NATIONAL WATER RESEARCH INSTITUTE

February 2, 2021

Sun Liang, PhD, PE
Manager, Water Reuse Development
Metropolitan Water District of Southern California

Subject: Advanced Purification Center Demonstration Project
NWRI Independent Science Advisory Panel Workshop 4 Report

Dear Dr. Liang:

The National Water Research Institute (NWRI) is pleased to present this technical letter report on the findings and recommendations from Workshop No. 4 of the Independent Science Advisory Panel (Panel) for the Regional Recycled Water Program (RRWP), Advanced Purification Center Demonstration Project (Project). The full Panel met on December 9, 2020, via videoconference. Ed Means, principal of Means Consulting and a contractually required NWRI subcontractor, facilitated the meeting. The following Panel members attended Workshop 4:

- Panel Chair: Charles Haas, PhD, BCEEM, Drexel University
- Paul Anderson, PhD, Independent Consultant
- Joseph A. Cotruvo, PhD, BCES, Joseph Cotruvo and Associates
- Thomas E. Harder, PG, CHG, Thomas Harder and Co.
- Nancy Love, PhD, PE, BCEE, University of Michigan
- Adam Olivieri, DrPH, PE, EOA, Inc.
- Vernon Snoeyink, PhD, University of Illinois
- Paul K. Westerhoff, PhD, PE, BCEE, Arizona State University

Meeting Objectives

Metropolitan's Project Team established two objectives for Workshop 4:

1. The Panel's independent review of the preliminary baseline testing results with particular emphasis on the 2.5 log credit from the membrane bioreactor (MBR) and the suitability of treated water quality for groundwater recharge.
2. The Panel's independent review and input related to the proposed Secondary MBR Testing and Monitoring Plan.

Questions Presented to the Panel

The Project Team presented the following questions to the Panel:

1. What additional information beyond the current data presented does the panel feel is needed to support regulatory application for a 2.5 log credit for MBR?
2. What additional information beyond the current data presented does the panel feel is needed to demonstrate the product water will be suitable for groundwater recharge in the proposed groundwater basins?
3. Is the secondary MBR testing and monitoring plan sufficient to evaluate the viability of the secondary MBR in this application?

This letter report addresses each of the questions.

General Comments

The Panel recognizes Metropolitan's substantial effort to move the Project forward since Workshop 3. The Panel also appreciates the quality of the written material and presentations prepared by the Project Team in support of the Panel's Workshop 4 review. However, the Panel is unable to give a consensus opinion on the desirability of secondary versus tertiary MBR alternatives. Therefore, the Panel looks forward to reviewing the results of further evaluation by the Project Team.

The Panel understands that the Project Team intends to present supplemental information related to Questions 1 and 2 at or before Workshop 5. Meanwhile, the Panel offers the following observations, findings, and recommendations.

Response to Questions

1. **What additional information beyond the current data presented does the Panel feel is needed to support regulatory application for a 2.5 log credit for MBR?**

   Response. The Panel appreciates the updated information and agrees with Project staff that more information will help it draw firm conclusions for this question. The investigations and results of the tertiary MBR Log Removal Values (LRVs) are excellent and impressive. The Panel offers the following findings and recommendations:

   - The Panel recommends and encourages the same level of monitoring and analytical effort to investigate secondary MBR LRVs and looks forward to seeing the results of the tertiary MBR LRVs for viruses. The Panel asks the Project Team to:
     - Present the final recommended operational parameters and performance envelope for both MBR investigations.
     - Use the more straightforward analytical method (i.e., empirical method) to present and document LRVs. In addition, the Panel encourages publication of the laboratory methods, including applicable quality assurance and quality control protocols.
   - The Panel recommends that Metropolitan:
     - Analyze both primary wastewater and MBR samples using an appropriate screening method for pathogens of concern other than enterics. This effort will help determine if cultures should include additional specific microbial or molecular biological tests.
     - Design a study of LRVs for reverse osmosis (RO) using surrogates.
   - The Panel finds that aerobic spores with a somewhat lower LRV than the other analytes merits further investigation. It recommends that regrowth of aerobic spores in biological treatment be assessed as a potential cause.

