OCWD R&D Department

R&D Project Update Report

Date: 27 April 2018

To: All Departments

From: Megan Plumlee (R&D)

Subject: R&D PROJECT UPDATE REPORT – Q1 2018

Beginning Q1 2017, this R&D Project Update Report is generated twice per year (Q1 and Q3) to summarize R&D projects. The first section, "Project Updates", provides a brief status report for each of approximately 25 different projects and programs. Later sections note recent publications and conference presentations by R&D staff, as well as external research projects in which OCWD's role as a participating utility is coordinated by R&D staff.

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Project Updates

Potable Reuse Water Quality

Project: Evaluating Post-Treatment Challenges for Potable Reuse Applications

R&D Staff Contacts: Shannon Roback, Ken Ishida
Start Date/Expected Completion: Fall 2016 to Winter 2018
External Funding: Yes (WE&RF and partner utilities)

This study is funded by the Water Environment & Reuse Foundation (WE&RF) and is investigating post-treatment optimization at the Advanced Water Purification Facility (AWPF), to balance competing goals of 1) maintaining pipeline integrity from corrosion while 2) minimizing NDMA reformation and 3) minimizing aquifer recharge metals mobilization. OCWD has conducted research and data collection on each topic independently; this WE&RF project is an opportunity to interpret these findings together and collect additional data to address knowledge gaps. The project team consists of OCWD, Trussell Technologies, and Stanford University, together with several participating utilities that contributed cash funding. With respect to the NDMA studies for this project, previously R&D evaluated historical data on NDMA occurrence and treatment efficacy in AWPF, initiated testing for possible NDMA contamination from lime addition post-UV/AOP, and measured NDMA formation potential in post-UV/AOP water. For this project, R&D will build on previous work through literature review and studies including 1) further evaluation of the lime addition step (impact of elevating pH on NDMA formation); 2) NDMA formation potential testing of individual RO permeates from AWPF RO membranes of different ages and manufacturers; 3) evaluation of impact of UV/AOP treatment on NDMA formation potential; 4) evaluation of NDMA formation in GWRS pipeline, among other tasks.

Project Updates

Current

- R&D has completed all sampling events of the RO feed/permeate for RO membranes of different types and ages. NDMA, NDMA precursors, CECs, VOCs and certain inorganics have been measured and rejection rates have been calculated.
- R&D has been tracking rejection of NDMA and NDMA precursors in a new ESPA2-LD membrane installed in March 2017 during each month of use to characterize changes during the first year of operation.
- R&D has completed 11 sampling events of the GWRS pipeline, which have shown reformation of NDMA during the travel time through the pipe (roughly 0.5 ng/L/hr).
- R&D has conducted two UV pilot experiments in partnership with Prof. Bill Mitch at Stanford University. These experiments will determine the influence of different UV treatment parameters (UV/HOCl, UV with and without H_2O_2, etc.) on destruction of NDMA, NDMA precursors and formation of NDMA post treatment.
- Trussell Technologies has begun their research tasks related to corrosion, using pipe loop systems that are installed in the RO building and are exposing samples of GWRS pipeline

concrete mortar lining to RO permeate and finished product water. R&D staff monitor the systems, measure water quality, and change out the water as much as weekly.

Future

- R&D will complete an additional UV pilot experiment to duplicate the second pilot test.
- R&D will complete two UV pilot experiments to evaluate the benefits and drawbacks of adding lime prior to UV/AOP rather than after (as is currently done at the AWPF).
- R&D will evaluate the influence of pH on NDMA formation in AWPF water in benchtop experiments. Plant UV/AOP product water will be collected and the pH will be increased using both lime and NaOH to determine the extent of NDMA "rebound" (formation) at various pH levels.
- Trussell Technologies will continue pipe loops studies set up in the RO building.

Project: Characterization of the Microbiome of a State-of-the-Art Water Reuse System to Enhance Treatment Performance

R&D Staff Contacts: Menu Leddy
Start Date/Expected Completion: Fall 2016 to Spring 2018
External Funding: Yes (USBR DWPR)

Funding for this study began in September 2016 from US Bureau of Reclamation (USBR), with supplementary funding from Water Environment and Reuse Foundation (WE&RF). The project team is Colorado School of Mines, OCWD, and CosmosID. The goal of the study is to apply Next Generation Sequencing (NGS) combined with metagenomics (via the advanced GENIUS sequencing algorithm from CosmosID) to conduct whole genome DNA sequencing of water samples and thereby identify microbial community signatures and their transformations through the AWPF treatment processes. NGS employs whole genome sequencing of DNA contained in a water sample, and thus can be used to identify all species detectable in the entire microbial community of the sample, allowing the sequencing of thousands of microorganisms in-situ without cloning. The study seeks to address uncertainties associated with microbial water quality by using NGS methods to improve understanding and monitoring of the advanced treatment process. In addition to identifying the microbial communities that are comprised of bacteria, protozoa, fungi, viruses, pathogens, and antibiotic resistance genes present at each stage of advanced treatment, the study proposes to assess correlations and possible relationships between the microbial communities and the standard bulk water quality monitoring and operating parameters used at the AWPF.

Project Updates

Current

- Due to low DNA recovery at all AWPF sampling locations that are after Q1 in the first round of sampling, the volume of water collected at each AWPF site was increased to 100 L during the second round of sampling.

- During the second round of sampling, water samples from several plant locations were concentrated to maximize DNA and RNA recovery using the Innovaprep Large Volume Concentrator (Innovaprep LLC, Drexel, MO). The large-volume filter membrane allowed for processing and concentration of up to 100 liters of water from each site to approximately 50 mL prior to further sample concentration onto 0.22 µm polycarbonate filter membranes for downstream analyses that included: DNA and RNA isolation and purification, microscopy, 16 sRNA, whole genome shotgun sequencing and bioinformatic analyses by CosmosID for high-throughput sequencing (HTS) of DNA and cDNA for community analysis.
- Reviewed HTS data from the second round of sampling at AWPF. Due to larger volumes of water, this set of samples identified a range of organisms in the Q1, MFF, and MFE samples by HTS. Sufficient DNA and RNA for HTS was not able to be recovered from ROP and UVP samples due to the very low amounts of DNA and RNA in these waters and/or inhibition effects from concentration the large volume.
- MF and RO biofilm samples were collected for HTS in addition to the water samples. Higher concentration of DNA (~4,600 ng) was recovered from most AWPF water samples, except at ROP and UVP (~6-22ng).
- Total RNA was also isolated from both the water and biofilm samples to further investigate the active microbial community in the GWRS system. The lowest concentration of RNA was detected in the ROP water samples.
- The project team submitted a final report to the primary grant funding agency, US Bureau of Reclamation (USBR).

Future

- The project team is in the process of analyzing additional data and preparing a draft of the final report for the supplementary funding from Water Environment and Reuse Foundation (WE&RF).
- A manuscript summarizing key findings is in process for journal submission.

Project: Non-Targeted Analysis of NDMA Precursors Found in the AWPF

R&D Staff Contacts: Shannon Roback, Ken Ishida
Start Date/Expected Completion: Spring 2016 to Summer 2018
External Funding: No

This is a collaborative project with Professor David Hanigan of University of Nevada, Reno (UNR) to isolate NDMA precursors from AWPF water at multiple locations. NDMA is a key contaminant of concern that is monitored by OCWD in the AWPF, and it forms from reaction of unidentified precursor compounds with chloramines that are maintained as a biocide. NDMA precursors will be extracted from water samples using a previously developed method for isolating amine compounds. In partnership with collaborators at University of Colorado (CU), Boulder who have expertise in non-targeted analysis, the extracts will be injected onto a high performance liquid chromatography (HPLC) time of flight (TOF) mass

spectrometry (MS) system to search for and identify NDMA precursors. In addition to potentially identifying unknown precursors in AWPF source waters, another objective is to evaluate the hypothesis that aged RO membranes may pass more NDMA precursors compared to newer membranes, and to assess whether the UV/AOP treatment step may produce NDMA precursors.

