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Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

Draft

BOSC Safe and Sustainable Water Resources Subcommittee

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CONTENTS

LIST OF ACRONYMS

ACE	Air, Climate, and Energy
AeMBR	Aerobic membrane bioreactor
AnMBR	Anaerobic membrane bioreactor
AOP	Adverse outcome pathway
BMP	Best management practices
BOSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
CEC	Contaminant of emerging concern
CSS	Chemical Safety for Sustainability
DBP	Disinfection by-products
DeRISK	Design of Risk-reducing, Innovative-implementable Small-system Knowledge
DO	Dissolved oxygen
DoD	Department of Defense
DPR	Direct potable reuse
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
IEUBK	Integrated Exposure Uptake Biokinetic
LID	Low-impact development
LRT	Liquid release test
LRV	Log-reduction value
NIEHS	National Institute of Environmental Health Sciences
NOAA	National Oceanic and Atmospheric Administration
PFAS	Perfluorinated alkyl substances
RW	Resource water
SHC	Sustainable and Healthy Communities
SHEDS	Stochastic Human Exposure and Dose Simulation (SHEDS)
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
USGS	U.S. Geological Survey
UV	Ultraviolet
WEF	Water Environment Federation

BACKGROUND

The SSWR BOSC Subcommittee met on 24-25 August, 2016, and was provided an in-depth review of one of SSWR's four research topics – Water Systems. The Water Systems topic consists of three projects:

Project 1: Current Systems and Regulatory Support

Project 2: Next Steps: Technology Advances

Project 3: Transformative Approaches and Technologies

Highly detailed briefings on Projects 1 and 2 were provided by Dr. Christopher A. Impellitteri, SSWR Associate National Program Director, and on Project 3 by Dr. Jay L. Garland, Director, National Exposure Research Laboratory, Systems Exposure Division. Dr. Suzanne van Drunick, SSWR National Program Director, members of her staff, and representatives from ORD were present for the entire meeting.

The Subcommittee found the presentations and associated commentary from Dr. van Drunick and others to be clear and thorough, and reflected a high level of commitment to a critical area of research. In general terms, the Subcommittee agreed that the Water Systems research program is very much on track, and that it is fulfilling its mandate.

The Subcommittee's meeting was held during EPA's 13th Annual Drinking Water Workshop (23-25 August, Cincinnati, OH) and Subcommittee members had the opportunity to attend several sessions of the Workshop and review poster presentations. The topic of the workshop was Small Drinking Water Systems, and the Subcommittee clearly benefited by having this opportunity.

One presentation is highlighted here because it provided a model for research planning that might be useful to the SSWR program. (Our selection of this one presentation should by no means be taken to suggest others were less valuable; rather, it was selected because of its relevance to one of the critical SSWR activities – research planning).

The presentation was made by Dr. Chad Seidel, University of Colorado, who directs the Design of Risk-reducing, Innovative-implementable Small-system Knowledge (DeRISK) Center—one of two national centers for innovation in small drinking water systems funded by SSWR through the Science to Achieve Results (STAR) Grants program. Dr. Seidel demonstrated how various research efforts directed to reducing health risk could be formulated and then analyzed with a decision model described in the important National Research Council report Science and Decisions (2009).[1] The NRC report was prepared for EPA, and the Agency has adopted the decision framework for use in other contexts.

The Subcommittee suggests SSWR investigate the research planning and evaluation framework developed under the DeRISK Center, and presented by Dr. Seidel, and perhaps adopt some form of it for its own purposes.

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[1] Dr. Seidel did not specifically cite this report, but the decision and risk model he described was completely consistent with it.

STRAP TOPIC 4: WATER SYSTEMS

ORD provides critical support to EPA's Office of Water and regional offices and water utilities to help current water systems provide safe drinking water and properly treated post-use waters. ORD also contributes essential information to the Office of Water on human health risks posed by contaminants (including microbial, chemical, and radiological) associated with water systems. In addition to this critical support to program and regional offices, ORD recognizes the need for addressing near-term and long-term challenges to water systems. The Water Systems topic research aims to push forward the next generation of technological, engineering, and process advances to maintain safe and sustainable water resources for humans and the environment, while also augmenting and improving water resources.

Research in the Water Systems topic is intended to support future community projects funded through the Water Infrastructure Finance and Innovation Act and the Clean Water and Drinking Water State Revolving Funds by identifying and promoting treatment processes and technologies that enhance energy efficiency and, for drinking water, make use of alternative sources of water (e.g., post-use or brackish). The Water Systems topic research will also develop approaches and evaluate technologies to help water systems evolve toward a more sustainable future. The three project areas in the Water Systems research topic are complementary and focus on continuous, integrated research. The integrated themes for the projects include the following:

- Integrated assessment tool to define optimal resource recovery-based water systems, including recovering and treating water fit-for-purpose at various scales.
- Advanced monitoring and analytical tools (i.e., multiple parameters) for effective integrated water system management to minimize human and ecological risk.
- Development and demonstration of individual technologies and integrated systems to improve the collection, treatment, and distribution of water (drinking water and post-use water) and the recovery of resources.
- Advancement of technologies for measuring health risks in current and future systems.