2. **What additional information beyond the current data presented does the panel feel is needed to demonstrate the product water will be suitable for groundwater recharge in the proposed groundwater basins?**

   Response. The Panel appreciates the updated information and agrees with the Project Team that more information will help it draw firm conclusions to this question. The Panel offers the following findings and recommendations.

   - The Panel recommends evaluating the post-advanced oxidation process (AOP) water treatment strategy and any anticipated modifications that will be necessary for water transport and recharge, including:

     - Assessing the effects of chemicals used in the AOP process, transport pipeline chlorine residuals, and post-RO water quality adjustments to minimize aggressiveness to concrete and cement mortar.

       Aggressive water can degrade cement and mortar-lined pipe, shortening the life of pipe and lining and suspending sediment that can clog basins or injection wells. The Panel notes that injection wells are more sensitive to the effects of aggressive water.

   - The Panel recommends developing a post-treatment water testing program to help identify cost-effective strategies to manage and mitigate the effects of aggressive water on Project facilities including:

     - Coupon testing of various potential pipeline materials using conditioned product water.

     - Limiting nitrosamine re-formation using treatment options. This should focus on NDMA formation potential when free chlorine is evaluated in lieu of hydrogen peroxide in the AOP system, because free chlorine can oxidize NDMA precursors and beneficially reduce NDMA re-formation in post-AOP-treated water.

   - The Panel recommends assessing dissolution of undesirable chemicals from aquifer materials. It is important to understand the compatibility of recharge water quality with aquifer chemistry in the various recharge basins to ensure that aquifer water

quality will not be degraded. Leachate testing on soil samples from the recharge basins using product water will provide information on the effects of recharge water on the aquifer. Experience at Orange County Water District has shown that the water may remain aggressive even with post-AOP water conditioning. Injected water may require redox studies with core samples.

- The Panel recommends identifying an intrinsic tracer or fingerprint for the final product water that can be used to assess travel times in the recharge facilities. The tracer should:
  - Be chemically stable.
  - Be easy to detect in trace amounts.
  - Have a higher concentration in the final product water than in the receiving groundwater.
  - Not sorb to soil particles.
- In addition to potential anion tracers, the Panel recommends considering isotopic tracers such as oxygen, deuterium, and strontium, and further recommends collecting weekly post-UV/AOP water samples to characterize seasonal variation.
- Given the schedule for the RRWP and the expressed intent to expand from groundwater recharge to direct potable reuse (DPR), the Panel recommends planning for DPR alternatives at the same time as the additional MBR process testing efforts. This planning is a necessary and critical element of the environmental documents. The Panel understands that more information on DPR plans will be forthcoming at the next Panel meeting in 2021.

Boron Recommendations

The lowest groundwater criterion for boron appears to be a potential issue in developing groundwater recharge alternatives. Boron concentrations in the advanced water treatment product water range from 0.46 to 0.56 mg/L with a median concentration of 0.49 mg/L (see Slide 120). The Main San Gabriel Basin Plan objective is 0.5 mg/L.

The adjustment of pH and implementation of a second-pass RO to remove boron was stated as having a significant cost. Therefore, the Panel:

- Recommends that Metropolitan more precisely characterize both capital and O&M costs required to meet Project boron criteria.
- Is interested in hearing more about Metropolitan's boron management strategy. The Panel continues to encourage the Project Team to investigate the Los Angeles Regional Water Quality Control Board (RWQCB) and the State Water Board's technical and public health bases that support the current groundwater basin plan boron water quality criteria.

  The boron limit was likely established to protect historical agricultural crops. Human health risk is not a factor at levels below 6 mg/L, which is the EPA Lifetime Health Advisory. The WHO Guideline for boron is 2.4 mg/L (increased from 0.5 many years ago), which may be sufficient to avoid second-pass RO costs and provide a larger margin of safety.

