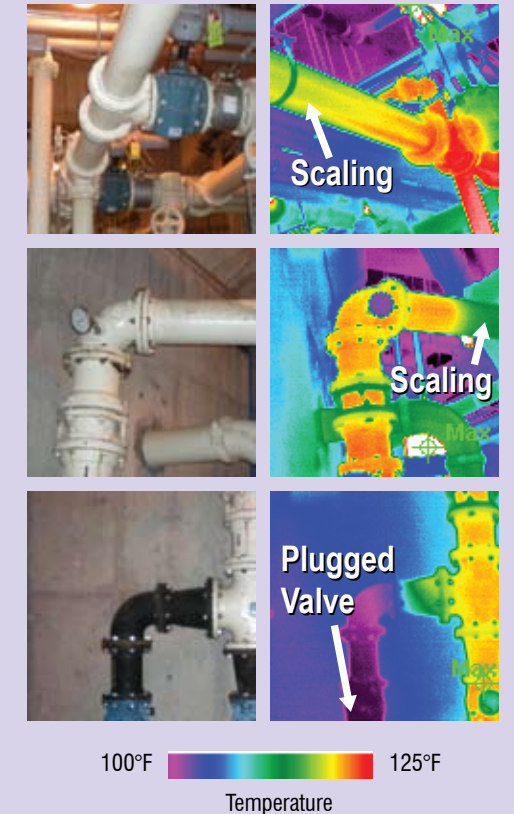


Figure 2. Piping with scaling or without flow shows lower surface temperature.

increase (+15°F). In addition, the digester feed was incorporated with recirculation sludge, causing a large sludge temperature decrease during feeding periods, when roughly equal flows of unheated raw sludge and heated recirculated sludge were mixed. Operation at these temperatures results in decreased vivianite solubility, and consequently scaling in the heat exchangers and downstream piping. Improvements to the digester feeding and heating, and recirculation systems have been scheduled to mitigate vivianite scaling by keeping the temperature in the heat loops between 95 and 100°F, as close to the optimum solubility range as possible.

### Conclusion

Chemical and biological phosphorus removal can result in scaling in anaerobic digestion facilities. When implementing phosphorus removal processes, improvements to the anaerobic digestion facilities to mitigate potential scaling problems should be considered. Digester mixing and sludge heating and recirculation systems are particularly prone to struvite and vivianite scaling, respectively. Thermal imaging proved quick and cost-effective for monitoring phosphate scaling in digester piping.

# Water Quality and Aquatic Impact of Advanced Wastewater Treatment Technologies



By Andy Salvesson, P.E. (asalveson@carollo.com), Jess Brown, Ph.D., P.E., Jose Lopez, P.E., PMP [South Florida Water Management District]

Advanced wastewater treatment (AWT) (filtration, carbon adsorption, phosphorus removal, and nitrogen removal) can effectively remove a majority of pollutants present in wastewater. However, the remaining trace organic compounds, including potential endocrine disrupting compounds, pharmaceuticals, and personal care products, in reclaimed water may raise public health and/or aquatic health concerns. Although certain trace organic compounds may persist following wastewater treatment, current research suggests that advanced treatment technologies can effectively remove them to concentrations below human health risk levels.

In addition, some research suggests that using advanced treatment technologies following conventional wastewater treatment can significantly reduce the risk to aquatic organisms. Additionally, some trace organic compounds found in municipal wastewater have only negligible effects on invertebrates and plants in the effluents and receiving environment. However, the literature also indicates that some trace organic compounds at or above 0.1 ng/L will induce endocrine-mediated changes in aquatic life. Other research suggests that trace organic compounds have accumulated in some aquatic organisms and altered their natural growth.