Topic Highlights

Updated analytical methods for contaminants of emerging concern in water, including improved analysis, detection, and treatment of HABs and algal toxins from watersheds to drinking water facilities.

Rapid toxicity screening of water contaminants of emerging concern and disinfection byproducts for effects on human health.

Project 1: Current Systems and Regulatory Support

Project 1 covers the development and evaluation of data, approaches, and technologies that will support the promulgation and implementation of federal water regulations and guidance while also addressing regional, state, and community concerns. The specific objectives of Project 1 are to (1) supply research results to support federal regulations and guidance; (2) provide strategies to regional offices, states, and communities for improved regulatory compliance; and (3) provide rapid and effective emergency response when appropriate (e.g., water system shut-down due to source water contamination). These objectives include research on contaminants that undergo periodic congressionally mandated regulatory cycles of review, such as the Microbial Disinfection ByProduct Rules, and chemicals and pathogens on the

Contaminant Candidate List and the Unregulated Contaminants Monitoring Rule List and other contaminants of concern (including groups of contaminants). Other objectives include optimizing treatment, monitoring, and analytical processes; exposure/risk assessments for compliance with post-use water treatment regulations; and improved pathogen control.

Project 2: Next Steps — Technology Advances

Although the approaches in this project may support current and near-future regulatory processes, or may be transformative in nature, they are reasonably well developed. They are not, however, ready for routine or regulatory use. Project 2 will expedite the development of these approaches to promote wider acceptance and implementation by program offices, regional offices, states, communities, and others within the time frame of the current project period (2016–2019). The project includes advances in several areas, such as resource recovery, treatment, monitoring and analytical measurements, collection and distribution systems, methods and approaches to predict or monitor human health outcomes, and risk assessment. It will also focus on new ways of assessing risks from chemical and microbial contaminants, provide data on currently unregulated contaminants, and develop new analytical methods based on identified future needs.

Project 3: Transformative Approaches and Technologies for Water Systems

This project will develop approaches and evaluate technologies that will help transform water systems toward a more sustainable future. Water systems challenged by issues such as shrinking resources, aging infrastructure, shifting demographics, climate change, and extreme weather events need transformative approaches that meet public health and environmental goals, while optimizing water treatment and maximizing resource recovery and system resiliency.

Project 3 involves four main efforts corresponding to the integrated themes described above. The first effort develops an integrated sustainability assessment framework based on linkages among drinking water, post-use water, stormwater, and natural infrastructure contained within a watershed. The framework will integrate various complementary system-based tools, such as life-cycle assessments and life-cycle costs; advanced water footprinting approaches; energy analyses; and resiliency to climate-induced events to evaluate alternative, innovative water system approaches quantitatively. The second effort focuses on the development of real-time (or near real time) measurements for monitoring potential chemical and microbiological risks from recycled water and other alternative sources. The third focus area emphasizes the demonstration and evaluation of alternative systems to generate performance data. Market adoption factors will be considered, including public acceptance, regulatory and policy drivers/barriers, and business and economic development potential. The final area involves the development of transformative approaches to waterborne human health risk measurements, including high-throughput sequencing to identify novel indicators and surrogates to assess the efficacy of water reuse systems.

Integration and Collaboration

The Water Systems research links with the other ORD research programs. For example, the energy footprint reduction connects with ORD's Air, Climate, and Energy (ACE) program. The work to increase resiliency and preparedness for extreme weather events links with ORD's Homeland Security research program. The monitoring protocols and health risk assessment research relate to ORD's Chemical Safety for Sustainability (CSS) program. Data development for human health risk will also link with research in ORD's Human Health Risk Assessment research program. Finally, the demonstrations and acceptance at the community level, along with testbed research, will interact with ORD's Sustainable and Healthy Communities (SHC).

The Water Systems topic research will provide input to EPA's Nitrogen and Co-pollutants Roadmap, particularly in the area of water quality nutrient and co-pollutant removal from post-use water in reuse and post-use water treatment. Pilot-scale research on monitoring and treatment systems will help underserved communities challenged by water treatment issues and aligns with EPA's Environmental Justice Roadmap and the EPA Administrator's initiative on making a visible difference in communities. The research projects align with EPA's Children's Environmental Health Roadmap through research on health risks from exposure to contaminants in drinking water (e.g., cell-based bioassays). Additionally, this research links with EPA's Climate Change Roadmap through research on energy-reducing or energy-producing treatment processes and broad life-cycle assessments for maximizing water system efficiency.