Project Updates

Current

- A manuscript based on the work completed for this project is currently in development with a likely submission date to a peer-reviewed journal in May 2018.

Future

- Once this manuscript is published, this phase of work will be complete. However, R&D recently obtained a grant from USBR to do further work with the UNR and CU team on non-targeted analysis. This is described below (next project).

Project: Understanding Formation of a Critical Disinfection Byproduct: NDMA and Previously Unidentified NDMA Precursors in Advanced Potable Reuse Treatment Plants

R&D Staff Contacts:	Shannon Roback, Ken Ishida
Start Date/Expected Completion:	Jan 2018 to Sept 2019
External Funding:	Yes (USBR DWPR)

The goal of this study is to determine the occurrence and fate of N-nitrosodimethylamine (NDMA) and NDMA precursors in the OCWD AWPF. NDMA and unknown precursors are present in the secondary effluent that feeds the plant. RO partially removes the NDMA while the UV/AOP effectively reduces the concentration below the 2 ng/L detection limit. However, a significant concern is that NDMA can form in the product water after UV/AOP treatment (i.e., NDMA reappears) likely due to the incomplete removal of NDMA precursors during advanced treatment. NDMA precursors are diverse and few are of known chemical composition. Therefore, in this study two non-targeted analytical techniques for the identification of unknown compounds will be used to identify new NDMA precursors. Non-targeted analysis tasks will be completed at University of Nevada, Reno, University of Colorado, Boulder and San Diego State University. The study will also investigate NDMA and NDMA precursors in permeate from different RO membrane ages and manufacturers, after membrane cleaning, and in product water after UV/AOP treatment using different oxidants. RO is the first line of defense for NDMA precursors and the effectiveness of this intervention is highly necessary to reduce NDMA formation post treatment. Finally, given the importance of NDMA as a disinfection byproduct of public health concern, and the industry interest in direct potable reuse, this study will assess the potential utility of developing a rapid online NDMA analyzer via high frequency sampling to assess diurnal trends in NDMA occurrence and treatment process reliability. These tasks will allow for a greater understanding of NDMA formation in advanced water treatment facilities and identify strategies for reducing the amount of NDMA formed post treatment.

Project Updates

Current

- R&D is working with USBR to finalize and execute the grant contract.
- Planning has begun for the high frequency NDMA sampling task and the UV/AOP pilot tasks.
- Samples have been collected from a collaborating utility, Padre Dam Municipal Water District (PDMWD) for the high frequency NDMA sampling task and the NDMA precursor characterization task.

Future

- R&D will conduct monthly high frequency NDMA sampling beginning in April.
- R&D will conduct the NDMA precursor sampling task in May.
- R&D will conduct UV/AOP pilot testing in May.

Project: Characterization of NDMA Precursors in an Advanced Water Treatment Facility Using the Polarity Rapid Assessment Method (PRAM) and Ultrafiltration

R&D Staff Contacts:	Shannon Roback
Start Date/Expected Completion:	Jan 2018 to June 2018
External Funding:	No

The primary objective of this collaborative study with UCLA is to use a polarity rapid assessment method (PRAM) and ultrafiltration (UF) method to characterize the polarity and molecular weight distribution of the bulk NDMA precursors as they travel through the AWPF. The project will evaluate structural changes in precursors of NDMA during advanced treatment for potable reuse. For example, polarity characterization of NDMA precursors via PRAM may demonstrate an increase in the percent of precursors that are polar after RO treatment, coinciding with the overall significant decrease in precursor concentration via RO. This information will be useful to understanding the character and fate of precursors through treatment, which may be helpful in the design of new treatment systems or development of new technologies. For example, the type of membrane used in AWPF could be chosen based on its ability to remove chemicals of a certain character that may be more likely to form NDMA (e.g. non-polar and/or positively charged) chemicals. This work will be completed under the direction of Dr. Mel Suffet of UCLA with sampling, oversight of the method, and results analysis by R&D staff.

Project Updates

Current

- R&D is working with Mel Suffet's MH3 corporation to complete contracting for the project.
- Initial work has been completed to determine whether ascorbic acid or sodium thiosulfate could be used to quench samples. Both of these agents caused a reduction of NDMA formation and thus will not be used.

Future

- R&D will collect samples in April for analysis by UCLA.
- R&D will collect samples in May for a second event.
- A final report will be completed by June.
- A publication will be authored describing the findings.

Project: Determine Role of Hydrogen Peroxide in NDMA Formation Post-UV/AOP

R&D Staff Contacts:	Shannon Roback
Start Date/Expected Completion:	Summer 2016 to Winter 2018
External Funding:	No

This is a collaborative research project with Dr. Stephen Mezyk from California State University, Long Beach (CSULB), Department of Chemistry and Biochemistry to quantitatively establish the role of H_2O_2 in the reformation of NDMA under OCWD post-AOP conditions. While some NDMA precursors have been identified in the literature, the role of the oxidizer involved is less certain. The project hypothesis is that the oxidizer H_2O_2 is essential in the post-AOP NDMA reformation process, and in particular, it is the ionized form of this compound (formed at high pH 11–12) associated with lime addition that is the essential reactive species. Experiments will be conducted under a matrix of water conditions (e.g., alkalinity, pH, temperature), with NDMA measurements performed by R&D. If as hypothesized the ionized form of H_2O_2 is found to be an important reactant species, then post-AOP water treatment to remove this oxidant before lime addition could be implemented to prevent NDMA formation.

Project Updates

Current

- Prof. Mezyk and his students have had significant, unexpected challenges with analyzing the samples from the experimental tests.

Future

- Prof. Mezyk will coordinate with R&D to identify a change in scope to complete this project. Once completed, they will prepare a final report for OCWD.

Pilot Treatment Studies – Product Evaluations

Project: Low-Pressure Membrane (MF and UF) Pilot Scale Product Evaluation for AWPF

R&D Staff Contacts:	Han Gu
Start Date/Expected Completion:	2015 to 2018
External Funding:	No

This project evaluates alternative low-pressure membrane products (i.e., microfiltration [MF] and ultrafiltration [UF] membranes) for the GWRS to support a product selection decision for the 30-mgd GWRS Final Expansion (FE). GWRSFE engineering design began in Fall 2017. Long-term piloting evaluations for both MF and UF products are currently underway at the OCWD Engineering Research Center as well as at OCSD Plant No.2. Testing at OCSD Plant No. 2 is necessary because effluent from this plant will be a new water source for the AWPF as part of the GWRSFE. Manufacturers include Evoqua Water Technologies, GE Water and Process Technologies, Toray Industries, Inc. and Scinor North America. Identifying suitable technologies will provide staff with options for replacing existing AWPF membranes and for the GWRS FE. Most evaluations have already been completed to meet the design schedule for GWRSFE but additional confirmation and chemical optimization via pilot testing for certain products is continuing in FY 2017-18 and likely FY 2018-19.

Project Updates

Current

- Product evaluations at OCSD Plant No. 2 this period include a PVDF UF membrane from Scinor, a longer module MF membrane from Evoqua (polypropylene, 1.52 times more surface area than the one currently used at AWPF), a longer module UF PVDF membrane from Evoqua, and beginning March 2018, a new generation PVDF membrane from Evoqua (same module length as current membrane at AWPF). Thus far, all PVDF products are performing well.
- Previously completed product evaluations at the ERC include UF (PVDF) membranes from Evoqua, Toray, Scinor and GE. Previously completed product evaluations at OCSD Plant No. 2 include Evoqua MF membrane currently used at AWPF for comparison (Evoqua polypropylene membrane) and Toray UF membrane.