- Recommends that the Project Team consider all available regulatory routes to modify these criteria, assuming the technical and public health rationales warrant a change. One possible route to consider is the availability of new information. Unless the current Main San Gabriel Basin Plan objective for boron is modified, additional costly—and potentially unnecessary—treatment may need to be considered.
- The Panel further recommends that Metropolitan consider *maximum benefit objectives* such as were implemented in the Chino Basin. The Chino Basin Watermaster used such an approach for nitrogen and total dissolved solids (TDS). The Watermaster developed higher nitrogen and TDS objectives to replace the lower Basin Plan objectives for these constituents. Chino Basin pursued this Basin Plan amendment with the Santa Ana RWQCB to enable Chino Basin to recharge tertiary treated wastewater with concentrations that exceeded the Basin Plan, because doing so provided maximum benefit to basin water users. Please refer to the order here: https://www.waterboards.ca.gov/santaana/board_decisions/adopted_orders/orders/2004/04_001.pdf.

- The amendment process included: developing an updated water quality control plan, chartering a task force consisting of water and wastewater agencies, conducting studies, holding public hearings, and Regional and State Board review and approval. The process began in 1994 and culminated in the amended Basin Plan in January 2004.
- Given the range of observed product water boron concentrations, the Panel recommends that the Project Team consider negotiating a boron rolling average with the RWQCB. The rolling average should account for fluctuations (quarterly or annual) for discharges to injection wells and recharge basins that may bring it into compliance. This would likely bring the boron concentrations in line with current Basin Plan objectives. Blending may be a fallback approach if amendments to the Basin Plan objectives are unsuccessful and if blending is less expensive than other treatment alternatives, such as ion exchange.
- The Panel notes, as stated in the Workshop 4 presentation, that the Main San Gabriel Groundwater Basin (Basin) is adjudicated. The adjudication settlement establishes specific rights and duties of basin water producers and beneficiaries and creates a court-appointed Watermaster with substantial scope and authority. The Watermaster has authority over water quality in the Basin and has been granted plenary authority on the volume and quality of any supplemental water added to the Basin via surface spreading. The Watermaster annually produces a one- and five-year Water Quality Supply Plan (WQS Plan). The WQS Plan process officially begins in April each year.

  In developing the Plan, the Watermaster considers RWQCB Basin Plan objectives and, "…shall also balance the need to maintain adequate water supplies with the need to preserve basin water quality." The Watermaster's current WQS Plan includes an objective to "…collaborate in the Metropolitan Water Districts Regional Recycled Water Program." Two of the three Basin producers are member agencies of the Metropolitan Water District of Southern California and use imported water to meet certain groundwater replenishment and quality obligations under the settlement. Accordingly, the Watermaster is an influential and essential ally in efforts to modify the boron criteria for the Basin.

The Panel recommends that Metropolitan consider appealing to the Watermaster for reconsideration of the current boron limit, consistent with accepted public health standards, applicable Basin water quality goals, and needed Basin water production, beginning in the next WQS planning cycle.

Any plan to change the boron limit may be a 2- to 10-year process. Decisions will need to be made sooner for boron treatment. Second-pass RO is a technical option to achieve this. The panel is not advocating second-pass RO, but provides technical considerations therein. Many benefits could be gained from second-pass RO beyond boron removal, for example: removal of other inorganic/organic solutes, more pathogen removal potential, and production of non-potable water (second-pass RO retentate) for on-site uses instead of going to discharge. These benefits should be articulated more clearly and potentially assigned an economic value. The Panel agreed that the non-technical, management/policy approach of encouraging recharge into the Basin should have priority.

3. **Is the secondary MBR Testing and Monitoring Plan sufficient to evaluate the viability of the secondary MBR in this application?**

   Response. The Panel has the following recommendations as to the general sufficiency of the MBR Testing and Monitoring Plan:

   - Fully explain the introduction of primary treated wastewater into the treatment process to account for potential reduction or elimination of a treatment barrier or introduction of a new critical control point (CCP) to account for shock loading and less hydraulic residence time to respond to incoming flow variability. Also, evaluate the effects of changing the secondary treatment modality from pure oxygen and potentially having an impact on VOCs or other pollutants. Other pollutants could include odor compounds such as natural compounds (geosmin), synthetic fragrances, or anything with high Henry's constant.