ORD researchers enjoy a long history of collaboration with EPA's programs and regional offices. In addition to EPA partners, researchers working under the Water Systems topic expect to continue collaborations with municipalities, utilities, and state officials and organizations (e.g., the Association of State Drinking Water Administrators and the Environmental Research Institute of the States). Collaborations will also continue with the Water Research Foundation, Water Environment Research Foundation, Water Reuse Research Foundation, and academia on research involving water treatment and reuse.

CHARGE QUESTIONS AND CONTEXT

The SSWR Subcommittee was charged with two questions:

Charge Question 1

Are we doing the right research: Taking resource limitations into consideration, is there any additional research that warrants new investment or current research that merits expansion, and are there areas of research that SSWR may consider divesting in?

Charge Question 2

Are we doing the right research at the right time? Comment on the balance of near, current and long-term research objectives.

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Project 1: Current Systems and Regulatory Support

Lead Author: Scott Ahlstrom

1. Regulatory mandates under the Safe Drinking Water Act and Clean Water Act require periodic review so the most current information is used to inform regulatory requirements and to ensure new areas of concern are addressed. Project 1: Current Systems and Regulatory Support seeks to meet this need by conducting research activities that:

- Support federal regulations and guidance.
- Provide strategies to regions, states, and communities for improved regulatory compliance.
- Provide rapid and effective response to emergencies, such as harmful algal bloom outbreaks.

2. Deliverables from this research will provide technical support for existing water-related rules as well as imminent issues, such as direct potable water reuse. The current research program includes the following tasks.

- Task 6.01A: Evaluating current wastewater treatment plants for contaminant removal
- Task 6.01B: Analytical methods and monitoring for regulatory and utility purposes
- Task 6.01C: Cost and effectiveness of water treatment to achieve regulatory compliance
- Task 6.01D: Improving the scientific foundation of regulatory decisions

3. A key activity in FY16 is to refine risk assessment models for direct potable reuse. Traditionally, water reuse practices have been categorized for regulatory purposes as non-potable, indirect potable or direct potable.

4. Indirect potable reuse typically involves releasing treated wastewater into groundwater or surface water sources with the intent of using it for a drinking water supply, and then reclaiming it and treating it to meet drinking water standards.

5. Direct potable reuse involves treating resource water with advanced treatment processes e.g. desalination and ultraviolet (UV) disinfection, and introducing it directly into a municipal water supply system without an environmental "buffer" of any kind.

6. In many cases, the distinction between indirect and direct potable reuse is insignificant. Treated wastewater discharged into a stream or pond and then pulled out a short distance downstream for treatment is not materially significantly different than a direct reuse application. We recommend EPA acknowledge this reality and evaluate risk based on the quality of the source water and its intended use. From a technical research perspective, there is no reason for EPA to make this distinction.

ORD's health effects research should thus focus on the technical aspects of potable reuse and quality of the water being treated and not confuse the analysis with the variability surrounding whether the reused water enters the potable water supply directly or indirectly.[2]

7. Some potable reuse applications are implemented to address long term supply issues while others are implemented as a short-term (less than a few years) response to drought or emergency conditions, i.e., until the preferred water supply is available again. The goal would be to define impacts that must be mitigated if reuse were practiced for a few years versus additional impacts that would become important to address whether reclaimed water is part of the permanent water supply. The research on short-term impacts would also be valuable to inform regulators, utilities, and technical experts dealing with response and recovery from natural disasters and other

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[2] The National Research Council publication Water Reuse: Potential For Expanding The Nation's Water Supply Through Reuse of Municipal Wastewater, 2012 also discusses an approach that does not define treatment requirements based on natural versus engineered processes but that is risk based and tailored to meet specific water quality objectives.

happenings that affect a community's water supply source. ORD might consider expanding potable reuse research to specify acute versus chronic impacts.

8. We understand ORD is conducting research to support the Office of Water's consideration of a household lead concentration action level that might be used in a revised lead copper rule. The plan to couple the Stochastic Human Exposure and Dose Simulation (SHEDS) and the Integrated Exposure Uptake Biokinetic (IEUBK) models is good since they are recognized tools with a long history of use. The current approach appears to be one where exposure from all other sources of lead will be determined and any remaining exposure allowance will be allocated to water. We suggest an approach where all exposure pathways are defined and opportunities to reduce exposure from each of those pathways are prioritized. A more holistic approach will offer greater societal benefits for the costs involved.

