SSWR Project Charter
Water Systems – Project 1 (6.01)

Project Title: Current Systems and Regulatory Support

Project Lead (PL): Thomas Speth, PhD. (NRMRL), Ann Grimm, PhD. (Deputy Project Lead-NERL)

Project Development Team Members: Carolyn Acheson, Bob Bastian (OWM), Thomas Baugh (Region 4), Maura Donohue, Nicholas Dugan, Susan Glassmeyer, Ann Grimm, Evelyn Hartzell, Angela Page, Nicole Shao (OSP), Jane-Ellen Simmons, Thomas Speth, Phil Zahreddine (OWM), Kevin Weiss (OWM)

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Project End Date: 9/30/2019

Executive Summary

This project aims to develop and evaluate data, approaches, and technologies that will support the promulgation and implementation of federal water regulations and guidance while also addressing regional, state, and community issues of concern. It fits within a construct that relies on each Topic 6 project informing all of the Outputs included in this Topic. The construct relies on all projects working as an integrated whole.

Research Project Description

This project within Topic 6 was developed in recognition of the critical support that the research laboratories of ORD provide to the Office of Water, the Regions, and water utilities to help current water systems in providing safe drinking water and properly treated wastewaters. Concurrent with this support is the requirement to provide the Office of Water with essential information on human health risks posed by contaminants (microbial, chemical, and radiological) associated with water systems, including those contaminants found in finished water that are either not removed by treatment, are formed or altered during water treatment and then later affected by residence time in water systems, or those impacted by wastewater treatment processes. The optimization of water systems involves understanding the impact of currently available technologies as well as process advances to address a variety of water

quality challenges. Although the approaches will address concerns that support current and near future regulatory processes and therefore could be transformative in nature, the approaches in Project 6.01 will focus on market-ready technologies and processes. The project considers advances in a number of water-related areas including resource recovery, treatment, monitoring and analytical measurements, collection and distribution systems, and risk assessment. The absolute driver for Project 6.01 is the necessity that ORD provide essential support to the Office of Water to allow it to fulfill its regulatory mandates and obligations such as those for the Safe Drinking Water Act (SDWA) and Clean Water Act (CWA).

Project 6.01's specific objectives are to: 1) Supply research results to support federal regulations and guidance, 2) Provide strategies to Regions, States, and communities for improved regulatory compliance and 3) provide rapid and effective emergency response where appropriate (e.g. water system shut-down due to source water contamination). These objectives include working with contaminants that undergo periodic Congressionally-mandated regulatory cycles of review such as disinfection byproducts (DBPs) and those on the Contaminant Candidate List (CCL) as well as other contaminants of concern (including groups of contaminants). Other objectives include evaluating novel in-plant wastewater peak flow management technologies and processes for compliance with wastewater treatment regulations and their impact on pathogen control.

Research efforts will focus on developing (1) analytical tools for more comprehensive and rapid assessment of chemicals and pathogens of concern, (2) the necessary data to develop or improve estimates of human health risk and inform risk management, and (3) treatment performance and cost data for compliance with regulations and for potential future regulatory actions and rule implementation. Other factors affecting adoption of market-ready technologies and approaches will also be considered when appropriate, including public acceptance, regulatory and policy barriers and incentives, and business and economic development potential.

The analytical tools research will develop methods for detecting and quantifying chemical and microbial contaminants, particularly focusing on CCL and other contaminants for which adequate health effects data are available for regulatory determination but exposure and/or occurrence data are lacking. In addition, contaminants for which sampling is mandated under the Unregulated Contaminant Monitoring Rule (UCMR), or that are of concern to utilities will also be a priority. To support the development of these new methods, some basic development and evaluation of new technologies will be done and new data on environmental contaminants will be collected. Another effort will be directed toward analytic tool development for process control and quantitation of efficacy for wastewater collection systems, wastewater and drinking water treatment systems, drinking water distribution systems, and natural systems (rivers) used as de facto treatment between wastewater outfalls and drinking water intakes. Finally, approaches to assess ecological and human health risks and their cumulative effects through the development of quantitative methodological processes (e.g. decision analysis tools, Quantitative Microbial Risk Assessment (QMRA), Expert Systems)

will be advanced. These models can be focused to achieve maximum public health impact through the monitoring and analysis of both qualitative and quantitative human health data.