   - Quantify additional benefits of second-pass RO, for example, for nitrate or boron. If/when used for nitrogen management, consider adding a nitrate sensor before the AOP process as a CCP. A target of 2.4 mg NO_3-N/L can be achieved by different percentage flows being treated by the second-pass RO system. There is no regulatory benefit of lower nitrate levels and a nitrate sensor here could help

manage energy consumption. This nitrate sensor would also indicate membrane performance as nitrate rejection differs from most other solutes. The Project Team may also identify other benefits of second-pass RO, such as improved removal of other pollutants or a lower CO_2 footprint compared to nitrification/denitrification (NDN).

- Improve net water recovery by putting second-pass RO retentate water to beneficial use, such as for on-site, non-potable water uses—or return it to the head of the plant. This is desalinated water and may account for two to four percent of the total plant capacity.
- Review and purge chemical monitoring lists of unnecessary components to reduce costs and focus on chemicals of direct local interest. For example, many of the pesticides on the Priority Pollutants List were banned more than 20 or 30 years ago, such as endrin, heptachlor, DDT and derivatives, and PCBs. The Panel notes that caffeine, sucralose, and several others are not chemicals of emerging concern (CECs) because they are not toxic, and caffeine is biodegradable. Sucralose is persistent but not toxic. Sucralose is a possible surrogate for treatment performance and for possible use as a tracer.
- Identify locally relevant potential chemicals of concern for tracking based on California's Recycled Water Policy, information derived from regulation of significant industrial users in the sewershed as part of the pretreatment program, and the NWRI Emerging Contaminant report.
- Identify the presence of nitrosamine precursors in MBR permeate and RO concentrates (such as dimethylamine, or methylamine moities).
- Increase the frequency and timing of targeted CEC monitoring to quantify diurnal or weekend impacts, such as from industrial discharges. Consider moving from grab to composite samples.
- Demonstrate that the sampling program is representative of the quality you are likely to see. Consider diurnal/weekly variation in key industrial chemicals, for example, when DOC is greater than 0.5 or 1 mg/L.

- Continue to quantify the total oxidizable precursor (TOP) assay or non-targeted PFAS/OA analysis on RO/AOP effluent.
- Analyze RO reject brine for PFAS/OA and similar next-generation chemicals.
- Verify that drinking water analytical methods (not wastewater methods) are being used for drinking water analytes of interest, such as bromate. Cite detection limits/methods used when reporting.
- Accelerate secondary MBR evaluation activities. Secondary MBR initially appears to have demonstrated benefits over tertiary MBR; for example, there is no need to supplement carbon substrate and it may cost less.
- Conduct a preliminary design process for the secondary MBR system before conducting the process via the demonstration plant. This preliminary design process would include a computational design that can be heavily informed by data that the team already has from the demonstration, lab, and pilot plants.
    - Calibrate and validate a simulation model (such as SUMO, BioWin, or GPS-X), especially for nitrification, with the data on hand. For the secondary MBR to perform NDN, identifying kinetic parameters and stoichiometric coefficients for cases when primary effluent is used will be heavily supported by the literature. This process has been done elsewhere, such as the Loudoun County, Virginia, MBR pilot plant from the early 2000s.
    - Verify the aerobic and anoxic solids retention time needed to achieve the level of total nitrogen (TN) removal desired. This design guideline can be demonstrated at the lab and/or pilot scale to help validate the model. Verification should be done before summer so that the secondary MBR NDN demonstration can hit the ground running and maximize the time available for the team to do the range of testing it wants with this particular system option.
    - The Project Team has shown that highly efficient nitrogen removal is possible with the indigenous biomass using lab-scale systems. The Panel has confidence

that the Project Team can get TN removal to work with the secondary NDN system in the demonstration plant using this approach.

- Consider reaching out to the National Alliance for Water Innovation for simulation models that are under development that link the bioreactor to desalination facilities and may have applicability here. Having the model will help for future work when tertiary NDN is reevaluated (noted as planned in the slides) and with whatever scaled-up design approach is ultimately used.