Future

- Pilot testing of MF and UF products will continue, in particular for the Scinor PVDF UF membrane that will also be tested at demonstration scale in one AWPF MF cell later in 2018, and Evoqua PVDF UF (short module, next generation) membranes at Plant No. 2. Summary reports will be prepared.

Program: RO Antiscalant Pilot Scale Product Evaluation for AWPF

R&D Staff Contacts:	Han Gu
Start Date/Expected Completion:	2008 - ongoing
External Funding:	No

The AWPF RO system requires chemical addition, antiscalant and acid, to the feed to prevent the precipitation of sparingly soluble minerals which foul the membranes. Identifying the appropriate antiscalant product, dosage and feed water pH through pilot testing is an ongoing program. R&D continually tests newly available antiscalants, as well as operating conditions (dose and pH), to identify

preferred products and minimum required doses via pilot-scale testing at the ERC using RO pilots. Antiscalant products found to be effective through these efforts are short-listed for bidding through the District's procurement process. This program has resulted in cost-savings totaling in excess of $1,000,000 annually; for instance, the recent plant switch from AWC A-110 to AWC A-108 antiscalant (March 2018) will result in over $1,000,000 annual antiscalant cost savings due to the lower cost product and lower dose.

Project Updates

Current

- A 6-month trial was conducted between January to July 2017 to evaluate the antiscalant product Avista Vitec 1500 at a dose of 2.5 mg/L and pH 6.9, using RO pilot system no. 2. Membrane autopsy and SEM/EDS analysis of the tail element of the RO membrane used in the trial was completed by R&D scientists and Avista. The final decision was to select AWC A-108, a product that had been pilot tested in a previous trial.

- A parallel re-trial of the AWC A-108 and Avista Vitec 1500 antiscalant products is underway at a dose of 2.5 mg/L and pH 6.9 for both products, using RO pilot system no. 1 and 2, which began 12/13/17 and will run for approximately six months. The purpose is to confirm the previous findings in a side-by-side comparison due to some anomalous previous results regarding salt passage. So far, these results (fairly significant increase in salt passage for tail element) have been reproduced, and for both antiscalants, suggesting that the choice of antiscalant is not a factor.

Future

- R&D staff will complete an internal report for the parallel re-trial of the AWC A108 and Avista Vitec 1500 antiscalant product trial results.

Program: RO Membrane Product Evaluations for AWPF (Satellite Vessels)

R&D Staff Contacts:	Han Gu
Start Date/Expected Completion:	2009 - ongoing
External Funding:	No

Commercial RO membrane products continue to be developed by manufacturers which have potential for significant benefits in terms of enhanced permeability and rejection. Products for the AWPF are continuously evaluated by R&D through conducting long-term testing (up to 12 months) using a series of eight test vessels (satellite vessels) located in the AWPF RO facility. Products deemed successful are short-listed for future membrane procurements. The goal is to expand the list of pre-qualified products to create a competitive environment within the District's procurement process.

Project Updates

- Currently, products being evaluated include Toray TLF-400DG, Hydranautics ESPA4-LD, and one Dow prototype. Last fall, the Toray TMG20-D400 and DOW BW30 XFRLE-400/34i membranes were qualified but are continuing to operate in the satellite vessels to develop a longer term dataset. In March 2018, LG Chemical BW 400 was added to the qualified product list and is also continuing to operate to develop a longer term dataset.

- DOW XFRLE-400 (from 2011) membranes are also operating in a satellite vessel as part of a long term performance evaluation.

- Membrane cleanings were completed for DOW BW30 XFRLE-400/34i, DOW XFRLE-400, Toray TMG20-D400 and Hydranautics ESPA4-LD to evaluate impacts of chemical cleaning.

Future

- The above evaluations will continue, and in some cases qualified products will be left in place to collect longer-term data in the event there is no other product competing for that position/testing.
- Reports will be prepared for Hydranautics ESPA2-LD MAX 440 and LG Chemical BW 400 ES (Spring/Summer 2018). A draft LG Chemical BW 400 report will be finalized and a previously completed Toray TMG20 and will be updated to reflect new information.

Pilot Treatment Studies – Research & Optimization

Project: Improving MF Treatment and Energy Efficiency through Monitoring and Removal of Colloidal Particle Foulants

R&D Staff Contacts: Jana Safarik
Start Date/Expected Completion: Summer 2015 to Spring 2018
External Funding: Yes (California Energy Commission)

OCWD is one of two demonstration sites for this $1.2 million study, led by Kennedy/Jenks Consultants and funded by the California Energy Commission (CEC). The other demonstration site is West Basin Municipal Water District. The objective of the project is to improve the energy efficiency of low pressure membrane treatment (e.g., MF) of recycled water through on-line monitoring and removal of colloidal particles that cause fouling. The colloidal particle monitoring is conducted using Malvern Instruments Nanosight NS500. OCWD is being reimbursed up to $40,000 through the grant funding for equipment/supplies related costs. R&D is providing project support via provision of Engineering Research Center pilot equipment and staff time for pilot operational support, project experimental design, membrane autopsies, and other analysis.

Project Updates

Current

- Two parallel MF pilot treatment units operated where one pilot received coagulant pretreatment, dosed according to nanoparticle load in the MF feed, and one pilot served as the control (no coagulant pretreatment). An RO pilot also operated, receiving MF effluent from the coagulant-dosed MF pilot, as part of a treatment train to test the effect of residual coagulant (if any) on RO performance. Two rounds of this MF and RO pilot treatment configuration were completed during this period. The third and final round of MF and RO coagulant pretreatment testing was started during this period and is estimated to be completed in April 2018.

Future

- Following completion of the third round of testing, excess coagulant will be introduced into the RO feed to simulate an MF breakthrough and evaluate potential impacts on the RO membrane and overall RO performance.
- This phase of testing will soon be completed. The remainder of the Kennedy/Jenks-led project testing will occur at a second site, West Basin Municipal Water District. The Nanosight NS500 will be relocated to West Basin.

Project: Desalitech Closed Circuit Reverse Osmosis (CCRO) Pilot Study for Water Recovery from RO Concentrate

R&D Staff Contacts:	Han Gu
Start Date/Expected Completion:	Fall 2016 to Winter 2018
External Funding:	No

The District discharges 18 million gallons per day (MGD) of concentrated reject water from the AWPF RO process to the OCSD ocean outfall, and this will increase to up to 23 MGD once the Final Expansion is complete. With additional treatment, the RO concentrate waste stream represents a significant new source of water for the District. Technologies with sufficient potential to warrant evaluation include closed circuit reverse osmosis (CCRO; in previous reports referred to as *closed circuit desalination*, CCD), forward osmosis, and conventional RO (as a fourth stage) or similar alternative such as high efficiency RO (HERO). OCWD purchased a pilot CCRO system from Desalitech to evaluate the potential of CCRO to treat RO concentrate for water recovery. CCRO is a newly developed, RO-based water treatment process that is patented by Desalitech, Inc. It consists of standard RO membranes and equipment, but is operated in a semi-batch mode, in which concentrate produced by the CCRO system is *recirculated back to the feed water side* until the desired water production is reached, at which time the concentrate is discharged from the system and replaced with feed water to begin again. CH2M is providing technical support for the study.