The human health risk research will involve 1) developing an understanding of the human health risks associated with consumption and use of disinfected water and how those risks change with changes in source water quality and disinfection processes; and 2) collecting and determining exposure and effects data for CCL contaminants, focusing on those for which exposure data are available, but health effects data are lacking such as those mandated under the UCMR, or groups of contaminants and for contaminants of concern to existing utilities. With regard to the latter, some states have existing rules and guidance for contaminants that are not regulated at the national level. It is the intent that the human health work located within Topic 6 focus on those contaminants contained in waters affected by treatment systems, such as drinking water treatment, storage, and distribution systems, and wastewater collection and treatment systems. Particular focus will be made on contaminant exposures through drinking water (e.g. chemicals, microbes, radionuclides) and contaminants formed (e.g. disinfection byproducts) in water during disinfection of drinking water. Attention will be focused on contaminants present in intake water that are transformed during the disinfection process. Topic SSWR3 (Project 3.02-Science to support new or revised water quality criteria to protect human health and aquatic life) is expected to handle the ecosystem health effects work and human recreational exposure research. Due to the overlap between developing human health risk data between the CWA and the SDWA a strong effort will be placed on coordinating health effects work in Topic 6 and Topic 3 (Project 3.02). Additionally, human health risk efforts in this project will be coordinated with projects in Chemical Safety for Sustainability involving computational toxicology and adverse outcome pathway modeling.

Both drinking water and wastewater research priorities include evaluating the performance and cost of currently available technologies to manage contaminants of concern. Social and economic factors affecting technology deployment will also be considered. This research is needed for contaminants undergoing regulatory development or guidance recommendations (e.g. best available technology determination) and those that are regulated but have many systems not in compliance. In drinking water research, particular emphasis will be placed on the needs of small systems due to the cost for these systems and the difficulty for them to comply with existing and new regulations. Also, wastewater and drinking water research is needed for determining the optimal practices and approaches for collection and treatment of wastewater and distribution of drinking water, as well as incentives and barriers to their implementation. This research includes better approaches to handle stormwater events; approaches to minimize deleterious effects on distribution systems (e.g. nitrification, biofilms, pathogens); the impact of aging water infrastructure; and issues related to premise plumbing (e.g. Legionella) and on-site treatment. Research is also needed to identify opportunities to reuse waters, recover resources, and increase the energy efficiency of treatment systems. Additionally, research is needed to evaluate novel high rate in-plant wastewater peak flow treatment technologies for compliance with wastewater treatment requirements and for their impact on downstream disinfection treatment. Finally, research is needed to assess the disposal and reuse options for residual streams. An example of linking current treatment and

reuse opportunities is to quantify chemical and pathogen removal through existing wastewater treatment and reuse facilities. This research will help develop guidance for communities who are interested in either direct potable or indirect water reuse. Also, water conservation projects need to be evaluated.

Short-term needs of the Program Offices, Regions, States, and communities will be rapidly addressed via flexible planning, providing timely input to inform regulatory and guidance issues to the agency. Therefore, much of the research support to the communities, States, Regions, and Program Offices (e.g., demonstrations, Regional Applied Research Effort (RARE) projects, Water Technology Innovation Cluster (WTIC) projects, EPA/DOE collaborations, support to regulatory development, or Six-Year Review projects) would be grouped within Project 6.01. The cyclical nature of the drivers for much of the research under Topic 6 should be noted. For example, the National Primary Drinking Water Regulations (NPDWRs), CCL, and UCMR undergo mandated periodic review and regulation cycles. Specific Office of Water (OW) priorities are listed in the Outputs section below for each of the four outputs associated with this topic. This project will inform, and be informed by, the other projects within this topic: 2) Next Steps: Technology Advances, and 3) Transformative Systems and Approaches. The goal is to work as a collective effort across the entire Topic. The Project Leads will work closely with one another and identify linkages across projects.

The research in Topic 6 has connections with the other research programs. Particularly, the energy footprint reduction and mitigating greenhouse gas work has connections to the Air Climate and Energy program. The resiliency and extreme weather events work has connections to the Homeland Security program. The monitoring protocols and models work has connections to the Chemical Safety for Sustainability (CSS) program. Human health risk data development will be linked with research in the Human Health Risk Assessment program. Finally, the demonstrations and acceptance at the community level, and testbed research links with the Sustainable and Healthy Communities program.

This project will also address priorities for New Climate Change and Water Research in support of the National Water Program Climate Strategy. Specifically, Priority 2: Effects of Climate Change on Pathogens and Pathogen Treatment, Priority 9: Facilitating Next Generation Water Reuse to Build Climate Resilience of Public Water Systems, and Priority 6: Climate Impacts on Drinking Water Quality. Specific areas to address include water reuse resilience, and effects of climate change on DBP formation.