To better understand the removal of trace organic compounds through AWT facilities and the potential impact of trace organic compounds on aquatic organisms, an AWT pilot study at the City of Plantation, FL, was funded by the WaterReuse Research Foundation (WRF 06-019), the U.S. Bureau of Reclamation, the South Florida Water

Management District (SFWMD), and the City of Plantation, FL. This work was performed by a joint team from Carollo, the SFWMD, the City of Plantation, the University of Florida, the University of Wisconsin, and other subconsultants. The AWT pilot facility consisted of a denitrifying filter (DNF), a membrane bioreactor (MBR), ultrafiltration (UF), and reverse osmosis (RO). Bench-top testing was also performed using a nonbiological membrane process (IMANS®) to examine the role of biological treatment in the removal of trace organic compounds. In an attempt to correlate trace organic compounds with biological responses, the toxicological and hormonal impacts to various organisms and cell cultures exposed to effluent from the various AWT processes were evaluated concurrent with chemical analysis.

A secondary objective of this project was to examine the fate and transport of select trace organic compounds from a hypothetical canal discharge location in South Florida to a drinking water aquifer. To provide perspective on the potential impact of these compounds to receiving water quality, limited testing of canal water near Plantation, FL, was performed.

All three membrane systems in this project (MBR/RO, DNF/UF/RO, and IMANS®) effectively removed trace organic

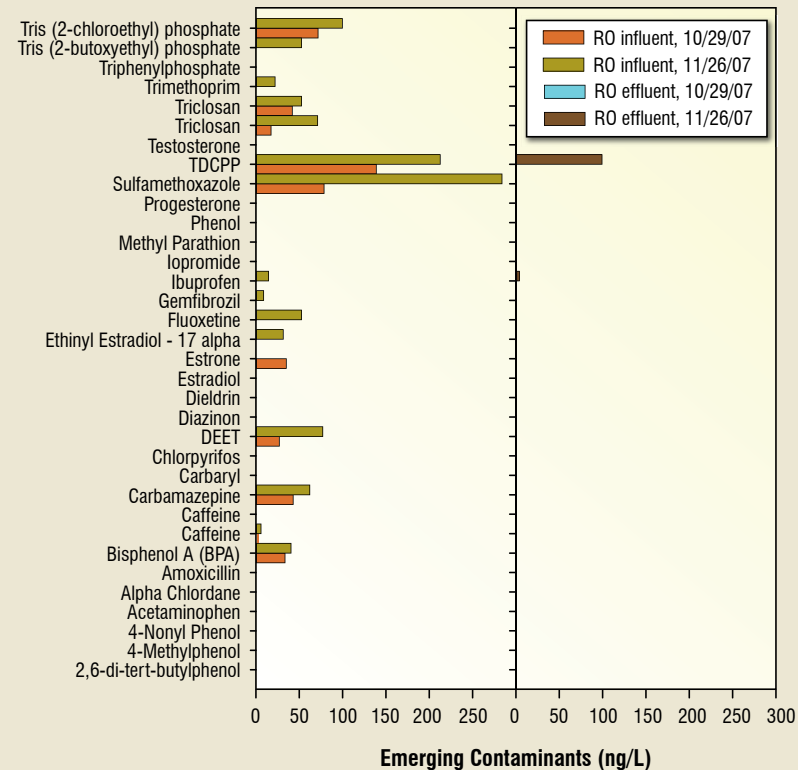


Figure 1. RO performance results show nearly complete removal of trace organics.

compounds, bulk organic matter, and salts (represented RO effluent results shown in Figure 1). The results within this report suggest that the discharge of reclaimed RO water (once stabilized) will not degrade the water quality of surface canals. Any of the three tested systems can be used to remove trace organic compounds and improve the quality of reclaimed water for canal discharge.