Project Updates

Current

- The Desalitech pilot system was delivered in July 2017. The pilot installation and commissioning was completed in mid-September 2017.
- Desalitech/CH2M provided a draft test plan for OCWD which has been finalized.
- Phase 1 of the pilot test began September 2017 and was completed in February 2018. Phase I utilized GWRS AWPF RO feed as the feed to the CCRO pilot.
- Phase 2 of the pilot test began March 2018. Phase 2 utilizes GWRS AWPF RO concentrate as the feed to the CCRO pilot.
- A project funding agreement is nearly finalized for a grant was secured from USBR in 2017 for further testing of CCRO, which will include comparison with forward osmosis to treat RO concentrate.

Future

- After Phase 2 is completed, Phase 3 will also use AWPF RO concentrate as the feed to the CCRO pilot and will evaluate effect of varying the quality (concentration) of the RO concentrate feed.

Project: Porifera Forward Osmosis Pilot Study for Demonstration of dprShield Technology in RO Concentrate Treatment

R&D Staff Contacts:	Han Gu
Start Date/Expected Completion:	Jan 2018 to ~Spring 2019
External Funding:	No (CEC funding to Porifera)

As described above for the Desalitech CCRO pilot study, the RO concentrate waste stream represents a significant new source of water for the District. The existing RO system removes most emerging contaminants, which are concentrated in this ROC stream to higher concentrations than the RO feed (ROF) stream. Therefore, robust treatment is important prior to potable reuse. The California Energy Commission (CEC) has provided funding to test dprShield technology as part of the Porifera forward osmosis (FO) technology demonstration at pilot scale at the GWRS with the intent to demonstrate dprShield and FO as innovative technologies to use less energy and reuse more water during potable reuse. dprShield is a new technology that combines FO and RO treatment processes with a type of real-time integrity monitoring and rejection mechanism called Breach-Activated Barrier™. OCWD is a partner site in the CEC funded project. The FO-RO pilot unit is located in the RO building.

Project Updates

Current

- Phase 1: Commissioning and system optimization – pilot was delivered in January 2018
- The objective of Phase 1 is adjust and optimize pilot unit performance and to determine appropriate maintenance requirements. Data generated during Phase 1 will not necessarily represent system performance for final cost estimates. Currently, Porifera staff in collaboration with R&D staff are working to troubleshoot system configuration and commissioning.

Future

- Phase 2: CEC funded demonstration test. Schedule: 5 months
- The objective of Phase 2 is to operate the FO-RO system and dprShield, and collect data for reporting.

Project: Increasing Potable Water Recovery to >95%: Pilot Evaluation of Closed Circuit Reverse Osmosis (CCRO) and Forward Osmosis (FO) Alternatives for Concentrate Treatment

R&D Staff Contacts:	Han Gu
Start Date/Expected Completion:	Spring 2018 to Early 2019
External Funding:	Yes (USBR DWPR grant)

The R&D Department is evaluating closed circuit reverse osmosis (CCRO – Desalitech) and forward osmosis (FO - Porifera) at pilot-scale to further treat and reuse a portion of the OCWD RO concentrate (ROC) reject stream that is currently discharged to the ocean. This project builds on the CCRO and FO studies described above, and uses USBR grant funding to evaluate the water quality of the product water produced by each of these systems as well as to complete other tasks. Successful treatment and recovery of RO concentrate at advanced potable reuse facilities like GWRS will minimize the volume of the waste stream while generating more water, increasing overall facility water recovery (plant efficiency) from 85% to greater than 90 or 95%. Using the pilot operational feasibility and optimization completed previously (see above project descriptions for each technology), this study will focus on pilot *performance* with respect to water quality, treatability, and acceptance for potable reuse. The study will include comprehensive water quality testing of the product water for chemical constituents and microorganisms, determination of virus log removal via seeding studies with MS2 coliphage, confirmation of suitability of the product waters for subsequent UV/AOP treatment, and cost analysis that will be completed by Carollo Engineers in collaboration with R&D staff.

Project Updates

Current

- Administrative work is underway to execute the USBR funding contract as well as set up grant-funded subcontracts with Desalitech, Porifera, and Carollo.
- A detailed water quality sampling plan for chemicals has been developed: four sampling events will be completed in 2018 for each pilot to characterize organics and general water quality of the pilots' feed and product water. This will be extra challenging due to the fact that the feed is RO concentrate, which is a difficult matrix for analyzing water quality.

Future

- Comprehensive chemical water quality analysis of feed and permeate from CCRO and FO pilots
- Comprehensive microbial water quality analysis of feed and permeate from CCRO and FO pilots
- Assessment of virus removal
- Suitability of UV/AOP for treatment of CCD and FO product water
- Cost and physical footprint evaluation

Method Development

Project: Utility Validation of Alternative Method for NDMA Analysis

R&D Staff Contacts: Shannon Roback
Start Date/Expected Completion: Fall 2017 to Fall 2018
External Funding: Yes (WE&RF)

This project is funded by WE&RF to validate a novel NDMA benchtop analysis method that requires less time, cost, and sample volume, and has potential for online (real-time) use. The method was developed by Professor Hitoshi Kodamatani (Kagoshima University, Japan) and has been adapted to recycled waters (Professor Takahiro Fujioka, Nagasaki University, Japan). Professors Kodamatani and Fujioka are advisors on the WE&RF study and have loaned OCWD the prototype detector. R&D staff obtained and repurposed a high performance liquid chromatography (HPLC) instrument that was no longer needed by the OCWD AWQAL. The method couples the HPLC with automated photochemical reaction (PR) and chemiluminescence (CL) detection of NDMA and other nitrosamines. The HPLC-PR-CL method is able to quantitate NDMA to approximately 2 ng/L. Through this study, the method will be tested for reproducibility, detection limit, matrix interference, and will be compared to AWQAL split sample results.

Project Updates

Current

- Optimization has been completed related to determining how many different nitrosamines can be analyzed by this method, and this depends on the chromatographic program. Testing included a NDMA/NMOR-only method, a four-nitrosamine and a six-nitrosamine method.
- Because increasing the number of nitrosamines can come at the expense of the detection limit for NDMA, the detection limits of the NDMA/NMOR-only method, the four- and six-nitrosamine method have been calculated.
- Accuracy and precision were determined for the four nitrosamine method and the six nitrosamine method and are within the acceptable ranges defined by EPA Method 521.
- The ion exchange unit (AEM) was replaced three times due to heavy use of the instrument and potentially the analysis of river water samples. Feedback was provided to the Japanese partners to aid in development of an improved AEM.
- The HPLC-PR-CL has been used to analyze approximately 7,144 R&D NDMA project samples. With an average NDMA analysis cost from a commercial lab between $75-$225, this instrument has allowed R&D to complete approximately $535,800 to $1,607,400 worth of analytical work over about 1.5 years, not including shipping costs.
- A manuscript was published for the journal *Environmental Science: Water Research and Technology* describing the use of the online HPLC-PR-CL system. Another publication describing the AEM system is in progress.
- Two conference presentations were given describing the use of this method.

Future

- R&D will continue to analyze split samples with AWQAL using weekly NDMA grabs from AWPF.
- R&D will conduct tests to determine the linearity and stability of the method, including determining acceptable hold times and storage conditions for NDMA samples.
- A standard operating procedure will be created.
- The final report to WE&RF (funding agency) will be drafted.