Project Impact

This project will supply EPA Program, Regional offices, and communities with data, approaches, and technologies to inform federal water regulations and guidance, while also addressing regional, state, and community issues of concern. Project research includes risk assessment (e.g., used in development of MCL standards for drinking water contaminants) and risk

management (DW Treatment Technologies to meet MCL requirements and action levels, including priority contaminants and groups of contaminants). It also includes performance evaluation of select novel in-plant peak wastewater flow treatment technologies for compliance with wastewater treatment requirements and effects on downstream pathogen disinfection. The needs are particularly acute for small systems as discussed above. Short-term needs of the Program Offices and communities can be rapidly addressed via flexible planning, providing timely input to influence regulatory and guidance issues to the agency. Collaborations with communities, businesses, economic development organizations and other stakeholders will be employed to foster innovation, improve technology transfer, streamline adoption, and accelerate the deployment of market-ready technologies and systems. Research support to the communities, states, regions, and program offices would be grouped within Project 6.01. This work would influence Project 6.02 (Next Steps: Technology Advances) and Project 6.03 (Long Term: Transformative Systems).

Project Scope

Methods and Tools for Contaminant Detection and Risk Assessments: Methods and tools will be developed to more effectively detect and quantify waterborne pathogens and chemicals that constitute public health risks in built infrastructure. This work will also include a qualitative and quantitative assessment of waterborne disease, the identification of populations at risk, and an improvement of software tools used to facilitate and integrate pathogen and chemical risk assessments and other analyses at a variety of scales throughout the nation. (See Outputs 1 and 2 below).

Assessment of the Impacts and Approaches to Control the Most Important Waterborne Contaminants Associated with Built Infrastructure: This scope includes collection and treatment of wastewater, and the treatment and distribution of drinking water. For drinking water systems, specific emphasis will be placed on small systems and consecutive systems such as hospitals, schools, and mobile home parks. Distribution system work will include efforts on water storage tank sediments and management. For wastewater, emphasis will be placed on water reuse guidance and resource recovery. The treatment and disposal of residuals will be evaluated for both drinking water and wastewater. Emphasis will also be placed on evaluating novel in-plant wastewater peak flow treatment technologies for compliance with wastewater treatment regulations, impacts on downstream disinfection processes, and energy efficiency. (See Output 3, below).

Health Information on Contaminants in Water: Focused attention will be given to: 1) those contaminants that are deemed high priority based on existing, but incomplete health information (an example is an association observed in an epidemiology study between exposure to the complex mixture of chemicals formed during disinfection of water and an adverse human health outcome); 2) understanding the influence of water characteristics that impact the suite of DBPs formed during treatment and the toxicity of the mixture; and 3) developing and using predictive models for both single contaminants and groups. (See Output 4, below).

Project Structure and Rationale

The tasks within Project 6.01 will relate to the four outputs relevant to this Topic (see Table 1). The outputs are further defined in the sections below. This approach is consistent with the other projects within Topic 6. The rationale is to integrate all of Topic 6 not only across tasks, but across projects such that each project will feed into the four outputs.

	Project 6.01. Current Systems and Regulatory Support	Project 6.02. Next Steps: Technology Advances	Project 6.03. Transformative Systems and Approaches
Output 1. Integrated Sustainability Assessment Tools for Water Systems and Resource Recovery	Task(s)	Task(s)	Task(s)
Output 2. Advanced Monitoring and Analytical Tools	Task(s)	Task(s)	Task(s)
Output 3. Performance Data on Technologies and Integrated Systems	Task(s)	Task(s)	Task(s)
Output 4. Advanced Approaches for Measuring Health Risks	Task(s)	Task(s)	Task(s)

Table 1. Topic 6-Water Systems Project Structure

The proposed approach is one in which exposure/occurrence/monitoring, health and engineering disciplines work to form integrated cross-disciplinary teams to enhance the provision of high quality water. The current state of the science is that large gaps often exist between our knowledge of exposure and effects. Much still needs to be understood about engineered water systems with respect to occurrence/exposure to waterborne chemicals, microbes, and human health effects that might occur due to these contaminants. Further, exposure and/or health effects can be due to either individual compounds or mixtures. Very importantly, the typical situation is that if exposures are known or estimated, the human health risks associated with these exposures are not known. Similarly, when human health effects are observed, the underlying contaminant(s) producing such effects are often not known. As regulatory decisions require both a quantitative dose-response understanding of toxicity/infectivity and information on the likelihood of contaminant occurrence in water, the

