

From: Watts, Michael J.
Sent: Fri, 13 Feb 2015 22:01:34 +0000
To: emcdonald@apaienv.com
Cc: Afsaneh Jabbar; David Sloan; erosenfeldt@hazenandsawyer.com; Odegard-Begay, Andrea M.; Graves, Michael, J; daniel.nix@wichitafallstx.gov
Subject: Proposal Submission for the 2015 WateReuse Texas Collaborative Research Program
Attachments: Garver WRT Proposal_Final.pdf

Dr. McDonald,

On behalf of our collaborative research team, I am pleased to submit the attached proposal for consideration for funding under the 2015 WateReuse Texas CRP.

Please do not hesitate to call me with any questions.

Regards,

Mike Watts



Michael J. Watts, PhD, PE
Senior Process Engineer
Water Technology Leader
Office: 479-287-4652
Mobile: 919-599-1982



Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse waters

2015 Texas Water Reuse Collaborative Research Solicitation



HAZEN AND SAWYER
Environmental Engineers & Scientists



Table of Contents

PROPOSAL

Research Objective	1
Technical Approach	1
Project Team	3
Originality and Innovation of Research	3
Potential Relevance and Future Applications	4
Budget	5
Schedule	5

CITATIONS/REFERENCES

INVESTIGATOR RESUMES

COMMITMENT LETTERS

PROPOSAL

Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse waters

Research Objective

The unique photochemistry of MF, RO, and tertiary filtered reuse waters during UV advanced oxidation treatment will be examined through on-site pilot testing at the Cypress Water Treatment Plant in Wichita Falls, TX (a WaterReuse Texas member since 2005). The enhancements and hindrances to efficient advanced oxidation (as defined by trace wastewater organic oxidation) in the tested filtrates (MF, RO, and media filtered effluent) will be determined in the context of variable

- Hydrogen Peroxide Dosing
- Initial Free and Total Chlorine
- Nitrogen speciation in sampled effluents (free ammonia, nitrate/nitrite)
- pH
- Total and Dissolved Organic Carbon concentrations
- Required UV Dose for AOP (as a function of filtrate UVT)

Technical Approach

A critical question that must be answered in the evaluation of alternative water supplies for Texas communities experiencing prolonged drought conditions is the necessity of reverse osmosis membrane filtration in a potable reuse scenario. The purpose of this pilot would be to identify the true pre-treatment requirements (i.e., the degree of filtration: rapid-sand, microfiltration, or reverse osmosis, and the selection of chemical oxidants: hydrogen peroxide or hypochlorite) that would

be needed to generate efficient UV advanced oxidation of wastewater micropollutants (that are often monitored as indicators of potable reuse treatment train performance). In addition, this research program will develop a better understanding of the technology to an unmatched level, discovering potential performance enhancements and cost savings when compared with traditional UV/H₂O₂ AOP, examining major limitations in performance related to pH and background radical scavenging, and developing modeling approaches to understand feasibility and operability of the technology for particular water qualities.

The UV pilot reactor is an annular reactor containing low-pressure germicidal UV lamps (TrojanUV UVMax Model C, Ontario, CN). With technical support from Trojan, the pilot unit will be delivered and installed at the Cypress WTP (Wichita Falls) in the summer of 2015. Testing with the UV pilot and with water samples will be completed in two (2) phases, with both phases conducted simultaneously to ensure expedited project completion.

Phase (1) Direct measurement of trace wastewater organic contaminants (TOC) photo-oxidation with a combination of either HOCl/UV or H₂O₂/UV. Photo-oxidation kinetics will be measured in MF filtrate samples, RO permeate samples, and mono-media filtered samples. MF filtrate and RO permeate will be sampled from the potable reuse treatment train at Cypress, which for the near future is treating Wichita Falls municipal wastewater effluent (7.5 MGD) with submerged microfiltration membranes, followed by reverse osmosis, and germicidal UV disinfection. Mono-media filtered samples will be

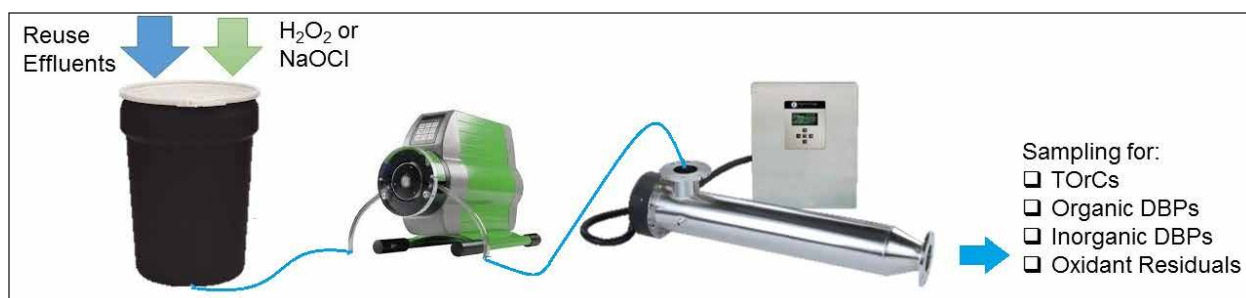


Figure 1 Testing schema for UV pilot operation at the Cypress WTP.