Advanced Treatment Processes

Project: Determination of Enteric Virus Log Reduction Values (LRVs) from Orange County Sanitation District Plant No. 1 and No. 2

R&D Staff Contacts:	Menu Leddy
Start Date/Expected Completion:	Spring 2018 – Summer 2019
External Funding:	No

R&D will lead a study partnered with the Orange County Sanitation District (OCSD) to evaluate the OCSD's Plant No. 1 and Plant No. 2 facilities for enteric virus concentrations in raw wastewater and secondary treated effluents, in order to determine log removal values (LRVs). LRV is a measure of the percent removal, in this case for viruses during wastewater treatment. The study will provide information and data for determining LRVs to be applied toward the pathogen control requirements for OCWD's GWRS facility, found in Groundwater Recharge Reuse Project (GRRP) regulations adopted into Title 22. It will also provide valuable information on the concentration of human viruses in OCSD's raw water. The study objectives are to determine the concentration of enteric viruses and specific microbial indicators in OCSD's raw wastewater influent at both OCSD's plants, to determine the concentration of the same enteric viruses and microbial indicators in OCSD activated sludge effluents (Plant No. 1), trickling filter effluent (Plant No. 1), and trickling filter/solids contact effluent (Plant No. 2), perform a final statistical analysis to determine the LRV for each process, and finally to recommend an overall LRV "credit" to be assigned to the wastewater treatment process that occurs upstream of the AWPF. With regulatory approval, this could be applied toward the AWPF potable reuse requirements for virus removal (total of 12 logs of virus removal required from raw OCSD influent to AWPF finished product water).

Project Updates

Current

- With assistance from OCSD, OCWD staff has drafted a study test plan for the State Water Resources Control Board - Division of Drinking Water (DDW).
- The draft test plan is in the process of being reviewed by the National Water Research Institute (NWRI) GWRS Independent Advisory Panel, Microbiological Subcommittee.

Future

- A final test plan that has incorporated the NWRI GWRS Independent Advisory Panel's recommendations will be submitted to State Water Resources Control Board for review and comments.
- Once the test plan is approved, OCWD staff will begin a one-year long virus monitoring program at OCSD Plant No. 1 and No. 2.

Project: Characterization of AWPF Feed Water

R&D Staff Contacts:	Jana Safarik
Start Date/Expected Completion:	2017 - 2019
External Funding:	No

The feed water for the AWPF is a combination of trickling filter (TF) and activated sludge effluent (ASE) from the Orange County Sanitation District (OCSD) Plant No. 1, which possesses significant particulate loading and effluent organic matter (EfOM). The addition of SEFE tanks (secondary effluent flow equalization) into AWPF in 2015 may also have associated water quality issues for the feed water stream. The SEFE tanks at the AWPF are upstream of the introduction of TF effluent and thus contain only ASE. Both the SEFE volume and TF:ASE ratio are dependent on OCSD's day to day operational parameters. These factors can contribute to rapid fouling of MF membranes with consequent loss of performance. Previous studies (Safarik, 2005, 2012) revealed that much of the material responsible for MF fouling appears to be biological debris. Carbohydrate, protein, and lipids were all identified on the surface and membrane matrices of fouled MF membranes. Much of the previous work was completed with ASE as the feed water. The aim of this project is to further elucidate and improve our understanding of the nanoparticulate and organic character of the foulants found in EfOM of AWPF feed water and their effect on MF fouling. Samples of ASE and TF from Plant No. 1 and the SEFE tanks will be characterized by three-dimensional excitation-emission matrix (EEM), nanoparticle size and distribution as well as other laboratory assays such as polysaccharide and protein.

Project Updates

Current

- To measure nanoparticulate and fluorescence (EEM) in AWPF feedwater, ISCO autosamplers with 24-bottle configurations collected hourly samples of ASE during SEFE tank filling cycles, SEFE effluent during SEFE drain cycle, TF during SEFE drain cycle, Q1 during SEFE drain cycle and MFF during SEFE drain cycle. For each water sample, ISCO sampling intervals were based on the goal of characterizing SEFE influence on MFF water quality. Laboratory analysis for each water sample included nanoparticle concentration and profile as well as fluorescence (EEM). Results are currently being analyzed.

Future

- A second sampling event is planned.

Project: Cartridge Filter Performance Evaluation using Rapid ATP Assay

R&D Staff Contacts:	Jana Safarik
Start Date/Expected Completion:	2015 - ongoing
External Funding:	No

Begun in 2015 in collaboration with Water Production Department (WP), R&D will continue monitoring the AWPF cartridge filters (CF) water quality for levels of adenosine triphosphate (ATP) as a surrogate for microbial activity using the Rapid LuminUltra Technologies kit method. Based on preliminary results, increased ATP levels in the CF effluent (RO feed water) may serve as a good indicator of RO biofouling potential. Bacterial growth in the CFs can result in decreased RO feed water quality, increased pressures in CF vessels, and decreased RO membrane performance. R&D will continue measuring and providing this data to Operations staff.

Project Updates

Current

- When CF differential pressures (dP) begin to rise, WP initiates individual CF vessel chlorine soaks and flushes. The purpose of the chlorine soaks is to reduce microbial activity inside the CF vessels. The CF vessels are flushed after a 2-hr chlorine soak to remove the inactivated microbial biomass. During this period, a comprehensive ATP survey of all 12 vessels was performed to quantitate the microbial biomass inactivation and removal during the soak and flush procedure. Individual CF vessel effluent ATP was measured directly before the chlorine soak and 24 hr following the procedure. Silt Density Index (SDI) measurements were collected in parallel from each CF vessel before and after the chlorine soaks.
- R&D submitted an abstract of project results to 2018 WEFTEC conference.

Future

- R&D will continue measuring and providing this data to Operations staff.

Project: UV/H_2O_2/Chloramine Matrix Pilot Studies

R&D Staff Contacts:	Ken Ishida
Start Date/Expected Completion:	2008 - ongoing
External Funding:	No

During UV/AOP treatment, UV irradiation and $HO^{\bullet}$ radicals derived from hydrogen peroxide (H_2O_2) are not solely responsible for bringing about oxidation; combined chlorine species (mono- and di-chloramine) present in the UV/AOP feed water may also play a significant role. R&D continues to investigate removal of 1,4-dioxane at varying H_2O_2 and combined chlorine levels utilizing the onsite UV/AOP pilot reactor under conditions that simulate the operation of the full-scale UVPhox. Studies focus on identifying the conditions for which optimal 1,4-dioxane removal occurs, based on past data suggesting synergistic effects of chloramine and H_2O_2. This project overlaps significantly with ongoing partner studies with University of California, Riverside (UCR) described below and CSULB and involves experiments coordinated with the university partner studies.

Project Updates

Current

- Work this quarter was tied to the operation of the pilot UV reactor and the generation of calibration curves for peristaltic dosing pumps for delivery of NaOCl, NH_2Cl, H_2O_2 and NaOH. R&D has shifted from operating the UV reactor in batch mode to continuous flow mode allowing for a greater number of experimental parameters to be tested in a single day. Calibration curves are needed so the precise concentrations of oxidants can be delivered into the RO permeate feeding the reactor.

Future

- R&D staff continue to conduct pilot experiments in collaboration with graduate students and post docs from Professor Haizhou Liu's research group at UCR (see next project below).