rate at which decisions can be made is seriously impacted. These gaps make it difficult to either identify the chemical or microbial contaminants underlying observed human health effects or to predict potential effects from known or estimated exposures to individual or mixtures of contaminants. By addressing these gaps, it may be possible to prioritize chemical and microbial contaminants as potential drivers of health effects, which can be used to direct corrective actions such as treatment or other approaches that will identify and evaluate technologies for removal of those contaminants deemed a high priority. The cost and sustainability of these treatment systems or other approaches can then be evaluated to estimate the costs/benefits of a regulation. This is especially important for small systems. In addition, addressing the research gaps will provide ways to prioritize individual contaminants and contaminant mixtures for risk assessment. Thus, the proposed approach is to integrate exposure with human health, to incorporate advances in current technologies to improve both experimental and predictive capabilities, and to evaluating the existence, cost, and effectiveness of existing and market-ready innovative technologies to remove contaminants of concern. Conducting this research in collaboration with the other Topic 4 projects ensures that decisions are made in a way that ensures long-term success in achieving both human and environmental standards at a cost that can be borne by communities.

Measure of Success

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2018)

- We expect to provide tools to assess the sustainability of reuse and recovery infrastructure.

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk (2018)

- We anticipate the integration of monitoring methods, modeling, and toxicity indicators to produce assessments that can be used to: (1) identify potential improvements needed in wastewater and drinking water treatment plants, and other parts of the built infrastructure; (2) target human disease causing pathogens, weighing dosing with potential health burden, including evaluation of the potential role of water-associated microorganisms on chronic disease epidemics in the US (e.g., diabetes, obesity, cystic fibrosis, kidney disease), and integration of exposure/dose characterization with predictive models, and (3) securing and analyzing human health data to estimate a population-based, public health burden of waterborne disease.
- We also aim to provide a list of pathogen methodologies that can be implemented in a variety of matrices and that provide direct detection and/or quantification of pathogen concentrations.
- We expect to provide an initial evaluation of the impact of exposure to contaminants (chemical, microbial, and radiological) in engineered water systems in susceptible populations.

Output 3. Develop and demonstrate individual technologies and integrated systems to improve the collection, treatment, and distribution of water and the recovery of resources (2019)

- We expect to provide cost and performance data for use in OW's cost modeling for contaminants of regulatory interest.
- We expect to train state primacy personnel on regulatory issues, and market-ready technologies that can reduce the number of non-compliant water utilities.
- We expect to merge the Treatability Database with OGWDW's cost models to provide a transparent approach for estimating DW treatment costs.
- We expect to provide or evaluate data and assess performance of novel high rate technologies for peak wastewater flow treatment for compliance with wastewater treatment regulations, effects on downstream disinfection processes, and energy efficiency.
- We expect to provide pathogen removal data (including surrogates) through wastewater and reuse facilities for use in discussion with OW and others on log removal issues for treated water.
- We expect to demonstrate a market-ready smart collection system where stormwater can be routed through various parts of the collection system to avoid CSO outflow events.
- We expect to provide approaches to control biofilm-associated pathogens (e.g. Legionella) in distribution systems.
- We expect to provide guidance on point-of-entry treatment devices and other approaches for large buildings for the control of pathogens within the building's premise plumbing.
- We expect to provide data and guidance on the presence and release of accumulated contaminants in distribution systems for use in Total Coliform Rule six-year review discussions.
- We expect to provide data and guidance on the control of DBPs for various scales of systems, and how DBP occurrence and toxicity are altered by changes in either water treatment or changes in source water quality.
- We expect to provide data and guidance on the treatment and disposal of residuals from drinking water and wastewater facilities.
- We expect to provide rule implementation support for small systems to reduce noncompliance with SDWA rules.
- We expect to provide technical assistance to water systems and regions to help troubleshoot distribution system issues and water treatment.

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

- We expect to provide key health effects data that inform the regulatory process. For regulatory determinations, six year review (e.g. DBPs, chemical, microbial and

radiological contaminants), CCL, and emerging contaminants (including nanomaterials in collaboration with the CSS program), health data will be provided on individual and groups of contaminants that provide information on regulatory processes, advances in technological water systems engineering, risk management, and remediation decisions.

- For the current CCL list, we will provide data to fill key health effects gaps for chemicals that have or will have adequate exposure information, as the combination of adequate health and exposure data is required for determination of whether to delist or move toward regulation, with the measure of success being an increase in the number of CCL chemicals for which decisions are made.
- For DBPs, CCL and emerging contaminants, an additional measure of success is an increased ability to consider contaminants as groups of chemicals using existing methods and tools for developing groups, for predicting the expected toxicity of chemical groups and for determining the chemicals within the group responsible for the majority of the toxicity exerted by the group.
- We expect to develop a family of physiologically-based pharmacokinetic (PBPK) models for groups of DBPs, allowing for assessment of total internal dose and toxicity for the group using a common dose metric, and the impact of altering the concentrations of the chemicals.