### Toxicity Evaluation Indicates that Chlorine and Ammonia Used in the RO Process May Be Problematic

The chronic toxicity tests done for this project included a chronic survival and growth test for *Pimephales promelas* and a chronic survival and reproduction test for *Ceriodaphnia dubia*. The survival rate of *P. promelas* and *C. dubia* in RO effluent was low during the first toxicity test, which was likely caused by residual chloramine in RO-treated effluents. Additional tests on RO effluent samples that were quenched with

sodium thiosulfate significantly reduced the toxicity and increased the survival of *P. promelas* and *C. dubia*. The final batch of toxicity experiments without using chloramine indicated that there was no significant difference between RO effluent and control (deionized) water for the survival and growth of *P. promelas* and the survival and reproduction of *C. dubia*. Similarly, there were no significant differences between surface (canal) water and control (deionized) water for the survival and growth of *P. promelas* and survival and reproduction of *C. dubia*.

These facts suggest that discharge of reclaimed water (RO effluent) has no adverse toxic effect on aquatic organisms if chloramines are not used or are properly quenched. However, unquenched chloramines or trace levels of ammonia in AWT facilities may contribute to the toxicity to *C. dubia* and should be removed by break-point chlorination followed by dechlorination, advanced oxidation, or other quenching process. The process deserves further investigation.

### Hormone Bioassays Indicate that RO Permeate Has No Hormonal Impact

The endocrine-disrupting potential of trace organic compounds in various treatment technology effluents was evaluated with E-Screen bioassays, YES assays, fathead minnow Vtg assays, and steroid immunoassays. Results of the E-Screen bioassays showed that estradiol equivalents in all RO effluents were below detection limits, but were present in secondary effluent, DNF effluent, MBR effluent, and UF effluent (Figures 2 and 3). Results of the E-Screen bioassays showed that RO effluent did not provoke a significant response in MCF-7 cells. Results of the YES bioassays were similar to those of the E-Screen bioassays; estradiol equivalents in RO effluent were below detection limits, although estradiol equivalents were detected in secondary effluent and DNF effluent, suggesting that RO effluent did not possess endocrine-disrupting potential. Results of the fathead minnow Vtg assays and steroid immunoassays did not show an increase of plasma Vtg in male fish, indicating that they were not exposed to estrogenic components at the concentrations required to produce this effect. Results of the steroid immunoassays indicated that testosterone concentrations

in all treatments were similar to those in the negative control group, and that there was no significant difference in plasma testosterone for any of the treatments compared to negative controls. All of these results suggest that RO effluent was not estrogenic. It is interesting to note that although the effluent of the nonbiological membrane process IMANS® contains few trace organic compounds, their impact on the endocrine-disrupting potential was not appreciable. Therefore, biological processes (as part of secondary treatment) may not be necessary for the removal of trace organic compounds and estrogenic activity, as long as there is a RO step in the process.

### Surface Water and Groundwater Modeling Show Different Attenuation Based Upon Compound Characteristics

Three compounds (sulfamethoxazole, triclosan, and phenol) were selected as representative trace organic compounds for modeling based on their physicochemical properties. Hydrodynamic and water quality models were developed to examine the fate and transport of these simulated trace organic compounds from AWT systems through surface canals. The hydrodynamic model was run to simulate the historical conditions in 2001 and 2002. The results indicated that the groundwater trends followed the observed data closely. The hydraulic model included the primary and secondary canals and main hydraulic structures (weirs, culverts, pumps, and gates) for these canals. It was shown that the surface water results are very sensitive to structure operations. The water quality model predicted that adsorption plays a dominant role in the transport of the trace organic compounds in

the canal network as well as in the aquifer system. While less significant, various other pathways of decay also impact the fate and transport of trace organic compounds.

Transport of trace organic compounds in the canal network was found to be lower for compounds with higher adsorption coefficients. The higher adsorption coefficient decreases the fluctuations in the dissolved concentration in the canals, which is likely a consequence of the adsorbed mass in the sediment layer acting as a buffer. The water quality model was not calibrated; future efforts should focus on collecting the data necessary to perform this calibration. Additional work could also be done to better estimate related parameters, such as trace organic compound biotransformation rate constants and the mass organic fraction and bulk density in groundwater and sediment layers.