collected from the nearby Lawton WWTP, OK (45-minutes from Wichita Falls). The sampling plan for phase (1) of pilot testing will include samples collected under the following UV AOP treatment conditions in Table 1.

Water	pH	UV Dose	NaOCl or H ₂ O ₂ Dosages
Cypress MF	> 7	200 mJ/cm ²	0, 5 and 10 mg/L
Cypress RO	> 6		
Lawton Filtered	> 7 > 6	200 and 300 mJ/cm ²	

Table 1 UV AOP test conditions for Wichita Falls (Cypress) and Lawton reuse effluents.

Samples collected from the UV pilot (both influent (pre-UV) and effluent (post-UV)) will be processed for selected analytes (Table 2) at either Cypress' WTP laboratory or Eurofins Eaton Analytical (Monrovia, CA).

Phase (2) Indirect measurement of Hydroxyl Radical ($\bullet$ OH) concentrations in UV pilot reactor with an innovative dye tracer method and development of feasibility assessments under various pre-treatment scenarios.

Due to its nonselective reactivity, the role that $\bullet$ OH plays in the destruction of organic contaminants in water is largely dictated by the presence and concentrations of background "scavenging" demand for $\bullet$ OH, with high scavenging levels negatively impacting treatment of targeted organic contaminants. In many cases, organic matter dominates the $\bullet$ OH demand, even in waters with relatively low DOC (< 2 mg/L total organic carbon (TOC)), although other species including carbonate, bicarbonate, and even chloramine can contribute to hydroxyl scavenging in applications such as post-RO treatment.

To improve understanding of background scavenging, co-PI Rosenfeldt has developed a bench-top background radical scavenging

Analyte(s)	Method	UV Influent	UV Effluent	Laboratory
TOrC (>25 anthropogenic organics)	LC/MS/MS ESI(-)	√	√	Eurofins Eaton Analytical
Chlorite/Chlorate	EPA Method 300	√	√	Cypress WTP
Bromate	EPA Method 317	√	√	Eurofins Eaton Analytical
Total THMs	EPA Method 551	√	√	Cypress WTP
HAA5	EPA Method 552	√	√	Eurofins Eaton Analytical
Chemical Oxidant Residuals	DPD-Colorimetric (APHA)	√	√	Cypress WTP

Table 2 List of analytes to be measured in each sample collected during UV AOP piloting at the Cypress WTP.

measurement device, which has been successfully deployed for collecting and using bulk-OH radical scavenging measurements. This analysis can then be used in conjunction with proven modeling approaches to assess reactivity of background organic material (Donham, Rosenfeldt et al. 2014), feasibility of various AOPs for target contaminant oxidation (Rosenfeldt and Duke 2013), compare effect of pre-treatment on efficiency (Rosenfeldt, Duke et al. 2013), and even assist in optimizing AOP operations to minimize cost (Rosenfeldt, Duke et al. 2013).

In phase 2 of this project, we will measure and incorporate the background radical scavenging into proven AOP performance models (Watts, Hofmann et al. 2012) to accurately explain AOP oxidation of emerging contaminants in the water quality conditions observed at each pilot site. Once calibrated, the models can be utilized to develop feasibility analyses plots similar to Figure 3 (Rosenfeldt et al. 2013) for the piloted conditions and for examining other pre-treatment scenarios. The flexibility afforded by this approach allows for accurate engineering assessment and comparison of a multitude of AOP pretreatment scenarios, considering impact of pre-treatment on economic, greenhouse gas emissions, and other environmental factors. This model development effort (calibrated with observations in Lawton and Wichita Falls reclaimed waters) will play a critical role in assessing the potential application of these