Stakeholders (outside ORD):

The principal internal stakeholders for the SSWR program are Office of Groundwater and Drinking Water (OGWDW), Office of Science and Technology (OST), Office of Wastewater Management (OWM), Office of Chemical Safety and Pollution Prevention (OCSPP)/Office of Pollution Prevention and Toxics (OPPT) and the Regions. External stakeholders include the people of the United States, consumers of drinking water and users of community wastewater systems, the individuals and organizations responsible for providing these services, state and local regulatory and public health agencies and officials, technology developers, vendors, and the scientific community such as Water Reuse Research Foundation, Water Research Foundation, Water Environment Research Foundation, water technology clusters, and academia.

Outputs

Topic 6 includes four integrated outputs (listed below) for Project 6.01 as well as Project 6.02 - Next Steps: Technology Advances and Project 6.03 - Transformative Approaches and Technologies for Water Systems. Although much of how Project 6.01 will inform the Topic 6 outputs is described above, and in the Key Products Identified section to follow, a brief explanation of anticipated work within Project 6.01 for each of these Outputs follows.

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2018)

Output Description: Project 6.01 will inform this output by evaluating the efficacy of currently existing, and market ready, resource recovery water systems. These data will inform the assessment tools utilized in this output. Also, select data will be generated for currently used systems that do not employ significant resource recovery technologies. These data will be used as a baseline to evaluate the sustainability of market ready systems studied herein, and the novel technologies and approaches studied in Projects 6.02 and 6.03. Examples of specific programs that will be active in this area include the NetZero, WTIC, and Small Business Innovation Research (SBIR) programs.

Delivery Date: 2018
Intended Users: OW, Regions, States, and communities

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk (2018)

Output Description: Project 6.01 will inform this output by evaluating existing and market-ready methods and tools to identify and quantitate contaminants of emerging concern. Specifically, analytical tools will be evaluated for more comprehensive and rapid assessment of algal toxins, DBPs, microbes, and other emerging contaminants. The results will allow for determinations not only of the applicability of the methods and tools, but also how they fit within the regulatory agenda both in promulgating regulations and in the implementation of the rules. This evaluation will include market-ready methods and tools for emerging contaminants and regulated contaminants. Also, chemicals or microbiological agents that may serve as tracers, surrogates, or indicators will be evaluated in an effort to identify effective contaminant methods/monitors to be used for better process control and to confirm that water systems are supplying water that meets regulations and guidelines. Examples of specific programs that will be active in this area include the WTIC and SBIR programs, along with in-house research.

Delivery Date: 2018
Intended Users: OW, Regions, States, and communities

Output 3. Develop and demonstrate individual technologies and integrated systems to improve the collection, treatment, and distribution of water (drinking water and wastewater), and the recovery of resources (2019)

Output Description: Project 6.01 will inform this output by evaluating existing and market-ready technologies for the collection, treatment, and distribution of water (drinking water and wastewater). The research will also include systems used for recovering resources from water systems. Wastewater system topics of concern include the control of nutrients, pathogens, and contaminants of emerging concern. These topics are true for both typical wastewater applications and those involving water reuse. Also, handling stormwater events remain a concern for many systems. This area can be broken down into work on smart collection systems to utilize the existing infrastructure to handle flows, and high-rate treatment studies to handle high flows at the plant.

On the drinking water side, technologies will be evaluated to remove contaminants of concern, and to avoid the introduction of contaminants in the distribution system. This evaluation includes the formation of disinfection byproducts and the introduction of contaminants due to corrosion, intrusion events, and biofilm formation. Also, many small systems need help in addressing currently-regulated contaminants. These small systems include large buildings such as hospitals that find themselves regulated as consecutive systems due to the introduction of point-of-entry treatment devices. These buildings often find it necessary to introduce treatment to minimize the growth of microbes such as *Legionella* or *Mycobacteria*. Examples of specific programs that will be active in this area include the WTIC and SBIR programs, along with in-house research.

Delivery Date: 2019
Intended Users: OW, States, Regions, and communities

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

Output Description: Project 6.01 will inform this output by producing health effects data for contaminants that are prioritized based on existing, but incomplete health information. This activity includes developing and using predictive models for both single and groups of contaminants. For instance, determining the association observed in epidemiology studies on the exposure to the complex mixture of chemicals formed during water disinfection and adverse human health outcomes. The work will determine the influence of water characteristics that impact the suite of DBPs formed during treatment and the toxicity of the mixture.

Delivery Date: 2019
Intended Users: OW, Regions, States

Key Products Identified

All products identified below will be used in combination with the products developed for monitoring both in this Project and with the Products developed in Projects 6.02 and 6.03.