Recommendations Specific to RO Concentrate Toxicity

The RO concentrate toxicity (acute and chronic) investigations are reasonable and appropriate.

- The Panel recommends the Project Team consider potential issues that may arise from blending and modifications to the final effluent water quality that might affect the approved mixing zone dilution ratio. For example, does the Project Team anticipate any density changes that could affect the estimate of the minimum diffuser initial dilution and/or modification to the dispersion-based dilution estimates? Consider using hydraulic modeling to assess.
- Based on the results presented by the Project Team at Workshop 4, the Panel supports the Project Team opinion that disinfecting the RO concentrate before discharge via the outfall system is not necessary.
- The project partners should be prepared for stakeholders to raise the bioaccumulation/food chain issue for compounds that have the potential to bioaccumulate but currently do not have water quality criteria for potential effects from bioaccumulation. Some of the PFAS/OA would fall into that category. It is possible that the combination of low concentrations in the effluent and high dilution at the discharge mitigate this concern; this is not, after all, a release to an inland water with extended periods of low flow and little dilution during summer and fall. However, a proactive back-of-the-envelope screening evaluation could prove helpful in allaying stakeholder concerns. For example, estimate a receiving water concentration and then either compare that to a predicted no-effect concentration (PNEC) that accounts for effects associated with bioaccumulation or, if such a PNEC is not available, develop a PNEC

based on bioaccumulation factors and toxicity thresholds for relevant receptors of potential concern.

Enhanced Source Control Recommendations

The Panel is impressed with the level of collaboration between Metropolitan and Los Angeles County Sanitation Districts. The Panel is interested in the status of cooperative/institutional efforts between the partners to establish enhanced source control that reflects the fact that the community's wastewater is now a source of the community's drinking water. Enhanced source control that supports potable reuse goes beyond the traditional management, operational, and permitted discharge limitations.

- Given that this project will support achievement of the region's 2035 water supply goals, the Panel recommends that the partners continue to work together to enhance source control and respectfully requests that the partners present their strategies for enhancements to the existing regional pretreatment program at Workshop 5.
- The Panel is also interested in learning more about the partners' plans for continued and/or expanded public outreach, even as Covid-19 continues to limit on-site visits and in-person outreach.

Conclusion

The Panel looks forward to Workshop 5. If you have any questions or concerns, contact Suzanne Sharkey, Project Manager, at ssharkey@nwri-usa.org.

Sincerely,

Dr. Charles Haas
Panel Chair

Attachment 1 • About NWRI

The National Water Research Institute is a 501c3 nonprofit organization and Joint Powers Authority, founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

Disclaimer

This report was prepared by an Independent Expert Advisory Panel (Panel), which is administered by National Water Research Institute. Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

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Attachment 2 • Panel Member Biographies

Chair: Charles N. Haas, PhD, BCEEM

Professor of Environmental Engineering and Head, Department of Civil, Architectural, and Environmental Engineering, Drexel University

Dr. Charles Haas has more than 45 years of experience conducting research in water treatment, risk assessment, environmental modeling and statistics, microbiology, and environmental health. He has led the Department of Civil, Architectural, and Environmental Engineering at Drexel University since 1991, and previously served on the faculties of Rensselaer Polytechnic Institute and Illinois Institute of Technology. Haas holds a BS in Biology and an MS in Environmental Engineering from Illinois Institute of Technology, and a PhD in Environmental and Civil Engineering from University of Illinois.

Paul A. Anderson, PhD

Independent Consultant

Dr. Paul Anderson has more than 30 years of experience in human health and ecological risk assessment. He has been involved in evaluating the potential effects of pharmaceuticals in the environment as well as constituents of emerging concern. His work has also included investigation and assessment of PAHs and metals in sediments and he has done significant work on the assessment of human health and ecological risks posed by dioxins/furans. Anderson holds a BA in biology from Boston University and an MA and PhD in biology from Harvard University.