Project: Optimization of UV/AOP with Chloramine and H_2O_2 via Computational Modeling Followed by Pilot-Scale Validation

R&D Staff Contacts:	Ken Ishida
Start Date/Expected Completion:	Summer 2015 – Fall 2019
External Funding:	No (NSF funding to UC-Riverside, not OCWD)

OCWD is a partner in University of California, Riverside (UCR)-led projects that have been awarded funding by the Water Research Foundation (WRF) and National Science Foundation (NSF) for Professor Haizhou Liu of the Department of Chemical and Environmental Engineering to build on the development of computational kinetic models from previous UCR studies funded by OCWD. Dr. Liu models radical chemical reactions in the UV/AOP at AWPF to predict destruction of target compounds (e.g., NDMA, 1,4-dioxane) under various oxidant and source water conditions. The WRF project will focus on the mono- and di-chloramine as oxidants and the NSF project will investigate the feasibility of using persulfate as an oxidant for the UV/AOP. These oxidants can produce unique reactive species under UV photolysis, and the solution chemical conditions (e.g., pH; dose of oxidant) can be optimized through computational modeling to maximize contaminant degradation, minimize the chemical dosage cost and minimize the energy cost of the UV/AOP of the AWPF. The multivariate computational kinetic model utilizes reaction rate constants obtained from literature and measured directly by Dr. Stephen Mezyk of CSULB /RadKEM from complimentary ongoing R&D collaborations. The predictions of the computational kinetic models will be validated using OCWD's UV/AOP pilot reactor. The WRF project is expected to be completed in Spring 2019 and the NSF project is expected to be completed in Fall 2019.

Project Updates

Current

- Dr. Kiranmayi Mangalgiri (post doc) and graduate students, Sam Patton and Liang Wu, in collaboration with R&D staff ran a number of pilot UV reactor experiments investigating the removal of 1,4-dioxane and acetone by UV/H_2O_2 and UV/monochloramine AOP.

- Dr. Lucy Li and Professor Liu have submitted a manuscript, *UV Photolysis of Chloramine and Persulfate for 1,4-Dioxane Removal in Reverse Osmosis Permeate for Potable Water Reuse* to *Environmental Science & Technology* that is currently under review.

Future

- UCR graduate students and post doc together with R&D staff will continue to carry out planned UV/AOP pilot studies utilizing the single-lamp reactor.

Project: Quantifying Chlorine Dimer Radical Anion Chemistry Under OCWD Advanced Oxidation Process Conditions

R&D Staff Contacts:	Ken Ishida
Start Date/Expected Completion:	August 2017 to June 2018
External Funding:	No

This is a collaborative research project with Professor. Stephen Mezyk from California State University, Long Beach (CSULB), Department of Chemistry and Biochemistry to investigate and quantify the formation of the chlorine dimer radical associated with the advanced oxidation process and its reaction with constituents in OCWD's recycled wastewater. This project is a continuation of our effort to understand the complex chemical dynamics of the UV/H_2O_2 AOP.

Project Updates

Current

- Rate constants for the chlorine radical and the chlorine dimer radical with monochloramine, dichloramine, nitrite and a series of nitrosamines (C1–C4) were measured by CSULB through studies conducted at the University of Notre Dame's Radiation Laboratory.
- The formation and reaction of the sulfate radical were also added to the study. The data demonstrated that the chlorine dimer radical reactivity is slower than that of the hydroxyl radical and sulfate radical. However, the kinetics are still sufficiently fast to require inclusion when quantitative AOP modeling studies are conducted. These results have an impact on the kinetic modeling being done in Professor Haizhou Liu's laboratory at UC Riverside (see above project).

Future

- CSULB will measure the chlorine dimer radical reactivity with the most prevalent wastewater matrix components, notably dissolved organic matter, bicarbonate and carbonate ions, hydrogen peroxide, and nitrite/nitrate over the temperatures of practical interest for the OCWD AOP operations in order to quantitatively assess the effectiveness of this radical in removing unwanted chemicals of concern.

Project: Trojan UV/HOCl Pilot Studies

R&D Staff Contacts: Ken Ishida
Start Date/Expected Completion: 2018 - 2019
External Funding: No

The water reuse industry has begun to transition from implementing UV/H_2O_2 AOP (as done at OCWD's plant) to UV/HOCl, i.e. UV/free chlorine. While a number of utilities currently use UV/HOCl, the chemical dynamics are not well understood and the efficiency of the process relative to UV/H_2O_2 is not well defined. Over the past two years Trojan Technologies has expressed an interest to conduct AOP studies at OCWD using our single-lamp pilot UV reactor, including for UV/HOCl research. At the end of 2017, Trojan made available a 4-lamp UV pilot reactor for delivery to OCWD. Trojan and R&D staff will run a series of pilot-scale experiments to characterize the UV/HOCl AOP.

Project Updates

Current

- The 4-lamp pilot UV reactor has been removed from its shipping crate, and Water Production staff have completed the plumbing and electrical installation.
- The experimental matrix is being developed and Trojan staff are working to schedule a time to conduct the experiments.

Future

- Trojan staff will come to OCWD to operate the pilot reactor and run a series of UV/HOCl and UV/H_2O_2 experiments varying parameters such as NaOCl concentration, pH and fluence (UV ballast setting). R&D staff will assist in the studies time permitting.

Groundwater Recharge Optimization and Monitoring

Project: Desilting Demonstration Project Phase III Support

R&D Staff Contacts: Christine Pham
Start Date/Expected Completion: 2013 – Fall 2019
External Funding: No

Led by the Planning Department (Adam Hutchinson), this project assesses the field-scale performance of a riverbed filtration system placed below the off-river facilities (i.e., 'riverbed filtration system') to desilt Santa Ana River and provide this as recharge water to Olive Basin. R&D staff at the Field Research Laboratory (FRL) in Anaheim provide support for this project in the form of water sample collection and analyses (total suspended solids [TSS], turbidity and particle profile/distribution). FRL staff also change the experiment configurations by opening and closing lateral valves.

Project Updates

Current

- R&D staff has continued water quality sampling.

Future

- R&D will complete laterals testing and continue water sampling and analysis.
- Laterals testing will involve testing the different laterals configurations in order to compare their performance in producing desilted water into Olive Basin. This testing was delayed until the replacement of flow instrumentation at the influent site of the system. This hydraulic testing is done by turning laterals on and off to test whether certain lateral types (slotted PVC pipes vs. rain tanks) or the direction of surface water flow relative to the laterials (parallel or perpendicular) lead to a greater amount of collected, desilted water.
- R&D will begin water quality sampling and analysis on a different, related pilot system once installed in the Santa Ana River.
- R&D will draft a Materials and Methods section for a future internal report.

Project: Miraloma Basin Percolation Decline Column Study

R&D Staff Contacts:	Christine Pham, Ricardo Medina
Start Date/Expected Completion:	Fall 2015 to Summer 2019
External Funding:	No

Through this project, R&D is evaluating potential cause(s) of the observed percolation rate decline at Miraloma Basin which receives 100% AWPF finished product water. The observed clogging has resulted in decreased cleaning intervals from every 12 months to every 3-6 months since the basin was initiated in 2012. A new basin (La Palma Basin) on line since November 2016 is also dedicated to AWPF finished product water recharge, and there is concern that this basin may exhibit similar behavior. R&D is running column studies using Miraloma Basin sand that compare clogging rates between different water types including: finished product water from AWPF, water collected at the end of the GWRS pipeline at Miraloma, water collected from Miraloma Basin, and GWRS pipeline water near Mid Basin Injection (MBI) from before and after pipeline epoxy coating (future). The study plan includes water quality testing.

Project Updates

Current

- Column testing at the Miraloma site is completed and data analysis is ongoing. Results thus far show that percolation rate for columns fed with finished product water (FPW) from AWPF declined much more slowly compared to columns fed water from the end of the GWRS pipeline at Miraloma or Miraloma Basin water. Columns fed with water from the end of the GWRS pipeline declined slower than columns fed with water from Miraloma Basin.
- The second replicate experiment of the columns at the AWPF site (fed with FPW) has been running for approximately six months, without significant clogging observed.
- Preliminary results of this study were summarized in a poster and presented at the 16th Biennial Symposium of Managed Aquifer Recharge (BSMAR) Conference in March 2018.
- An additional experimental variation has been planned, to feed columns with GWRS water that has been conveyed via a pipeline to the Mid Basin Injection (MBI) before and after the pipeline is coated with epoxy. The purpose of epoxy coating is to prevent pipeline deterioration from exposure to GWRS water and is planned by engineering staff, but may have additional benefits to reducing basin clogging and by extension injection well clogging. The column study will help confirm these assumed benefits with respect to clogging potential. For example, if columns fed

with water from the epoxy-coated pipeline clog at a rate identical to the FPW-fed columns, this will indicate that the coated pipeline fully preserves the GWRS water quality.