9. The SSWR Subcommittee recognizes ORD's work to support the Office of Water for drinking water health advisories for perfluorinated alkyl substances (PFAS) toxicity studies and best available technologies for DW treatment. The Subcommittee supports the actions to address and advance the understanding of how to deal with PFAS contaminated water of critical importance. This is especially important given the current lack of understanding of how to treat shorter chain substitutes and the increasing presence of PFAS in drinking water sources.

10. Current and impending regulations require reduction in the formation of disinfection by-products and have generated growing interest in the use of UV disinfection. UV disinfection is the process of using ultraviolet light to alter cellular molecular components essential to cell function. Significant research is proposed to expand the understanding of UV disinfection of drinking water and resource water and to optimize treatment processes. Research is also proposed on the health impacts of disinfection by-products (DBPs) associated with traditional disinfection processes. However, no research is proposed to investigate the potential chronic toxicity associated with UV disinfection. The SSWR Subcommittee recommends ORD assess the current body of knowledge regarding human health effects from by-products of UV irradiation and determine if additional research is needed.

11. The vast majority of drinking water systems produce water safe for human consumption at the point where the water enters the distribution system. How water quality changes as the water flows through the distribution system to the end user is an area where significant discovery is still occurring.

ORD should continue to define research activities that expand our understanding of how to manage drinking water after it leaves the treatment plant and limit degradation of water quality in the distribution system. This includes the part of the distribution system within existing buildings where conservation measures have been implemented that reduce the quantity of water being used. Premise plumbing designed to accommodate higher flows may experience negative water quality changes at reduced flows that could results in waterborne disease outbreaks.

It will be important to focus this research on areas of new learning. Simply developing a decision support tool to "right-size" plumbing and distribution systems with the "right" materials is not the type of activity recommended. Instead, increased understanding of the benefits of looped systems versus dead-end pipes and the identification of materials that help preserve water quality is recommended. In addition, building owners need information that demonstrates how the additional cost of a well-designed system is justified by the water quality benefits. We recommend carefully focusing this task on deliverables that build understanding of actions needed to preserve water quality beyond the traditional actions such as flow rate and frequency of use.

Recommendations: Project 1

Recommendation 1.1: ORD's health effects research should focus on the technical aspects of potable reuse and quality of the water being treated, and not confuse the analysis with the variability surrounding whether the reused water enters the potable water supply directly or indirectly.

Recommendation 1.2: If UV disinfection of resource water continues to be a major area of research, planning of health effects research on byproducts should also begin.

Recommendation 1.3: ORD should continue to define research activities that expand our understanding of how to manage drinking water after it leaves the treatment plant and limit degradation of water quality in the distribution system.

Project 2: Next Steps – Water Systems Technology Advancements

Lead Author: Shahid Chaudhry

In recognition of the many challenges facing the U.S. water systems, the SSWR StRAP recognizes the importance of advancing a variety of new or improved technologies for water treatment and monitoring, and for risk reduction. Project 2 comprises the following Tasks.

- Task 2A: Treatment, Monitoring and Risk Assessment for Water Reuse
- Task 2B: Novel Monitoring Technologies for Occurrence, Exposure and Effects for Individual and Groups of Contaminants
- Task 2C: Water Treatment Technologies for Enhanced Reduction of Chemical and Microbial Risks
- Task 2D: New methods and tools for measuring human and ecological health risks from chemicals (individual and mixtures) and pathogens

Each task involves numerous activities and each activity has its own outputs. These tasks, associated activities, and respective outputs are briefly discussed below:

Task 2A: Treatment, Monitoring and Risk Assessment for Water Reuse

One of the highlights of research conducted within this Task involves the development of anaerobic membrane bioreactors (AnMBR) technologies for resource water (RW) treatment, combined with direct potable reuse (DPR). The technology appears to be quite effective at extracting unwanted nutrients from RW with minimal energy consumption, and can be integrated into DPR treatments. Other membrane technologies are being tested for water recovery and salt rejection. The Subcommittee finds this area of research highly important and believes efforts to move these technologies into real world uses should be pursued.

The Subcommittee found the research on producing media from drinking water for multiple uses such as neutralization of acidic waste streams, treatment of air pollutants, and adsorption of multiple contaminants from various liquid streams, to be fruitful and supports its continuation.

Finally, completion of efforts to identify a denitrifying bacterial group which removes nitrogen and accumulates phosphate at very high levels under low-DO conditions is an outstanding achievement.

The remaining activities were found to be well designed to achieve the StRAP objectives. The Subcommittee believes this area of research is clearly on track, and should be maintained.

Task 2B: Novel Monitoring Technologies for Occurrence, Exposure and Effects for Individual and Groups of Contaminants

Next-generation analytical and monitoring tools to utilize advanced technologies for regulatory purposes is a highlight of this research area, as is the work to develop a toolkit to assess the contribution of component chemicals and subgroup mixtures to the toxicity of complex mixtures. These research areas are crucial to achieving StRAP objectives, and should be maintained.