Joseph A. Cotruvo, PhD, BCES

President, Joseph Cotruvo and Associates, LLC

Dr. Joe Cotruvo is president of Joseph Cotruvo & Associates, an environmental and public health consulting firm in Washington, DC, and a Research Professor in the Departments of Chemistry and Biochemistry, and Environmental Sciences, at the University of Toledo. Previously, he was director of the Drinking Water Standards Division of the EPA Office of Drinking Water. He received a BS in Chemistry from the University of Toledo and a PhD in Physical Organic Chemistry from the Ohio State University. He is board certified by the

American Academy of Environmental Engineers and Scientists and recipient of the AAEES Science Award for 2019.

Thomas E. Harder, PG, CHG

Principal Hydrogeologist, Thomas Harder & Co.

Mr. Thomas Harder has more than 22 years of professional groundwater consulting experience. He has provided technical direction and management for large water resource projects in southern California, including the Chino Desalter Well Field Design and Construction, the West Coast Basin Barrier Project, and the Mojave Water Agency's Regional Recharge and Recovery Project. His expertise includes regional groundwater basin analysis, perennial (safe) yield, artificial recharge, groundwater management and models, contaminant hydrogeology, and wells. Harder holds a BS in Geology from California Polytechnic University, Pomona, and an MS in Geology with emphasis in Hydrogeology from California State University, Los Angeles. He is a registered geologist and hydrogeologist in California.

Nancy G. Love, PhD, PE, BCEE

Borchardt and Glysson Collegiate Professor, University of Michigan

Dr. Nancy Love is the Borchardt and Glysson Collegiate Professor in the Department of Civil and Environmental Engineering at the University of Michigan. There, she directs the Love Research Group, which works at the interface of water, infrastructure, and public health in both domestic and global settings. They focus on assessing and advancing public and environmental health using chemical, biological, and analytical approaches applied to water systems using both physical experiments and computational models. Dr. Love received her BS and MS at the University of Illinois, Urbana, and her PhD is from Clemson University. She has also been recognized for her scholarship and leadership with the Water Environment Foundation, the Water Research Foundation, and the National Science Foundation. She is a licensed professional engineer in Michigan.

Adam Olivieri, DrPH, PE

Principal/Founder, EOA, Inc.

Dr. Adam Olivier has more than 35 years of experience in the technical and regulatory aspects of water recycling, groundwater contamination by hazardous materials, water

quality and public health risk assessments, water quality planning, wastewater facility planning, urban runoff management, and on-site waste treatment systems. Dr. Olivieri is currently Vice President of EOA, Inc., in Oakland, California, where he manages a variety of projects, including serving as Santa Clara County Urban Runoff Program's Manager since 1998. He received a BS in Civil Engineering from University of Connecticut, an MS in Civil and Sanitary Engineering from University of Connecticut, and both an MPH and DrPH in Environmental Health Sciences from University of California, Berkeley. He is a registered professional engineer in California.

Vernon Snoeyink, PhD

Professor Emeritus, Civil and Environmental Engineering, University of Illinois

Dr. Vernon Snoeyink's research has focused on drinking water quality control, including removal of organic and inorganic contaminants from water using adsorption systems, especially granular and powdered activated carbon systems coupled with membrane systems. His expertise includes mechanisms of formation and means to control water quality in distribution systems in response to reactions of iron, aluminum, and other inorganics. He has also been recognized for excellence in teaching and advising. He holds a BS in Civil Engineering, an MS in Sanitary Engineering, and PhD in Water Resources Engineering from University of Michigan.

Paul K. Westerhoff, PhD, PE, BCEE

Professor, Sustainable Engineering/Built Environment, Arizona State University

Dr. Paul Westerhoff's research focuses on emerging contaminants, water treatment processes, and water quality, including occurrence, characterization, and oxidation of natural organic matter; removal of oxo-anions from drinking water; algal metabolites and algal biotechnology; wastewater reuse; and nanotechnology and sensors. Westerhoff holds a BS in Civil Engineering from Lehigh University, an MS in Civil and Environmental Engineering from University of Massachusetts, Amherst, and a PhD in Civil, Architectural, and Environmental Engineering from University of Colorado at Boulder. He is a registered professional engineer in Arizona.