Future

- To establish an experimental control, multiple replicates of the column study at MBI will be conducted prior to the epoxy coating application to the pipeline in September 2018. Monthly water quality sampling for TSS and ATP will be conducted of the source water to the MBI columns.
- Flow and water quality data will be compiled and evaluated, and an internal report or journal publication will be completed.

Project: FODTS to Measure Percolation Rate in La Palma Basin

R&D Staff Contacts: Christine Pham, Ricardo Medina
Start Date/Expected Completion: Summer 2016 – ongoing
External Funding: No

R&D is collaborating with California State University, Long Beach (CSULB) to install a fiber optic distributed temperature sensing (FODTS) system to monitor percolation rates at La Palma Basin. This basin is newly constructed (Fall 2016) and dedicated to recharge of advanced treated recycled water. This technology utilizes heat as a tracer of infiltration and provides improved resolution of percolation rates throughout the study site compared to traditional water balance methods. By tracking spatial and temporal variations of infiltration across the basin, FODTS can reveal specific areas where clogging occurs and help to optimize operations by improving cleaning strategies which enhance long-term basin performance. R&D will evaluate the first year of data toward developing a long term dataset, identify regions of greater or lesser percolation, and evaluate FODTS's utility for improved basin management (e.g., cleaning). The project will likely transition to a long-term study because the FODTS system has been permanently installed at La Palma Basin, enabling continued evaluation of data over time.

Project Updates

Current

- The FODTS cables are continuously collecting temperature data from both sides of the basin, as Operations has directed water to both sides as of 08/01/17. CSULB has developed an algorithm to process this data and data processing/ analysis is ongoing. Basin performance data collection and analysis is ongoing.
- CSULB presented the preliminary results of the FODTS study at the 16th Biennial Symposium of Managed Aquifer Recharge (BSMAR) Conference in March 2018.
- Autonomous temperature loggers will be installed in the basin to estimate infiltration alongside the surface cable; if the data is in agreement, the surface cable will be replaced by the temperature loggers to streamline the data collection process.

Future

- The existing algorithm will be updated by CSULB to incorporate the temperature logger measurements to estimate infiltration rates across the basin.
- CSULB will continue to train R&D staff on the Matlab processing and DTS instrument use followed by method validation (comparison of FODTS infiltration rates to water balance).
- Ongoing data collection will continue to establish at least one year of data before publishing findings in a journal; data collection can continue if it is determined to be of value to OCWD.

Project: NDMA Destruction in Groundwater Recharge Basins via Solar Photolysis

R&D Staff Contacts: Shannon Roback
Start Date/Expected Completion: April 2017 to June 2018
External Funding: No

The primary objective of this study is to determine the extent of NDMA photolysis in OCWD recharge basins. NDMA is a contaminant found in secondary effluent used as the source water to the AWPF, and also forms during advanced treatment at AWPF as a disinfection byproduct. Even though it is completely removed by the AWPF UV/AOP treatment system, NDMA forms again ("rebounds") in transmission lines carrying AWPF-treated water to recharge basins, resulting in NDMA occurrence between 2 and 10 ng/L. However, NDMA is extremely photosensitive and water in groundwater recharge basins is exposed to sunlight as water percolates into the basin bottom. The shallow depth of the water allows sunlight to penetrate through to the bottom of the basin making photolysis of NDMA more complete. Samples will be collected from recharge basins during daylight and non-daylight hours to determine the rate of NDMA photolysis in the basin. Control samples with spiked NDMA in containers near the basin will also be tested, as NDMA concentrations in the basin may be low on the sampling day.

Project Updates

Current

- R&D has conducted four sampling events: three in La Palma Basin and one in Miraloma Basin. There have been two events conducted on sunny days and two on cloudy days. Overall, results show that NDMA is degraded rapidly to non-detect levels during the day within just a few hours of exiting the GWRS pipeline and entering the pond, before the water percolates into the ground. Excellent removal is still observed on cloudy days.
- R&D has conducted three controlled experiments in which basin water was spiked with NDMA to determine the extent of degradation by natural sunlight.

Future

- R&D will collect complete one more event with control samples during a sunny day.
- A final report will be completed by Robert Reny (R&D intern) for his Master's project.

- A publication will be authored describing the findings.

Watershed Monitoring

Project: Middle Santa Ana River Pathogen Total Maximum Daily Load Study

R&D Staff Contacts: Menu Leddy
Start Date/Expected Completion: 2008 - ongoing
External Funding: Yes (SAWPA)

This is a long-term study managed by the Santa Ana Watershed Project Authority (SAWPA), with OCWD and the Regional Water Quality Control Board (RWQCB) as Technical Leads, and funding and sampling support from San Bernardino County Flood Control District, Riverside County Flood Control and Water Conservation District, other counties, and RWQCB. The objective is to evaluate pathogen sources in the Santa Ana River (SAR) Watershed. R&D will continue in a support role for *Bacteroides,* fecal indicator bacteria (FIB), and general water quality analysis. As with previous years, R&D will analyze for presence/absence (P/A) of *Bacteroides* and additional qPCR-based markers; if required, concentrations will be determined. Samples from the Upper SAR will be analyzed for FIB which will be correlated with the qPCR-based markers. OCWD is compensated on a per-sample basis, which includes analysis costs plus staff time for laboratory work, meeting participation, and report writing.

Project Updates

Current

- Staff participated in editing pertinent sections of the QAPP related to qPCR protocols.
- Staff attended the MSAR TMDL/Regional Water Quality Monitoring Task Force Meeting to provide monitoring updates.

Future

- R&D will continue to support MSAR TMDL/Regional Water Quality Monitoring Task Force water quality efforts for monitoring for *Bacteroides* and FIB in the MSAR and attend Task Force Meetings held on an as-needed schedule.

Reporting Period Publications

Hitoshi Kodamatani, **Shannon L. Roback, Megan H. Plumlee, Kenneth P. Ishida**, Hiroto Masunaga, Noboru Maruyama, and Takahiro Fujioka. *An Inline Ion-Exchange System in a Chemiluminescence-Based Analyzer for Direct Analysis of N-Nitrosamines in Treated Wastewater*. Journal of Chromatography A (*in press*), 2018.

David M. Warsinger, Sudip Chakraborty, Emily W. Tow, **Megan H. Plumlee**, Christopher Bellona, Savvina Loutatidou, Leila Karimi, *et al.* A review of polymeric membranes and processes for potable water reuse. Prog. Polym. Sci. (*in press*), 2018.

Menu B. Leddy, **Megan H. Plumlee**, Rose S. Kantor, Kara L. Nelson, Scott E. Miller, Lauren C. Kennedy, Blake W. Stamps, John R. Spear, Nur A. Hasan, Rita R. Colwell. *High-Throughput DNA Sequencing to Profile Microbial Water Quality of Potable Reuse*. Water Innovations (wateronline.com) January 2018, 33-37. Available at: https://www.wateronline.com/doc/high-throughput-dna-sequencing-to-profile-microbial-water-quality-of-potable-reuse-0001.