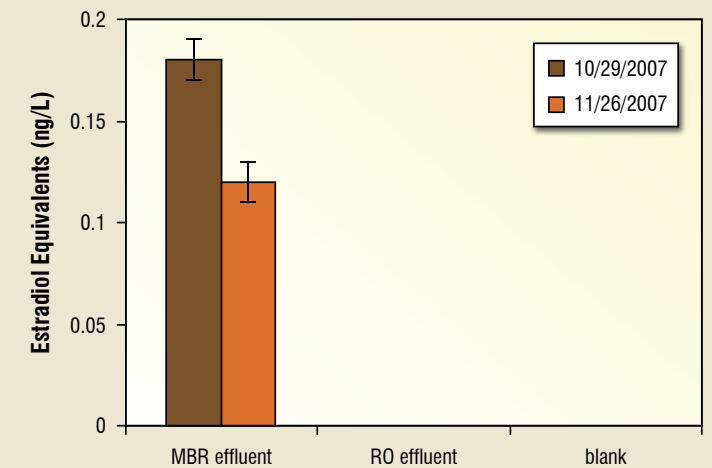


Figure 2. No hormonal impact in MBR/RO effluent was observed with E-screen bioassay.

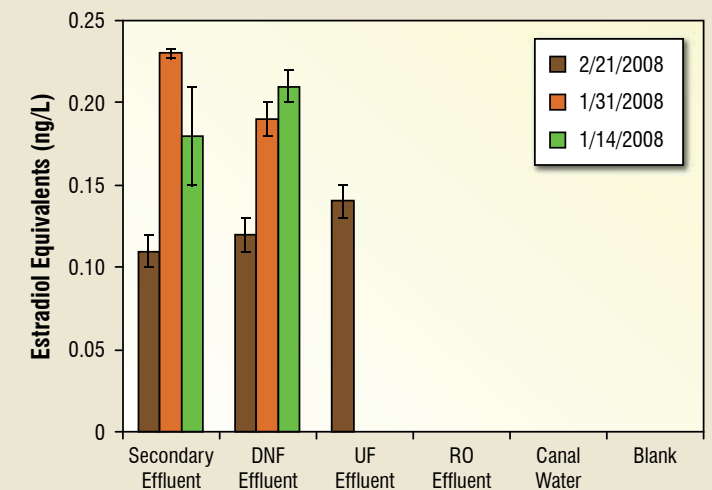


Figure 3. No hormonal impacts in DNF/UF/RO effluent and canal water were observed with E-screen bioassay.

## PROJECT UPDATES

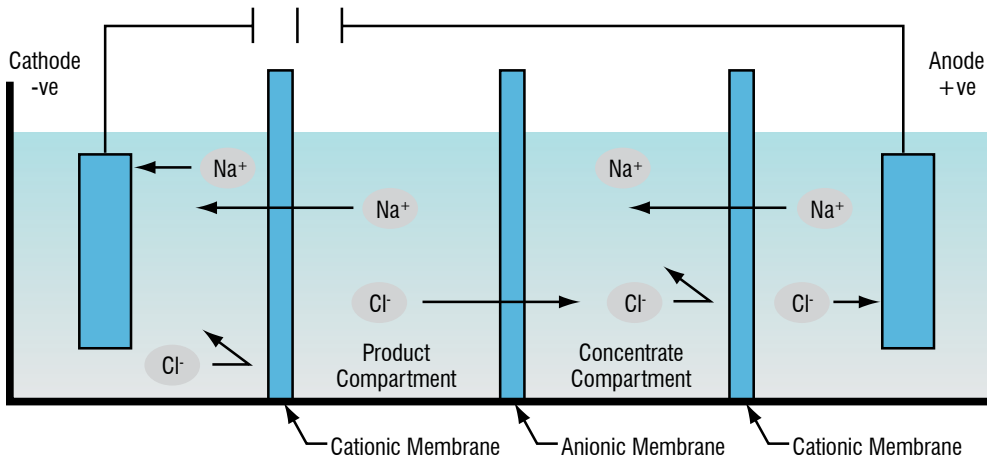


Figure 1. EDR is an electrochemical separation process. When ions enter in the feed, the positive ions (cations) are attracted to the cathode (negative electrode) and negative ions (anions) are attracted to the anode (positive electrode). Only anions are allowed through the anionic membranes and only cations are allowed through cationic membranes, creating product and concentrate compartments.