Small Water Distribution Systems will benefit from developing monitoring processes to quantify microbial contaminants in small, consecutive, DW distribution systems.

Task 2C: Water Treatment Technologies for Enhanced Reduction of Chemical and Microbial Risks

Engineering design guidance and full scale application of biological ammonia systems, development and pilot-scale demonstration of an innovative biological nitrate removal process, and treatment of emerging contaminants using UV light, percarbonate, and peracetic acid appear to be effective, and can perhaps be moved to the application stages.

An effort in the small systems category focuses on the development of communication materials and case studies using latest treatment options available for small systems is well-directed and is encouraged.

Efforts to develop standard operating procedures for sample collection, preservation and analysis for emerging chemical contaminants in resource water and biosolids have much practical value.

Development of holistic approaches to providing safe water to consumers by improving plumbing systems and plumbing configurations during construction, additions, and changes does not appear to moving fast, but it is of great importance and deserves continuing support.

Task 2D: New methods and tools for measuring human and ecological health risks from chemicals (individual and mixtures) and pathogens

Research on exposures and effects posed by contaminants in source, drinking, waste and re-used water will result in developing the scientific basis for sound regulatory decisions on priority, unregulated waterborne contaminants. This work is foundational and is essential groundwork for future regulation and the provision of safe drinking water.

Efforts to develop approaches to evaluate human health response to waterborne contaminants includes investigating an innovative salivary immunoassays to link health effects with drinking water exposures for future drinking water regulations. The Subcommittee endorses this activity. If successful, the assay could be very useful as a public health tool.

In addition, extramural research is underway on water infrastructure sustainability, demonstration of innovative drinking water treatment technologies in small systems, and on subjects of mutual interest through collaborations and interagency agreements.

The Subcommittee found the research content of Project 2 to be very impressive. It was difficult to identify any significant gaps, and we commend EPA's solid efforts regarding technology advancement.

Additional Comments

The Subcommittee also recognizes that the research efforts are prioritized and selected in consultation with and based on the needs of regional offices and research partners. In this context, apparently on-going projects are in line with stake-holders' needs. Looking at on-going projects, it seems that research is appropriate for identified needs, but without clearly specifying which projects focus on short term issues and which ones on the long term. Efforts should be made to divide more carefully technology research efforts according to the timelines for completing and implementing developments. This would provide clarity regarding technology development and short and long-term needs for these technologies.

The Subcommittee understands that EPA's, and for that matter SSWR's, annual budget varies from year to year and continuation of on-going research and development (R&D) programs sometimes may be severely affected. However, there are many other federal agencies involved in water related research programs. It would be helpful if SSWR develops a thorough profile of all of these activities, and thereby achieve a better understanding of the total impact and effectiveness of these many federal programs.

As we move forward, several broad problems that limit water utilization will become important. First, water desalination seems to be increasing for several reasons: (1) droughts result in increased salts in rivers, to the point of being problematic in the West (e.g., Colorado River); (2) salts are concentrated in some desert cities, such as Phoenix and El Paso, where ground waters often exceed 1000 mg/L TDS; (3) seawater intrusion is a global problem, likely to become much worse due to sea level rise and high withdrawals from near-coastal freshwater aquifers; and (4) in cold climates, application of road salt over the past several decades has caused salt levels in aquifers to increase. Learning to treat and use saltier waters may be essential for cities of the future. Second, in rural areas particularly, nitrate has now become a problem not only in domestic wells, but also in some community water supplies. We can expect that nitrate problems in groundwater will steadily become worse as the use of high rate N fertilization continues. Finally, there is growing concern regarding contaminants of emerging concern (CECs) as well as organic contaminants of known concern (pesticides, etc.). These concerns will require considerable research to develop water treatment technologies for the 21st century. Doing this research is urgent, because we will need to replace much water infrastructure within the next few decades. The many activities being undertaken under Task 2 will be important contributors to meeting these evolving challenges.

Recommendations: Project 2

Recommendation 2.1: Efforts should be made to divide more carefully technology research efforts according to the timelines for completing and implementing developments. This would provide clarity regarding technology development and short and long-term needs for these technologies.

Project 3: Transformative Approaches and Technologies

Lead Author: Shane Snyder

Project 3, Transformative Approaches & Technologies, contained 4 Tasks (A-D):

- Task 3A: System Approaches;
- Task 3B: Monitoring & Analytical Methods;
- Task 3C: Treatment;
- Task 3D: Health Effects.