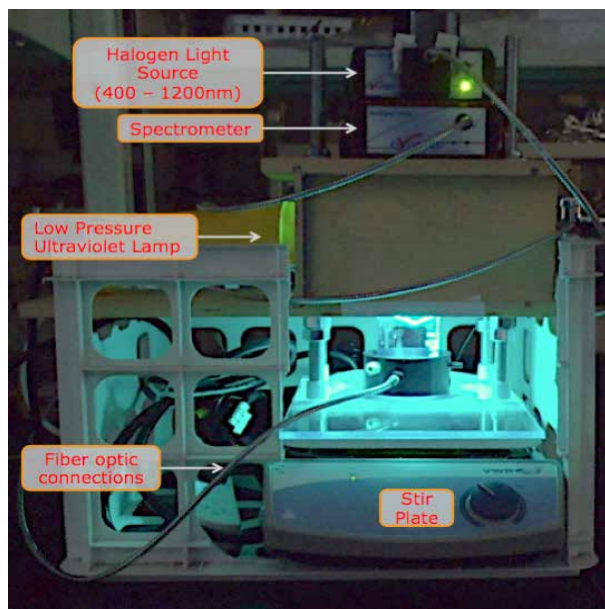


Figure 2 The bench-top background radical scavenging measurement device.

distinct UV AOP approaches in other reuse effluents.

Project Team

The project team will be led by Dr. Michael Watts, a Water Technology Leader at Garver for Oxidation and Disinfection technologies. As co-principal investigators, David Sloan (FNI) and Dr. Erik Rosenfeldt (H&S) will have critical project roles (see project personnel – Table 3).

Originality and Innovation of Research

Advanced Oxidation Processes (AOPs) are energized water treatment processes that use ultraviolet (UV) irradiation or ozone

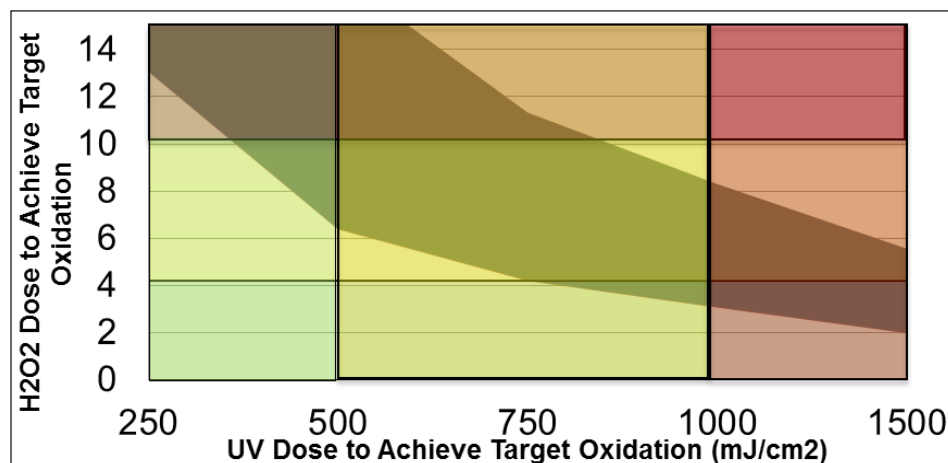


Figure 3 Example UV/H₂O₂ treatment feasibility assessment, highlighting expected UV and H₂O₂ dosing conditions. Green to Red: More favorable to less feasible conditions.

David Sloan, PE, BCEE Co-Principal Investigator Freese and Nichols (817) 735-7277 dws@freese.com Pilot Operation Freese and Nichols Coordination of all on-site pilot activities at the Cypress WTP. Quality Control.	Michael Watts, PhD, PE Principal Investigator Garver (479)287-4652 mjwatts@garverusa.com Responsible for project management and all required reporting to WateReuse Texas, and Phase (1) experimental design.	Erik Rosenfeldt, PhD, PE Co-Principal Investigator Hazen & Sawyer (804)266-1400 erosenfeldt@hazenandsawyer.com Laboratory Testing of •OH Scavenging Hazen & Sawyer Phase (2) experimental design, and testing coordination.
---	--	---

Table 3: Key project personnel.

reaction to produce hydroxyl radicals (•OH), a powerful, non-selective, oxidant. By carefully controlling influent water quality conditions, the engineer can design a UV AOP reactor to oxidize organic micropollutants of concern within a brief reaction window (< 1 minute of hydraulic residence time). While the currently accepted state-of-the-art for UV advanced oxidation requires the addition of H₂O₂ prior to germicidal UV irradiation, the water treatment industry continues to look for improvements in process efficiency. In recent years, significant attention has been given to replacing H₂O₂ with free (active) chlorine as the photolabile source of •OH. On the laboratory bench, investigations have focused on water quality, UV emissions spectra, and chlorine speciation that improve advanced oxidant yields and micropollutant destruction (Watts and Linden 2007, Watts, Rosenfeldt et al. 2007, Jin, El-Din et al. 2010, Chan, Gamal El-Din et al. 2012, Wang, Bolton et al. 2012). While not yet a mature technology, the successful advanced oxidation observed on the bench has led to pilot-scale testing of sequential chlorination and UV irradiation (Sichel, Garcia et al. 2011, Plewa, Wagner et al. 2012). However, unanswered questions remain which limit the full-scale application of this potential cost- and energy-saving technology:

*How does free chlorine photochemistry affect disinfection by-product formation in reclaimed wastewaters, with a mix of natural and *effluent* organic matters?