## EDR Provides Effective Treatment Approach for Concentrating RO Brine

As sources of fresh water become scarce, utilities are looking for additional water supplies. For many utilities, treatment of brackish groundwater is a

potential new source of water for their customers. When considering brackish groundwater treatment, a solution must be provided for the disposal of the concentrated waste stream. Traditional methods of concentrate disposal, such as ocean discharge, are becoming more costly and are not feasible for inland locations. Because of this, interest in zero-liquid-discharge (ZLD) treatment is growing. However, the tail-end technologies that can provide ZLD, such as brine concentrators, are often cost-prohibitive. To reduce the costs of ZLD, the brine volume needs to be reduced through further treatment upstream of the high-cost tail-end process. One approach is to soften the RO concentrate and then provide a second desalting step to treat the softened water. This study evaluated electro dialysis reversal (EDR) treatment of RO concentrate for increasing overall recovery and reducing brine volume to reduce the costs of ZLD at an inland facility.

### KEY TEAM MEMBERS

Andrew Wiesner, P.E.  
(awiesner@carollo.com)

Adam Zacheis, Ph.D., P.E.

Graham Juby, Ph.D., P.E.

Renee Morquecho, Ph.D. [IWVWD]

Tom Mulvihill [IWVWD]

The Indian Wells Valley Water District (IWVWD) is located in the Mojave Desert and serves nearly 30,000 residents. A potential new source of water for IWVWD's customers is desalinated

brackish groundwater. However, given the District's geographical location, membrane desalting would ultimately require a ZLD treatment system. A 2005 feasibility study selected a ZLD approach that included pretreatment, primary RO desalting, secondary EDR desalting, and thermal brine concentration. The secondary desalting unit was added to increase the recovery of the system and limit the volume of concentrate sent to the thermal concentration process.

EDR was selected for secondary desalting because it is fundamentally different than RO; these differences give the EDR an advantage when treating brine. The RO process uses hydrophilic membranes and pressure to desalinate water. At high pressures, water is forced through the membrane creating a low TDS product and concentrating the salts, including silica, on the outside of membrane. The EDR process is different; it does not use pressure to desalinate the feed water.

EDR is an electrochemical process that uses direct current (DC) potential and alternating hydrophobic cation and anion exchange membranes to create product and concentrate streams (Figure 1).

One of the main advantages of EDR over RO is that the EDR process does not concentrate silica. Silica is a non-charged species and so is not attracted to the cathode or anode. One of the challenges with treating water from IWVWD's northwest well field is the high levels of silica (50 mg/L) in the groundwater. These high silica levels limit the achievable recovery in the primary RO process and any further treatment with RO would require a softening step to remove silica. For this groundwater, the EDR process is an excellent fit because silica is unaffected by the EDR process allowing concentration of the waste to the solubility limit of the next least soluble salt without softening.

Another advantage when treating brine is that the EDR process becomes more efficient as TDS increases. When the TDS of a water increases, both the osmotic pressure and the electrical conductivity of the water increase. When osmotic pressure increases in the RO process, the feed pressure has to be increased to produce the same amount of product water. In the EDR process, as the electrical conductivity of the water increases the electrical resistance in the membrane stack decreases, allowing the EDR to transfer more current through the water in the membrane stack producing the same amount of product with less energy.

To determine if the selected approach is a viable alternative for the IWVWD, an extensive 6-month pilot study was performed. During the pilot study, the EDR was operated continuously for 1,600 hours. The EDR treatment of RO brine was found to be highly effective; the EDR unit produced high-quality, low TDS product water. During pilot testing, the EDR product TDS was consistently less than 600 mg/L and when blended with the RO permeate the TDS was approximately 200 mg/L. The EDR unit was operated at recoveries from 75 to 80 percent, stable performance was achieved at all recoveries, and the EDR experienced little to no scaling or fouling. The EDR process was able to increase the overall system recovery to 90 percent and reduced the brine volume by 60 percent, significantly reducing the size and cost of the tail-end process.