Task 3A: System Approaches for Assessment of Transformative Fit-for-Purpose and Resource Recovery-Based Water Systems

Development of a transformative technology toolkit library: Key outputs from this toolkit library would include information regarding newer technologies, including aerobic membrane bioreactors (AeMBR), anaerobic membrane bioreactors (AnMBR), anaerobic digestion, constructed wetlands, struvite, and 5-level nutrient removal treatment train. Example data was shown which compares AeMBR and AnMBR at scaling levels (0.05-10 MGD) and AnMBR at 35 and 20 degrees C. Another example of 5-level nutrient removal trains compared for cumulative energy demand. Without question, AnMBR is an important technology for consideration, which may lead to savings in energy and improvement in water quality. The same is true for the 5-level nutrient removal, which compares (generally) technologies for achieving various levels of phosphorus and nitrogen removal and compares to cumulative energy demand. Both examples are of great value to water agencies in the USA; however, it is unclear how these examples are applicable to water quality scenarios in various geographies. While the BOSC Subcommittee assumes the actual toolbox will be far more comprehensive, and as the current two examples seem promising, far more data will be needed to be certain these examples are applicable to water qualities encountered in various regions of the USA. It is also unclear how EPA will define a “transformative” technology (for instance, 5-stage Bardenpho is already operating at full-scale in some cities). How does EPA define “transformative” and how can EPA ensure that examples will be applicable across broad geographies and water qualities?

Metrics, Tools Improvement, and Expansion: Three examples were provided as simple bullet points, risk assessment (Log reduction targets for non-potable water reuse), life cycle assessment (water scarcity index), and energy (loop and recycling pathway). The BOSC Subcommittee commended EPA for proposing to develop log-reduction values (LRVs) for non-potable reuse, but strongly advocated that EPA also consider developing LRVs for potable water reuse. Further, EPA should also consider an evaluation of the LRVs used and particularly investigate the assumptions of pathogen occurrence in raw sewage. These values may also be informative for non-potable reuse.

Insufficient information was provided to the Subcommittee on the water scarcity index and energy topics to allow provide meaningful comment.

System Analyses Comparing Conventional and Transformative Community Water Systems and Applications in Community-Based Case Studies: This project focuses on comparison of centralized (Cincinnati, OH) to de-centralized (San Francisco, CA) to a small-scale community system (Bath, NY). The committee notes that working with San Francisco on alternative scenarios is a good example of partnership with a municipality. The evaluation of centralized and decentralized systems is an excellent topic that could be transformative. EPA is encouraged to expand this work to consider other geographies and water qualities in the future. The resource recovery small system project also has great promise and is generally understudied. EPA should continue, and potentially expand, research efforts in this area.

Task 3B: Novel Detection Tools for Systems Applications

Development of a knowledgebase and proof-of concept for AOPs and biosensor technology to capture the presence of major classes of contaminants that pose a risk to human health: This project brings together a diversity of stakeholders to discuss adverse outcome pathways (AOPs) along with biosensor technologies. The BOSC Subcommittee believes that use of bioassays/biosensors to rapidly screen chemical mixtures in water for AOP toxicity is of great importance. This is especially true in potable water reuse where the “source” water is known to contain highly complex and unpredictable mixtures of chemicals and subsequent water treatment techniques also can form potentially hazardous transformation products (aka by-products). We believe that this type of work is critical for the advancement of potable water reuse and for more comprehensive monitoring of conventional water resources. Partnerships from the U.S. Geological Survey (USGS), Water Environment Federation (WEF), U.S. Army, National Oceanic and Atmospheric Administration (NOAA), and Cincinnati Water Works is encouraging. However, EPA would also benefit by establishing additional partnerships with NIH/NIEHS, Academic Institutions, and possible commercial entities who already produce technologies that are implementable.

The BOSC Subcommittee recommends that EPA also should consider non-in situ bioassay screening tools which could provide relatively fast information but without the necessity/complexity of being on-line or field deployable. While field deployable and on-line offer even faster resolution, it is likely not a necessity for most water resource screening scenarios, thus we recommend that EPA not exclude off-line rapid high-throughput bioassays in this evaluation.

Design and Development of an AOP Targeting Biosensor: This task follows on to the previous knowledgebase and develops novel sensor systems. The BOSC committee’s comments to this task are generally the same as provided to the first (above).

Task 1C (assumed 3C): Case Studies & Demonstrations of Transformative Approaches for Water Systems & Water Reuse

Demonstration and Evaluation of Decentralized Wastewater Treatment for Water Reuse: This task includes the demonstration of an AnMBR in collaboration with the Department of Defense (DoD). A trailer-mounted AnMBR pilot was installed at Fort Riley, Kansas, in June 2016. The BOSC committee believes these types of partnerships are important to leverage resources and to provide additional data for larger dissemination within the water community and thus continue and further expanded. The long-term goal to show performance data from the pilot is reasonable. The short-term goal for “sewer mining using different treatment technologies and different scales and population densities” is not clear. This short-term goal is admirable, but it is not clear how the EPA research program is addressing this goal as a FY16 product. More details would be required for the BOSC to provide additional feedback on the short-term goal.