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2019)

Example of Key Products that could feed into this output

Key Product Title: Pathogen log removals through wastewater treatment and reuse facilities
Description: This product will include data and discussion on the log removal of pathogens and surrogates through wastewater and reuse facilities.
Delivery Date: 2018
Intended Users: OW

OW/Regional needs which may be met (wholly or in part) include:

- Innovative technologies for resource recovery (nutrients, carbon, water) from wastewater-including recovery at source (grey water, black water, urine diversion)

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk (2019)

Example of Key Products that could feed into this output

Key Product Title: Analytical tools for more comprehensive and rapid assessment of algal toxins, DBPs, microbes, and other emerging contaminants
Description: This product will cover analytical tools that would be helpful to drinking water and wastewater utilities with regard to regulatory compliance and contaminants of concern.
Delivery Date: 2018
Intended Users: OW, States, and utilities

Key Product Title: A family of PBPK models for the regulated trihalomethanes
Description: This product will be a family multi-route PBPK model for the regulated trihalomethanes for both humans and rats that will allow for estimation of total internal dose to key target organs, determination of the major routes of exposure, evaluation of mechanistic hypotheses, consideration of susceptible/vulnerable populations and disease states. These models will allow for extrapolation of observations in experimental rat models to humans based on internal dose metrics and for predictive modeling of the impact of changes in water systems (such as a change in a water treatment system). This will be integrated with the CSS program.
Delivery Date: 2019
Intended Users: OW, States, and utilities

Key Product Title: Impact of Changing Input Water Characteristics and Water Treatment Scenarios on DBP and Transformation Product Formation/Occurrence and Health Effects.
Description. This product will develop integrated occurrence and health effects information, focusing on the impact of input water characteristics (for example, bromide/iodide, nitrogen, CCL or emerging contaminant concentrations) and treatment processes on health effects.
Delivery Date: 2019
Intended Users: OW, States, and utilities

OW/Regional needs which may be met (wholly or in part) include:

- Research on fate and transport of emerging contaminants (including trace organics, nanoparticles, and pathogens) in wastewater, surface water, and biosolids, and development of cost effective test methods and management/treatment options to inform risk assessment and potential future wastewater treatment regulations.

- Detection, identification, and quantification of individual and groups of contaminants in drinking water sources. This area of research includes method development and improvement for CCL chemicals and pathogens. Methods developed under this research area could be used in the UCMR program. This area of research also includes development of tools to prioritize groups of contaminants for CCL; methods to evaluate human health risk to groups of contaminants; transformation of source water contaminants during water treatment (chlorination and chloramination); assays to test DBP mixtures, and risk models for alternative water disinfection strategies.

Output 3. Develop and demonstrate individual technologies and integrated systems to improve the collection, treatment, and distribution of water (drinking water and wastewater), and the recovery of resources (2019)

Example of Key Products that could feed into this output

Key Product Title: Defining performance and cost of best available technologies for regulatory purposes
Description: This product would evaluate drinking water and wastewater technologies, including those used for the collection and treatment of wastewater and the treatment and distribution of drinking water. Within this construct, specific consideration will be given to small systems because of the difficulties such systems have in implementing drinking water regulations and water treatment standards. The merger of the Treatability Database and OW Cost Models is included in this product. Analyses on contact time (CT values) for pathogens will also be included in this product.
Delivery Date: 2019
Intended Users: OW

Key Product Title: Predictive Models for Groups of Chemicals
Description: The product will provide and utilize innovative methods, approaches and predictive models to assess groups of regulated chemicals for toxicological evaluation, to estimate the predicted toxicity of groups of chemicals and to determine the chemical(s) within a group responsible for the majority of toxicity. These models will be used to evaluate treatment systems and approaches.
Delivery Date: 2018
Intended Users: OW, States, and utilities

OW/Regional needs which may be met (wholly or in part) include:

- Research on fate and transport of emerging contaminants (including trace organics, nanoparticles, and pathogens) in wastewater, surface water, and biosolids, and development of cost effective test methods and management/treatment options to inform risk assessment and potential future wastewater treatment regulations.

- Pathogens: What is the capability of existing treatment technologies in wastewater and drinking water treatment facilities to control and treat the types and populations of pathogens associated with the warmer water temperatures expected to result from a changing climate?

- Drinking water treatment-Increase infrastructure sustainability and effective/innovative/low cost treatment technology, especially for small systems.

- Research on pathogen and BOD removal performance for wet weather management approaches and on innovative technologies for handling wet weather flows associated with extreme events.

- Protect human health from chemical and microbial contaminants, including support for: Contaminant Candidate List, Regulatory Determinations, Lead and Copper, Six Year review of NPDWRs. Examples include epidemiology and toxicology studies on DBPs, impacts of pH, DIC, and orthophosphate on lead corrosion, VOC work, impacts of water quality on lead and copper, and biofilm changes with conversion from chlorine to chloramine.