*Are there reclaimed wastewater conditions (pH, DOC, etc.) that are more favorable to advanced oxidation with HOCl/UV than H₂O₂/UV?

To the latter question, recent kinetic modeling of advanced oxidation in surface waters with HOCl/UV and H₂O₂/UV have indicated that at lower NOM concentrations H₂O₂ is more efficient than HOCl at production of photo-sensitized OH radicals (at neutral pH); however, as NOM increases, these distinct photochemical oxidation processes are equivalent in efficiency of trace organics oxidation (Watts, Hofmann et al. 2012, Rosenfeldt, Boal et al. 2013). This pilot study represents a first-of-its-kind opportunity to test this hypothesis in reuse waters of varying quality.

Potential Relevance and Future Applications

Due to geographic proximity, both the Cities of Lawton and Wichita Falls have experienced historic drought, against which water conservation measures have not been enough

to sustain their freshwater resources. In both cases, the reuse of municipal wastewater for potable purposes is either a current or future reality. In another drought-stricken state, California, regulators have mandated the sequential use of reverse osmosis and UV AOP for treatment of municipal wastewater for groundwater aquifer injection (an indirect potable reuse regime). While the same regulatory determination has not been made in Texas, there is clearly a trend towards this treatment approach in communities like Big Spring and Wichita Falls. The results of the proposed pilot testing will be widely disseminated in both Texas and the wider

region, and have the potential to change the perception of pre-treatment requirements for both advanced oxidation and elevated log-removals of priority pathogens.

Budget

To complete the proposed pilot testing, the following project budget will be required. Funds for this project will represent a combination of WaterReuse Texas funding, and both cash and in-kind support from participating research partners (the Cities of Wichita Falls and Lawton, and the professional services firms: Garver, Freese and Nichols, and Hazen & Sawyer).

	WaterReuse Texas	Wichita Falls (cash/in-kind)	Lawton (cash/in-kind)	Garver (cash/in-kind)	Freese and Nichols (cash/in-kind)	Hazen & Sawyer (cash/in-kind)
Project Personnel	\$3,000			\$1,000/ \$4,000	\$1,000/ \$4,000	\$1,000/ \$1,500
Travel	\$3,000			\$1,000/ \$1,000	\$1,000/ \$1,000	\$1,000/ \$1,000
Consumables	\$1,000		\$250/\$0	\$250/\$0	\$250/\$0	\$250/\$0
Sampling and Analysis (including shipping)	\$16,000	\$0/\$5,000	\$7,750/ \$1,000	\$2,750/\$0	\$2,750/\$0	\$2,750/\$0
Total (Cash)	\$23,000		\$8,000	\$5,000	\$5,000	\$5,000
Total (In-Kind)		\$5,000	\$1,000	\$5,000	\$5,000	\$2,500
Additional In-Kind Support from TrojanUV:						\$5,000
Total Project:						\$69,500

Schedule

A lead-time of 8 weeks from the time of award is anticipated for delivery of the UV pilot reactor, and procurement of other necessary equipment (metering pumps, carboys, consumable sampling supplies, etc.). Following equipment procurement, an additional 2 weeks will be scheduled to install and perform on-site calibration with pilot equipment. Both Phase (1) and Phase

(2) testing will be completed on-site at the Cypress WTP over 2 weeks. Following test completion, a final 12 week period is requested for data analysis and final report development for WaterReuse Texas by the investigators. With an anticipated project start date of June 1, 2015, the final project deliverable will be submitted by December 1, 2015.