Development of Improved Guidance for Non-Potable Water Reuse: The BOSC committee has discussed this topic previously above.

The BOSC committee believes that working with NWRI can provide additional benefit; however, we suggest EPA consider developing independent guidance with their own experts and independent experts retained under FACA rules.

The BOSC further believes that both potable and non-potable liquid release test (LRTs) from EPA would provide large benefit to U.S. agencies that are seeking to reuse water. The BOSC Subcommittee believes that development and validation of more appropriate pathogen surrogates is of high-value to U.S. water systems. These data extend beyond potable and non-potable reuse and should be considered for conventional drinking water systems in the USA, especially in consideration of those utilities drawing source waters from wastewater impacted sources.

The BOSC recommends EPA to consider further investigation of molecular (i.e., PCR) methods to infectivity and culturable techniques. However, the use of molecular techniques alone could lead to erroneous decision making since non-viable organisms are still detectable.

Case Studies and Demonstrations of Transformative Approaches for Water Systems and Water Reuse (note - listed as a second "2" in PowerPoint provided): This objective includes low-impact development (LID) and best management practices (BMPs) for capturing rain and storm water for aquifer recharge in the arid southwest USA. Within this objective, EPA has provided an example of an aquifer recharge technology demonstration at Fort Irwin, California. The BOSC committee believes, as stated previously, that these types of partnerships with DoD entities are likely to yield synergistic value.

Task 3D: Water Technology Innovation Clusters

Leveraging technology clusters to solve water challenges and create economic opportunity: Several example technologies and benefits were described. The Cincinnati Water Cluster was shown as an example of broad partnerships between EPA, local and state government agencies, academia, and the private sector. The BOSC committee sees great value in the cluster coordination and within the project examples provided.

We suggest EPA consider ways to increase transparency as to how, specifically, interested parties can cooperate in technology testing by EPA and how conflicts of interest can be avoided in such circumstances (i.e., when multiple companies produce the same type of equipment – how does EPA select a partner to go forward).

Two objectives were listed, but they seem intertwined and indistinguishable.

Task 3E: Approaches to Assess the Overall Health of a Community

The role of waterborne and environmental pathogens as a trigger for Type 1 Diabetes: This project sounds transformative towards better understanding of diabetes. We recommend that EPA consider collaboration with the Centers of Disease Control and Prevention (CDC) and the National Institute of Environmental Health Sciences (NIEHS) for this project.

Characterizing Waterborne Disease through Outbreak Surveillance: This project seems to be of very high value and the BOSC Subcommittee looks forward to the anticipated publication. We are particularly intrigued by the figure suggesting chemical association to outbreaks, it is unclear if this is about chemical contamination or chemicals associated with disinfection.

Waterborne Disease Associated with Distribution System Deficiencies: This is yet another project that seems to be of great value; however, only sparse details were provided. Water pressure is well known to be of great importance to the protection of public health from drinking water exposures. Further linking of water contamination from low-pressure events is of value.

Task 3F: Human & Ecological Health Impacts Associated with Water Reuse & Conservation Practices

STAR Grants: Five STAR grants were awarded and the titles provided to the BOSC Subcommittee. The committee believes these topics are of value towards moving forward on water reuse topics; however, the link to water conservation and ecological health impacts are not clear. The committee notes that the explanation of how STAR grants interface with ORD needs was improved and additional information regarding these projects will be of great interest forward. However, the links to ecosystem health and conservation are not clear. EPA is encouraged to increase the STAR grant program resources going forward as the program provides clear synergy with leading research groups within the USA.

Additional Comments

The BOSC Subcommittee greatly appreciated the opportunity to meet with EPA staff to learn more about transformative research endeavors. The BOSC Committee expressed concern that very little, if any, information was provided relative to ecological receptors. Specifically, how does the work at Mid-Continent Ecology Division Laboratory (Duluth), and others, tie into the transformative research programs of ORD? In terms of water reuse, most of the research to date indicates potential impacts to aquatic organisms from wastewater discharges, while impacts to human health (from chemicals) seems far less likely.

The BOSC Subcommittee suggests that EPA provide more information as to how ecological impacts are being considered by the ORD within the transformative research framework.

Recommendations: Project 3

Recommendation 3.1: EPA should consider an evaluation of the LRV's used and particularly investigate the assumptions of pathogen occurrence in raw sewage. EPA is developing various pathogen identification and quantification techniques, the and we recommend these be applied to raw sewage to better understand the types and quantities of pathogens occurring to support better decisions on LRVs for potable water reuse.