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

Example of Key Products that could feed into this output

Product Title: Development of human health risk data (exposure and effects) in support of program office, regions, and states needs
Description: This product will include all available human health risk data for contaminants that are currently regulated, or heading toward regulatory promulgation, with an emphasis on human health risks from groups of contaminants (e.g. DBPs).
Delivery Date: 2019
Intended Users: OW, Regions, and States

OW/Regional needs which may be met (wholly or in part) include:

- Detection, identification, and quantification of individual and groups of contaminants in drinking water sources. This area of research includes method development and improvement for CCL chemicals and pathogens. Methods developed under this research area could be used in the UCMR program. This area of research also includes development of tools to prioritize groups of contaminants for CCL; methods to evaluate human health risk to groups of contaminants; transformation of source water contaminants during water treatment (chlorination and chloramination); assays to test DBP mixtures, and risk models for alternative water disinfection strategies.

- Characterize increased exposure/risk implications from bromide use at coal fired plants. (R5: aquatic life criteria for salt mixtures that look at toxic equivalency factors or biotic

ligand model-like approaches to incorporate additive and synergistic effects of mixtures of salts.

- Develop hydrodynamic process models, including fate and transport, for chemicals and pathogens to facilitate estimation of downstream impacts of pathogen and chemical sources. (R4: Assessing and mitigating impacts on surface water quality from land application of municipal wastewater and CAFO wastewater).

- **Assumptions and Constraints**
  - All products require collaboration with the Program Office.
  - All products require appropriate FTEs, extramural support, and technical support (including contractor support) for laboratory methods development, field monitoring, and process work.
  - Modeling and Demonstration Products require a software engineer (FTE) familiar with integrated environmental modeling.
  - Modeling and Demonstration Products require some degree of collaboration from outside technology developers, if software from other agencies or those not associated with EPA are involved.
  - The need to conduct integrated planning across exposure, ecological and human health to ensure that, where appropriate, the project conducts integrated research increases the planning lead time and requires that the planning be conducted by the implementing scientists
  - Products with technology transfer, adoption, and deployment components will require collaboration with technology developers, vendors, water technology clusters, communities, economic development organizations and/or other stakeholders as appropriate

SSWR Project Charter
Water Systems – Project 2 (6.02)

Project Title: Next Step: Technology Advances

Project Lead (PL): Vickie Wilson, PhD (NHEERL), Adam Biales, PhD (Deputy Project Lead-NERL)

Project Development Team Members: Vickie Wilson (Lead Writing Team) NHEERL; Adam Biales (Co-Lead Writing Team) NERL; Darren Lytle (Co-Lead Writing Team) NRMRL; Alan Lindquist NRMRL; Jonathan Pressman NRMRL; Eunice Varughese NERL; Santhini Ramasamy (Tentative OW); Heather Galada (Tentative OGWDW); Lee Vane NRMRL; Kevin Oshima NERL; Evelyn Hartzel (Tentative NRMRL); Jane Ellen Simmons (NHEERL); Mike Elovitz NRMRL; Scott Huling NRMRL

Project Start Date: October 1, 2015

Project End Date: September 30, 2019

Executive Summary

This project will push forward the next generation of technological, engineering, and process advances to address challenges in providing safe and sustainable water to humans and the environment. Although the approaches may address concerns that support current and near future regulatory processes, or may be transformative in nature, they are reasonably well developed but not yet ready for routine or regulatory use. Project 6.02 will expedite the development of these approaches and methods to promote wider acceptance and implementation by Program Offices, Regions, States, communities and others within the time frame of the current project period. The project includes advances in a number of 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.