CITATIONS/REFERENCES

Citations

- Chan, P. Y., M. Gamal El-Din and J. R. Bolton (2012). "A solar-driven UV/Chlorine advanced oxidation process." Water Research **46**(17): 5672-5682.
- Donham, J., E. Rosenfeldt and K. Wigginton (2014). "Photometric hydroxyl radical scavenging analysis of standard natural organic matter isolates." Environmental Science: Processes & Impacts **16**: 764-769.
- Jin, J., M. G. El-Din and J. R. Bolton (2010). "Assessment of the UV/Chlorine process as an advanced oxidation process." Water Research.
- Plewa, M. J., E. D. Wagner, D. H. Metz, R. Kashinkunti, K. J. Jamriska and M. Meyer (2012). "Differential Toxicity of Drinking Water Disinfected with Combinations of Ultraviolet Radiation and Chlorine." Environmental science & technology **46**(14): 7811-7817.
- Rosenfeldt, E., A. Boal, J. Springer, B. Stanford, S. Rivera, R. Kashinkunti and D. Metz (2013). "Comparison of UV-mediated Advanced Oxidation." Journal-AWWA **105**(7): 29-33.
- Rosenfeldt, E. and A. Duke (2013). Using Bench Scale Tests to Determine the Feasibility of AOP for Taste and Odor and Emerging Contaminants. VA AWWA / VWEA Joint Annual Meeting (WaterJAM). Richmond, VA.
- Rosenfeldt, E., A. Duke and K. Rule (2013). Assessing Feasibility of UV and Ozone based AOP for Treatment of MIB, geosmin, algal toxins, and other Emerging Contaminants. International UV Association World Congress. Las Vegas, NV.
- Sichel, C., C. Garcia and K. Andre (2011). "Feasibility studies: UV/chlorine advanced oxidation treatment for the removal of emerging contaminants." Water research **45**(19): 6371-6380.
- Wang, D., J. R. Bolton and R. Hofmann (2012). "Medium pressure UV combined with chlorine advanced oxidation for trichloroethylene destruction in a model water." Water Research **46**(15): 4677-4686.
- Watts, M. and K. Linden (2007). "Chlorine photolysis and subsequent OH radical production during UV treatment of chlorinated water." Water Research **41**(13): 2871-2878.
- Watts, M., E. Rosenfeldt and K. Linden (2007). "Comparative OH radical oxidation using UV-CI sub (2) and UV-H sub (2) O sub (2) processes." Aqua- Journal of Water Supply: Research and Technology **56**(8): 469-477.
- Watts, M. J., R. Hofmann and E. J. Rosenfeldt (2012). "Low-pressure UV/Cl₂ for advanced oxidation of taste and odor." Journal - American Water Works Association **104**(1).

INVESTIGATOR RESUMES

Michael J. Watts, PhD, PE

Dr. Michael Watts is a senior process engineer, and the disinfection and oxidation technology leader with Garver. Dr. Watts has hands-on experience in cutting-edge physical-chemical water and wastewater treatment. His experience includes training and supervising future engineers in their research and coursework on water treatment unit process and plant design, water quality analysis, water conveyance, water reclamation, and publication of peer-reviewed water research. In addition, he has developed and implemented bench- and pilot-scale treatment evaluations, and assisted utilities with compliance with water quality and water reuse regulations.

Positions

(2013 – Present) Water Technology Leader for Oxidation and Disinfection - Garver

(2008 – 2013) Assistant Professor – Civil & Environmental Engineering – the Florida State University, Tallahassee

Experience

8 years

Education

PhD Environmental Engineering – Duke University, Durham, NC

MS, BS Civil Engineering – University of South Carolina, Columbia

Registrations

Professional Engineer in: Texas (#118398), Florida (#127789), Alabama (#34709-E), Arkansas (#16396), Oklahoma (#27613)

Relevant Project Experience

Alternative Water Supply Feasibility Study for the City of Lawton (OK)

Project Engineer for the conceptual design of municipal water supply augmentation plans using direct and/or indirect potable reuse treatment of municipal wastewater (2015).

Lake Thunderbird Water Reuse for the Central Oklahoma Master Conservancy District (OK)

Design Engineer for the preliminary design of treatment and conveyance processes for the augmentation of Lake Thunderbird (a critical water supply reservoir for central OK) with reclaimed municipal wastewater (2014-2015).

Relevant Publications

- Feng, L., Watts, M.J., Yeh, D., Esposito, G., van Hullebusch, E.D. (2015). The efficacy of ozone/BAC treatment on non-steroidal anti-inflammatory drugs removal from drinking water and surface water. *Ozone: Science & Engineering*, DOI:10.1080/01919512.2014.99910.
- Ghazi, N.M., Watts, M.J., (2014). Hydroxyl radical (OH) scavenging in young and mature landfill leachates. *Water Research*, 56, 148-155.
- Watts, M.J., Hoffmann, R., Rosenfeldt, E.J. (2012). Low-pressure UV/Cl₂ for Advanced Oxidation of Taste and Odor. *Journal-AWWA*, 104(1), 47-48.
- Watts, M.J., Linden, K.G. (2009). Advanced oxidation kinetics of aqueous trialkyl phosphate flame retardants and plasticizers. *Environmental Science & Technology*, 43(8), 2937-2942.