Recommendation 3.2: EPA should consider non-in situ bioassay screening tools which could provide relatively fast information but without the necessity/complexity of being on-line or field deployable. While field deployable and on-line offer even faster resolution, it is likely not a necessity for most water resource screening scenarios, and EPA should not exclude off-line rapid high-throughput bioassays in this evaluation.

Recommendation 3.3: The BOSC recommends EPA to consider further investigation of molecular (i.e., PCR) methods to infectivity and culturable techniques.

Summary List of Recommendations

Project 1

- **Recommendation 1.1:** ORD's health effects research should focus on the technical aspects of potable reuse and quality of the water being treated, and not confuse the analysis with the variability surrounding whether the reused water enters the potable water supply directly or indirectly.
- **Recommendation 1.2:** If UV disinfection of resource water continues to be a major area of research, planning of health effects research on byproducts should also begin.
- **Recommendation 1.3:** ORD should continue to define research activities that expand our understanding of how to manage drinking water after it leaves the treatment plant and limit degradation of water quality in the distribution system.

Project 2

- **Recommendation 2.1:** Efforts should be made to divide more carefully technology research efforts according to the timelines for completing and implementing developments. This would provide clarity regarding technology development and short and long-term needs for these technologies.

Project 3

- **Recommendation 3.1:** EPA should consider an evaluation of the LRV's used and particularly investigate the assumptions of pathogen occurrence in raw sewage. EPA is developing various pathogen identification and quantification techniques, the and we recommend these be applied to raw sewage to better understand the types and quantities of pathogens occurring to support better decisions on LRVs for potable water reuse.
- **Recommendation 3.2:** EPA should consider non-in situ bioassay screening tools which could provide relatively fast information but without the necessity/complexity of being on-line or field deployable. While field deployable and on-line offer even faster resolution, it is likely not a necessity for most water resource screening scenarios, and EPA should not exclude off-line rapid high-throughput bioassays in this evaluation.
- **Recommendation 3.3:** The BOSC recommends EPA to consider further investigation of molecular (i.e., PCR) methods to infectivity and culturable techniques.

APPENDIX A: MEETING AGENDA

TIME	TOPIC	PRESENTER
Wednesday, August 24, 2016		
8:00 – 8:15	Registration	
8:15 – 8:30	Welcome, Introduction, and Opening Remarks	Joe Rodricks, Chair
8:30 – 10:00	2016 EPA Drinking Water Workshop: Small Systems Poster Session and Meet the Experts (Regency A and Regency BC)	
10:00 – 10:15	*Break*	
10:15 – 10:30	DFO Welcome and FACA Rules	Tom Tracy, DFO
10:30 – 11:00	Welcome and Remarks from Tom Burke	Tom Burke, ORD Deputy Assistant Administrator, EPA Science Advisor
11:00 – 11:45	Discuss meeting objectives, Water Systems charge questions, and poster session	Joe Rodricks, Chair; Suzanne van Drunick, NPD; Tom Tracy DFO
11:45 –1:00	*Lunch*	
1:00-1:30	Partner Input: EPA Office of Water and Regions	Peter Grevatt-Director, OW-Office of Groundwater and Drinking Water; Carole Braverman-Region 5 Regional Science Liaison
1:30 – 2:30	Overview and Deep Dive into Regulatory Support Project 1	Christopher Impellitteri, Associate National Program Director, SSWR
2:30 – 3:30	Overview and Deep Dive into Technology Advances Project 2	Christopher Impellitteri, Associate National Program Director, SSWR
3:30 – 3:45	*Break*	
3:45 – 4:45	Overview and Deep Dive into Transformative Approaches and Technologies Project 3	Jay Garland, Project Lead 6.03
4:45 – 5:00	Wrap-up and adjourn	Joe Rodricks, Chair; Tom Tracy, DFO

Thursday, August 25, 2016		
8:00 – 8:15	Registration	
8:15 – 8:25	DFO Reconvene meeting, attendance	Tom Tracy, DFO
8:30 – 9:45	Small Systems Workshop: WINSS and DeRISK Status Reports (Regency ABC Ballroom)	
10:00 – 10:30	Public Comment Period	Tom Tracey, DFO
10:30 – 11:00	NCER STAR and National Priorities Water System Grants	Michael Hiscock, NCER
11:00 – 11:30	2016 BOSC EC Report Discussion	Joe Rodricks, Chair, All
11:30 – 12:30	Water Systems Charge Questions Discussion	Joe Rodricks, Chair, All
12:30 – 2:30	*Subcommittee Working Lunch*	
2:30 – 3:00	Committee Membership, Next Subcommittee Meeting, January BOSC EC Meeting	Joe Rodricks, Chair, Suzanne van Drunick, NPD, Tom Tracy, DFO
3:00	Adjourn meeting	