Reporting Period Conference Presentations

Han Gu, Megan H. Plumlee, Michael Boyd, Mo Malki, Mike Hwang, and Jim Lozier, *Pilot Evaluation of Closed-Circuit Reverse Osmosis for RO Concentrate Treatment*. WateReuse California Annual Conference, Monterey, CA, March 25-27, 2018.

Jana Safarik and **Ken Ishida**. Investigation of Cause of Quartz Sleeve Hazing in UV/AOP System for Potable Reuse. International Ultraviolet Association (IUVA) Americas Conference, Redondo Beach, California, February 26-28, 2018.

Sandy Scott-Roberts and **Han Gu.** *Groundwater Replenishment System Final Expansion Challenges.* AWWA Membrane Technology Conference, West Palm Beach Florida, March 14th, 2018.

Shannon Roback, Megan Plumlee, Ken Ishida, Takahiro Fujioka, Hitoshi Kodamatani. *High frequency and near real-time monitoring of N-nitrosodimethylamine using a novel extraction-free chemiluminescence-based method*. 2018 National American Chemical Society Meeting and Expo, New Orleans, LA, March 18-22, 2018.

Christine Pham, Grisel Rodriguez, Jasmin Jamal, Megan H. Plumlee, Adam Hutchinson. *Effect of Pipeline Transit and Environmental Factors on Clogging Rates of Groundwater Recharge Basins Receiving Advanced Treated Recycled Water*. 2018 11th Biennial Symposium on Managed Aquifer Recharge (BSMAR), San Diego, California, March 6-7, 2018 (Poster).

Patrick O'Connell, Matthew Becker, Michael Hodges, **Christine Pham, Grisel Rodriguez, Adam Hutchinson, Megan H. Plumlee**. *Evidence For Lateral Groundwater Flow Beneath Recharge Basins*. 2018 11th Biennial Symposium on Managed Aquifer Recharge (BSMAR), San Diego, California, March 6-7, 2018.

Sandy Scott-Roberts, Han Gu. *GWRS Final Expansion Project Water Quality Challenges*. 2018 AWWA Int'l Symposium on Potable Reuse, Austin, TX, January 22-23, 2018 (Poster).

Menu B. Leddy, Blake W. Stamps, Nur A. Hasan, Poorani Subramanian, Rita R. Colwell, **Megan H. Plumlee** and John R. Spear. *Use of Next Generation Sequencing to Track Removal of Microorganisms*

in an Advanced Water Treatment Facility. 2018 AWWA Int'l Symposium on Potable Reuse, Austin, TX, January 22-23, 2018.

Shannon Roback, Megan Plumlee, Ken Ishida, Hitoshi Kodamatani, Takahiro Fujioka. *Use of Rapid, Novel NDMA Analysis Method to Discern Diurnal and Seasonal Trends in NDMA and NDMA Precursors at an Advanced Water Treatment Facility*. 2018 AWWA Int'l Symposium on Potable Reuse, Austin, TX, January 22-23, 2018.

Patrick O'Connell, Matthew Becker, **Christine Pham, Grisel Rodriguez, Adam Hutchinson, Megan H. Plumlee**. *A Percolation Monitoring Program Using Distributed Temperature Sensing*. 2017 26th Annual Groundwater Resources Association (GRA) Conference, Sacramento, California, October 3-4, 2017.

Dian Tanuwidjaja, Hoon Hyung, Eugene Rosenbaum, Roy Daly, **Han Gu, Megan H. Plumlee**, Tom Knoell. *Piloting of Thin Film Nanocomposite RO Membranes for Indirect Potable Reuse in Orange County Water District's GWRS*. 2017 WateReuse Symposium, Phoenix, Arizona, September 10-13, 2017.

William T. Hunt, Han Gu, Megan H. Plumlee. *Secondary Effluent Water Quality Impact on Microfiltration/Ultrafiltration for Potable Reuse*. 5th Busan Global Water Forum, Busan, Korea, September 6-7, 2017.

Shannon Roback, Megan H. Plumlee, Ken Ishida, Takahiro Fujioka, and Hitoshi Kodamatani. *Validation and Use of a Novel Extraction-Free Method for NDMA Analysis to Determine the Influence of Reverse Osmosis Membrane Age on Rejection of NDMA and NDMA Precursors*. Gordon Research Conference & Seminar - Drinking Water Disinfection by-products, Boston, MA, July 29-August 4, 2017.

Participating Utility Projects

OCWD regularly participates in collaborative research with universities and other partners, often facilitated by R&D staff, in which OCWD provides water samples, data, operating history, and other support as an in-kind contribution to a partner-led study. In this role, OCWD is referred to as a "participating utility". Current projects of this nature in which R&D or other District staff are coordinating OCWD participation include:

Water Research Foundation (WRF)*

*Merger with WE&RF (below) to be completed by end of 2018

- Estimating the Comammox Contribution to Ammonia Oxidation in Nitrogen Removal Systems, WRF U4R16
- Assessment of Techniques to Evaluate and Demonstrate the Safety of Water from Direct Potable Reuse Treatment Facilities, WRF 4508
- Blending Requirements for Water from DPR Treatment Facilities, WRF 4536
- Building-Scale Treatment for Direct Potable Water Reuse & Intelligent Control for Real Time Performance Monitoring, WRF TC-16-007
- Characterization of Organic Carbon and Microbial Communities for the Optimization of Biologically-Active Carbon (BAC) Filtration for Potable Reuse, WRF U1R16

- Evaluating Fate of Coliphages in WRRFs and Potential Costs to Reduce Coliphages in WRRF Effluents, WRF U3R15

Water Environment and Reuse Foundation (WE&RF)*

*formerly WateReuse Research Foundation (WRRF)

- DPR-2: Project Description for Pathogen Monitoring (SWRCB Direct Potable Reuse [DPR] Research)
- DPR-4: Project Description for Treatment for Averaging Potential Chemical Peaks (SWRCB Direct Potable Reuse [DPR] Research)
- Integrating Management of Sensor Data for a Real Time Decision Making/Response System, WRRF 14-01
- Triple Bottom Line Comparison of DPR and Other Water Supply Options, WRRF 14-03 (completed in this reporting period)
- From Collection System to Tap: Resiliency of Treatment Processes for Direct Potable Reuse, WRRF 14-13
- Predicting RO Removal of Toxicologically Relevant Unique Organics, WRRF 14-19 (completed in this reporting period)
- Developing Curriculum and Content for DPR Operator Training, WE&RF-15-05
- Optimization of Ozone-BAC Treatment Processes for Potable Reuse Applications, WRRF 15-10
- Establishing a Framework for Pathogens Removal Credits to Desalination Subsurface Intake Wells, WE&RF 14-06
- Establishing Pathogens Log Reduction Credits for WWTP, WE&RF 14-02

National Institutes for Water Resources

- The National Institutes for Water Resources / U.S. Geological Service (NIWR/USGS) “The Role of Environmental Buffers in Potable Water Reuse”. PI: Olya Keen; Graduate student: Xueying Wang, University of North Carolina at Chapel Hill.
- The National Institutes for Water Resources / U.S. Geological Service (NIWR/USGS) “Human and Ecological Health Impacts Associated with Water Reuse: Engineered Systems for Removing Priority Emerging Contaminants”. PI: Susan Richardson, University of South Carolina.

U.S. Department of Education / Graduate Assistantship in Areas of National Need (GAANN) Fellowship

- Assessment of the Use of Optical Measurements to Differentiate Effluent Organic Matter from Natural Organic Matter in Water Reuse Applications. Graduate student: Sydney Ulliman; Advisor: Karl Linden, University of Colorado, Boulder.