Erik Rosenfeldt, PhD, PE

As a member of the Hazen and Sawyer's drinking water process, water reuse process, and applied research groups, Dr. Rosenfeldt's work focuses on identifying and studying innovative water treatment solutions for emerging drinking water issues. His research in the areas of water technology has focused on cutting edge processes, including advanced oxidation processes and traditional and emerging adsorption media for treatment of emerging contaminants. He has performed bench and pilot studies evaluating AOP for emerging contaminants, created methods for monitoring and water quality effects on AOP performance, modeled contaminant destruction, and developed alternative (UV/Cl₂) AOPs.

Relevant Project Experience

UV AOP pilot studies, Suffolk County Water Authority (NY) and Greater Cincinnati Water Works (OH)

Technical lead on this applied research project, funded by the National Science Foundation, examining the feasibility of UV/Cl₂ advanced oxidation process (AOP) as an alternative to traditional UV/H₂O₂ AOP for removal of groundwater pollutants and harmful algae byproducts.

UV AOP Feasibility and Design, Washington DC and Spotsylvania (VA)

Evaluated the feasibility of utilizing advanced oxidation (UV and ozone based) for year round emerging contaminant oxidation and periodic taste and odor control. This evaluation relied upon patent-pending technology and has been used to ensure the most efficient design and most meaningful comparisons of AOP alternatives.

Rapid methods and tools for determining background hydroxyl radical scavenging in water

Worked collaboratively to develop patented methods for measuring background hydroxyl radical scavenging in water. The methods have been successfully utilized for evaluating feasibility and optimizing process control of advanced oxidation processes for treating a variety of chemical contaminants.

Relevant Publications

- Donham JE, **Rosenfeldt EJ**, Wigginton, KR (2014) Photometric hydroxyl radical scavenging analysis of standard natural organic matter isolates, *ESPL*, **16 (4)**, 764-769
- **Rosenfeldt EJ**, Boal AK, Springer J, Stanford B, Rivera S, Kashinkunti RD, Metz DH Comparison of UV-mediated Advanced Oxidation, *JAWWA Tech Talk*, July 2013
- Watts MJ, Hofmann, R, **Rosenfeldt EJ** (2012) Low-Pressure UV/Cl₂ for advanced oxidation of taste-and-odor, *JAWWA*, January 2012.
- Linden KG, **Rosenfeldt EJ** (2010) "Chapter 18: Ultraviolet Light Disinfection and UV-Advanced Oxidation" in *AWWA: Water Quality and Technology*, 3rd Ed., November 2010.
- Watts MJ, **Rosenfeldt EJ**, Linden KG (2007) Comparing OH radical formation by UV irradiation of H₂O₂ (AOP) and HOCl. *JWSRT: Aqua* 56 (8): 469 - 477

Experience

14 years

Education

PhD, MS Civil and Environmental Engineering – Duke University, Durham, NC

BS Chemical Engineering – Washington University, St. Louis, WA

Registrations

Professional Engineer in: Virginia (#0402053908), Massachusetts (#47884)

David Sloan, PE, BCEE

David Sloan is an FNI Associate and Senior Treatment Process Engineer, serving as the firm's leader in water reuse planning and design. A recognized leader in potable reuse implementation, David has been a frequent speaker at potable reuse events, including the WaterReuse Association's 2012 webcast, "The Future of Potable Reuse," the 2013 WRA Potable Reuse Conference and the 2012 AWWA Annual Conference and Exposition, based on his work with the CRMWD to plan, permit, design and start up the District's Raw Water Production Facility in Big Spring, the first operating direct potable reuse public project in North America. David is the vice-chairman of the WEAT Water Reuse Committee and has been an active member of WaterReuse Texas since its creation.

Relevant Project Experience

Raw Water Production Facility, Colorado River Municipal Water District Project Manager for CRMWD's Raw Water Production Facility in Big Spring. The \$14-million project was featured in the Texas WET Magazine's November 2005 and 2011 issues. The facility, which uses membrane filtration, reverse osmosis and UV/Advanced Oxidation, began its blending operation in April 2013.

Emergency DPR Facility Extensions, City of Wichita Falls

Project Engineer for addition of UV disinfection at the Cypress Water Treatment Plant Membrane Treatment Facility, currently used to purify treated effluent from the River Road Water Resource Recovery Facility. Additional disinfection credit for Cryptosporidia was required by the TCEQ for continued operation beyond the initial 6-month approval for the DPR program. This fast-track project resulted in procurement, regulatory approval, installation and startup of the UV reactors within a 6 month time frame. Mr. Sloan is also PM for a parallel project to obtain TCEQ approval to blend brackish surface water with DPR source water prior to membrane treatment. This modification will allow the City to utilize the full capacity of the membrane plant while conserving dwindling supplies in their freshwater reservoirs.