# Radium Removal: An Evaluation of Treatment Technologies for a Groundwater in West Texas

The City of San Angelo (COSA), TX, is developing a new groundwater source to diversify their drinking water supply options. However, the closest, most viable source is 60 miles away and contains high iron and combined radium levels (up to 2.9 mg/L and up to 40 picocuries per liter [pCi/L], respectively). The maximum contaminant limit (MCL) for combined radium in drinking water is 5 pCi/L, and the options for disposal of radium-laden waste in sewers, landfills, and other receiving bodies is very limited and expensive. The selected treatment process for COSA, therefore, must be capable of removing 90 percent of the combined radium, while minimizing waste generation.

An initial evaluation compared various strategies for removing the radium from the groundwater and disposing of the treatment residuals. Several conventional and new technologies for radium removal were evaluated using process models and bench-top testing to estimate treated water and waste characteristics. These included lime softening (upflow clarifier and fluidized bed), ion exchange ([IX] single-use and regenerative), and membrane separation (RO and nanofiltration [NF]). Waste disposal was evaluated using calculated waste characteristics, available disposal methods (e.g., sewer, landfill), and State and Federal regulations.

Waste characteristics varied widely among the treatment alternatives



## KEY TEAM MEMBERS

**Justin Sutherland, Ph.D., P.E.**  
(jsutherland@carollo.com)  
**Lance Rothe**  
**Hutch Musallam, P.E.**  
**Paul Walker, P.E.**  
**Will Wilde, P.E. [City of San Angelo]**  
**Tom Kerr, P.E. [City of San Angelo]**

evaluated. Single-use media and lime softening processes were estimated to generate solid wastes with a weight and radium concentration ranges of 37 - 1,100 pounds per million gallons and 250 - 7,600 pCi/g, respectively. Regenerative IX and the membrane separation processes were estimated to generate liquid wastes with a volume and radium concentration ranges of 12,000 - 100,000 gallons per million gallon and 360 - 2,800 pCi/L, respectively.

Selection of the best treatment-waste disposal combination was driven by the volume and concentrations of radium-laden waste. For COSA, two treatment-waste disposal combinations were viable:

1. Two-stage membrane separation (either RO or NF) with deep-well injection of the brine.
2. Single-use media (either IX or enhanced zeolite) with out-of-state disposal of the spent media.

A comparative cost analysis of these options was performed. Single-use media with out-of-state landfill disposal was determined to be the most economical alternative for COSA's new 6-mgd groundwater treatment plant.

Based on the results of this initial evaluation, a pilot study was developed to evaluate the

*Close-up of Dowex RSC media used during testing.*



*Carollo used these small-scale column skids for single-use media testing during the pilot study for the City of San Angelo, TX.*

performance of two iron pretreatment options and three single-use media for radium removal to meet the Texas Commission on Environmental Quality's treated water quality requirements. The iron pretreatment options include:

1. Sequestering iron with phosphate.
2. Oxidizing the iron with air and subsequently removing it with a monomedia anthracite filter.

The single-use medias included in this study are Dowex RSC, Resintech 50HP, and Water Remediation Technology's Z-88 enhanced zeolite. The RSC and 50HP medias are being tested in downflow mode in 1-inch diameter columns and the Z-88 is being tested in upflow mode in 4-inch diameter columns, per manufacturer specifications.

The pilot study is expected to be complete in early 2011.