Lake Thunderbird Augmentation, Central Oklahoma Master Conservancy District

Technical Advisor for Disinfection Evaluation for indirect potable reuse preliminary engineering report prepared by Garver Engineering. The District is planning to augment Lake Thunderbird by directing advanced-treated effluent from the City of Norman WRRF to a tributary of Lake Thunderbird. UV disinfection and chlorination are proposed to achieve high-level disinfection of a range of potential pathogens.

North and South Holly Water Treatment Plant Upgrade, Ozone Addition, City of Fort Worth

Project manager for the installation of ozone disinfection at the North and South Holly WTPs, 80- and 100-MGD, respectively.

Membrane Water Treatment Plant No. 2, City of Midlothian

Technical Advisor/Process Engineer for a new 6-MGD WTP. FNI designed the membrane system, disinfection strategy, and chemical feed system including on-site hypochlorite generation and hydrogen peroxide for advanced oxidation.

Experience

32 years

Education

MS Environmental Engineering – University of Texas, Austin

BS Civil Engineering – University of Texas, Austin

Registrations

Professional Engineer in: Texas (#63946), North Carolina (#41729)

Board Certified Environmental Engineer (#95-10020)

COMMITMENT LETTERS



3010 Gaylord Parkway
Suite 190
Frisco, TX 75034

TEL 972.377.7480
FAX 972.377.8380

www.GarverUSA.com

February 13, 2015

Ellen McDonald, PE, PhD
WateReuse Texas President

Re: Letter of Commitment

Dear Dr. McDonald,

Garver is pleased to support the WateReuse Texas Collaborative Research Program for 2015 through participation in the proposed research effort. This project seeks to answer critical questions regarding treatment process selection and optimization for potable water reuse in both Texas and the greater, drought-impacted region. We feel that the proposed project outcomes will be of great benefit to the Texas Commission on Environmental Quality, and the Texas Water Development Board in state-wide efforts to develop water reuse guidance and regulations.

In the event that the project is funded, we (Garver) agree to carry out project responsibilities as are assigned and delegated in the award. The total amount requested of Garver, LLC is \$10,000, with \$5,000 offered as in-kind contribution.

We look forward to working with you, and WateReuse Texas in 2015.

Very truly yours,

GARVER

Michael J. Graves
Vice President

February 13, 2015

Ellen McDonald, PE, PhD
President
WateReuse Texas

Re: Letter of Commitment

Proposal Title: Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse waters

Principal Investigator: Michael J. Watts, PE, PhD, Garver

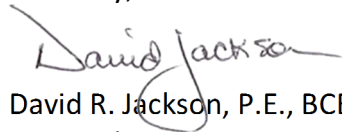
Dear Dr. McDonald:

Freese and Nichols, Inc. is pleased to participate in this proposal to the WateReuse Texas Collaborative Research Program (2015), on the above named project. In the event that the project is funded, we agree to work with the other project investigators and to carry out project responsibilities as are assigned or delegated in the award. The total amount requested for this support is \$10,000, with \$5,000 offered as an in-kind contribution by Freese and Nichols' personnel.

Please contact Dr. Watts with any questions regarding the scientific aspects of this proposal at (479) 287 - 4652. All questions regarding our participation should be referred to David Sloan, P.E., BCEE at (817) 735-7277.

Freese and Nichols enthusiastically looks forward to collaborating with this inaugural research effort by WateReuse Texas.

Sincerely,



David R. Jackson, P.E., BCEE
Principal
Manager, North Texas Water &
Wastewater Treatment Group

HAZEN AND SAWYER

Environmental Engineers & Scientists

8350 N Central Expressway
Suite 775
Dallas, Texas 75206

(214) 382-5750
hazenandsawyer.com

February 13, 2015

Ellen McDonald, P.E., Ph.D.
President
WateReuse Texas

Re: Support Letter for 2015 Texas Water Reuse Collaborative Research Solicitation Proposal "Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse water"
Hazen and Sawyer Investigator: Erik Rosenfeldt, P.E., Ph.D.

Dear Dr. McDonald:

Hazen & Sawyer is pleased to support the WateReuse Texas Collaborative Research Program for 2015 through participation in the proposed research effort. The questions regarding treatment selection and optimization for potable water reuse that this proposal seeks to answer are critical for developing potable reuse in Texas and beyond the region. The proposed scope fits well in Hazen & Sawyer's corporate vision of reuse technology and treatment selection, and we are excited for the opportunity to participate in this collaboration with the project partners and the WateReuse Texas Collaborative Research Program. In the event that the project is funded, we agree to carry out contract and project responsibilities as are assigned or delegated in the award. The total amount requested of Hazen & Sawyer is \$7500, with \$5000 offered as cash and \$2500 offered as an in-kind contribution.