# Which is Better: Dual Distribution or Indirect Potable Reuse?

Which is better: dual distribution or indirect potable reuse? The answer is ... it depends. Which is why Carollo was interested

**KEY TEAM MEMBERS**  
**Guy Carpenter, P.E.**  
([gcarpenter@carollo.com](mailto:gcarpenter@carollo.com))  
**Richard Humpherys, P.E.**

in teaming with Stratus Consulting and leading experts in water reuse, including Jim Crook, Margie Nellor, and Bahman Sheikh, on a new WateReuse Research Foundation project (WRF-09-02), *Framework for Informed Planning Decisions Regarding Indirect Potable Reuse and Dual Pipe Systems*. This project will help utilities identify and evaluate the influencing factors that should be considered when a water recycling utility is making decisions about the best way to implement or expand a beneficial water reuse program.

Water scarcity requires water resource managers to make cost-effective decisions about the deployment of available water supplies within the context of often complex rules, competing interests, and water quality needs. Identification and selection of appropriate investments in water resources and associated infrastructure can be a daunting task.

In addition to the water resources options for meeting potable needs, there are often a number of available water resources to be considered for meeting demands that do not require water of potable quality, or that historically and culturally have not been considered as adequate sources for treatment and management for direct potable supply. These may include saline and brackish sources, domestic wastewater treatment plant effluents, industrial treatment plant effluents, remediated groundwater, produced water (from the extraction of gas, oil, or other natural

resources), and storm water. Making decisions about how to develop these sources and make the highest and best use of them requires systematic consideration of a number of influencing factors.

The goal of this project is to create a decision support tool (DST) that captures the possible influences of a water project in a focused and defensible evaluation process, resulting in a clear direction for moving forward with regard to deploying the alternative water sources through a separate piping system from the potable supply, or deploying it through an indirect potable reuse project, such as through aquifer recharge or surface water

**The goal of this project is to create a decision support tool that captures the possible influences of a water project in a focused and defensible evaluation process, resulting in a clear direction for moving forward with regard to deploying the alternative water sources through a separate piping system from the potable supply, or deploying it through an indirect potable reuse project.**

augmentation, or a hybrid of both. Important tasks that will be completed as part of the project include: gathering and developing information about the influencing factors, case studies of utilities which have considered a variety of means for making use of alternative water sources; development of a decision logic framework, development, beta-testing, and refining of on electronic DST, and the development of a manual for the use of the DST.

Twelve utilities from the U.S., Europe, and Australia are participating as utility partners on the project to help ensure applicability to a broad cross-section of utility types, regulatory structures, and regional-specific socio-economic influences. The DST is scheduled to be ready for use by April 2012. If your utility is interested in beta-testing the tool or in providing case-study information that could help the tool's development, please contact the authors.

- Phoenix, Arizona
- Yuma, Arizona
- Fresno, California
- Inland Empire, California
- Orange County, California
- Pasadena, California
- Sacramento, California
- San Diego, California
- San Francisco, California
- Thousand Oaks, California
- Walnut Creek, California
- Denver (Broomfield), Colorado
- Denver (Littleton), Colorado
- Broward County, Florida
- Miami, Florida
- Orlando, Florida
- Palm Beach County, Florida
- Sarasota, Florida
- Boise, Idaho
- Kansas City, Kansas
- Las Vegas, Nevada
- Reno, Nevada
- Charlotte, North Carolina
- Portland, Oregon
- Austin, Texas
- Corpus Christi, Texas
- Dallas, Texas
- Fort Worth, Texas
- Houston, Texas
- San Antonio, Texas
- Salt Lake City, Utah
- Seattle, Washington

**RESEARCH SOLUTIONS**  
**carollo**  
*Engineers...Working Wonders With Water®*

**RESEARCH GROUP**  
Jess Brown, Manager  
Phone (941) 371-9832  
[jbrown@carollo.com](mailto:jbrown@carollo.com)

**PRODUCED BY**  
Laura Corrington

**EDITOR**  
Erin Mackey

**DESIGN AND PRODUCTION**  
Matthew Parrott  
Kim Lightner





*This publication is printed with soy inks on FSC® certified 100% recycled content (50% post-consumer waste).*