Please contact Dr. Erik Rosenfeldt, co-PI, with any questions regarding the scientific aspects of this proposal at (804) 266-1400. All administrative questions should be referred to Mike Watts (PI) at (479) 287-4652.

Very Truly Yours,

HAZEN AND SAWYER, P.C.



Chamindra Dassanayake (CD), PhD, PE
Vice President and Southwest Regional Manager



February 13, 2015

Ellen McDonald, PE, PhD
President
WateReuse Texas

Re: Letter of Commitment

Proposal Title: Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse waters

Principal Investigator: Michael J. Watts, PE, PhD, Garver

Dear Dr. McDonald:

Trojan Technologies is pleased to participate in this proposal to the WateReuse Texas Collaborative Research Program (2015), on the above-named project. In the event that the project is funded, we agree to work with the project investigators and to carry out project responsibilities as are assigned or delegated in the award. Trojan offers in-kind contributions, including the provision of a bench-scale UV-oxidation system, estimated at \$5,000.

Please contact Dr. Watts with any questions regarding the scientific aspects of this proposal at (479) 287-4652. All questions regarding our participation should be referred to me, Adam Festger, at 520-297-3637 or afestger@trojanuv.com.

Trojan looks forward to our collaboration with your organization on this project.

Sincerely,

A handwritten signature in black ink, appearing to read "Adam Festger".

Adam Festger, M.S.
Market Manager, Drinking Water | Environmental Contaminant Treatment
Trojan Technologies



PUBLIC WORKS DEPARTMENT

February 13, 2015

Ellen McDonald, P.E., PhD
President
WateReuse Texas

Re: Letter of Commitment

Proposal Title: Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse waters

Principal Investigator: Michael J. Watts, P.E., PhD, Garver

Dear Dr. McDonald:

The City of Wichita Falls is pleased to participate in this proposal to the WateReuse Texas Collaborative Research Program (2015), on the above named project. In the event that the project is funded, we agree to work with the project investigators and to carry out project responsibilities as are assigned or delegated in the award. The City of Wichita Falls will support this effort by providing space, utilities, logistic support and testing of selected parameters at our certified on-site laboratory. The total value of these in-kind services is estimated to be \$5,000.

Potable reuse has been and continues to be an important water management strategy for Wichita Falls and we are eager to contribute to the body of knowledge available for future projects.

Please contact Dr. Watts with any questions regarding the scientific aspects of this proposal at (479) 287 - 4652. All administrative questions regarding our participation should be referred to Daniel Nix, Public Utilities Operations Manager at (940) 691-1153.

The City of Wichita Falls enthusiastically looks forward to our collaboration with your organization on this project.

Sincerely,

Russell Schreiber, P.E.
Director of Public Works

CITY OF WICHITA FALLS

1300 7th Street • P.O. Box 1431 • Wichita Falls, Texas 76307 • t (940) 761-7477 • f. (940) 761-6873
www.wichitafallstx.gov



Office of the Mayor

Fred L. Fitch

212 SW 9th Street

Lawton, Oklahoma 73501

Ph: (580) 581-3301 Fax: (580) 581-3536

February 13, 2015

Ellen McDonald, PE, PhD
President
WateReuse Texas

Re: Letter of Commitment

Proposal Title: Optimizing selection of filtration pretreatment and chemical oxidant for UV advanced oxidation of potable reuse waters

Principal Investigator: Michael J. Watts, PE, PhD, Garver

Dear Dr. McDonald:

The City of Lawton Public Works Administration is pleased to participate in this proposal to the WateReuse Texas Collaborative Research Program (2015), on the above named project. In the event that the project is funded, we agree to work with the project investigators and to carry out project responsibilities as are assigned or delegated in the award. The purpose of this project is to determine the best filtration technology that provides adequate removal of chemicals and pathogens that makes advanced oxidation more efficient. The City is pleased to provide funding in the amount of \$8,000 as contribution to the Garver Team to pay for the analysis performed by a third party lab that measures advanced oxidant scavengers in the City of Lawton's effluent. Finally, we pledge to provide monthly sampling and review the research material as an in-kind service valued at \$1000.

In return for our contribution, we will receive the following information:

- A detailed analysis of advanced oxidant scavengers that will be sufficient to define the type of filtration required for advanced oxidation.
- Full access to the final report and associated data set.

Please contact Dr. Watts with any questions regarding the scientific aspects of this proposal at (479) 287 - 4652. All administrative questions regarding our participation should be referred to Afsaneh Jabbar, PE at (580) 581-3410. The City of Lawton enthusiastically looks forward to our collaboration with your organization on this project.

Sincerely,

A handwritten signature in blue ink, appearing to read "Fred L. Fitch", is written over the word "Sincerely,".

Fred L. Fitch, Mayor
City of Lawton