Research Project Description

EPA is responsible for protecting America's water resources under the Clean Water Act (CWA) and for ensuring that the Nation's drinking water is safe under the Safe Drinking Water Act (SDWA). Further, it is the responsibility of EPA to conduct research and analyses to inform decisions ensuring that our Nation's water resources are safe for use and can be sustained for future generations. The project will take a systems based approach to three areas; 1) contaminants and their impact on health, 2) adequate removal of contaminants from various water systems and, 3) water and resource recovery within treatment systems. Specifically, this project will develop the next generation of technological advances to establish safe and sustainable water resources, to provide guidance and implement programs in support of drinking water and wastewater treatment regulations, while maximizing resource conservation and recovery. The research described herein integrates exposure with ecological or human health as appropriate and incorporates advances to improve both experimental and prognostic capabilities. Market adoption factors including public acceptance, regulatory and policy drivers/barriers. Business and economic development potential may also be considered. Efforts in this project include but are not limited to: a) the development of new and innovative disinfection and treatment approaches for wastewater and drinking water, b) novel human and environmental assays targeting both exposure and effect that can be integrated into predictive models for individual and groups of contaminants, c) advanced treatment technologies to assess levels of contaminants and removal of contaminants in various water systems, including small systems, d) novel holistic approaches to address water distribution and collection system issues, e) new or improved resource recovery and reuse approaches, and f) advanced monitoring tools for mixtures (e.g. bioassays/activity). Within Topic 6, products completed within this project (6.02) will build upon Project 6.01 (Current Systems and Regulatory Support) products and possibly inform Project 6.03 (Transformative Approaches and Technologies for Water Systems). This project will closely align with contaminant research in Topic 3 (Watershed Sustainability) specifically in regards to source water protection. Contaminants (microbiological and chemical) related research in Projects 6.01 and 6.02 will be closely aligned with relevant watershed related contaminant research in Topic 3 to ensure that common technologies, tools and models are effectively employed across the water cycle (informing research on the basis of the interrelationships between contaminants in water system discharges, fate and transport in the environment, and resulting levels in source or drinking water). Research results from Project 6.02 will contribute to high priority areas in support of the National Water Program Climate Change Strategy. These priority areas include: Climate change impacts on nutrient removal, Effects of climate change on pathogens and pathogen treatment, and Climate impacts on drinking water quality.

Project Impact

United States water suppliers are faced with a growing number of chemical and microbial contaminant challenges, due to increased water demands, deteriorating infrastructure,

emerging contaminants, and external pressures such as climate change and water scarcity. All of these issues result in increased pressures on the nation's existing water sources in terms of both the quantity and the quality of source water available as inputs into engineered water systems. The emergence of new chemical and microbiological contaminants, as well as the lack of knowledge regarding health effects from individual and groups of contaminants, increase the need to develop and deploy innovative approaches to limit and reduce chemical and microbial contamination in source and drinking waters while ensuring sustainability of water resources by managing the contaminant health risks in source and drinking water, reducing the contaminant load re-introduced to the environment from wastewater treatment processes, ensuring that safe and effective water reuse technologies exist, and maximizing recovery of resources from water.

This project will support regulations and advances in drinking water and clean water programs by aiding the integration of innovation into the national water program by providing the program offices and regions with timely analyses of the state-of-the-science and emerging trends, and identifying, developing, and demonstrating new approaches/technologies.

Project Scope

The scope of Project 6.02 encompasses research that advances next generation tools targeting 1) more effective monitoring of water related to water systems, 2) more accurate assessment and prediction of risk posed from contaminants and pathogens, 3) more effective and holistic treatment and disinfection approaches to reduce organic matter, chemical contaminants and pathogens associated with water systems. Project 6.02 is expected to work closely with Project 6.01; however, Project 6.02 will focus on advancing new and emerging technologies, tools, methods and models, whereas Project 6.01 will focus mostly on immediate needs of the Program Office through current science. More specifically, research within Project 6.02 is expected to include advancing new approaches for assessing health risks, new analytical techniques to meet future regulatory needs and provide occurrence and health data on currently non-regulated contaminants in support of decision making for possible future regulation. The expectation is that Project 6.02 will link closely to Topic 3 Project 3.01 and 3.02; however, Project 6.02 will focus solely on issues directly associated with water systems and their source waters. Project 6.02 is anticipated to also link with SSWR Topic 4 (Nutrients), Project 4.01 (Reducing Impacts of Harmful Algal Blooms) particularly in the areas of analytical methods development and risk assessment of cyanotoxins.

Project Structure and Rationale

The tasks within Project 6.02 will relate to the four outputs relevant to this Topic (see Table 1). The outputs are further defined in the sections that follow. This approach is consistent with the other Projects within Topic 6. The rationale is to integrate all of Topic 6 not only across tasks, but across Projects such that each Project will feed into the four Outputs.

	Project 6.01. Current Systems and Regulatory Support	Project 6.02. Next Steps: Technology Advances	Project 6.03. Transformative Systems and Approaches
Output 1. Integrated Sustainability Assessment Tool for Water Systems and Resource Recovery	Task(s)	Task(s)	Task(s)
Output 2. Advanced Monitoring and Analytical Tools	Task(s)	Task(s)	Task(s)
Output 3. Performance Data on Technologies and Integrated Systems	Task(s)	Task(s)	Task(s)
Output 4. Advanced Approaches for Measuring Health Risks	Task(s)	Task(s)	Task(s)

Table 1. Topic 6-Water Systems Project Structure

The proposed approach in Project 6.02 is a series of efforts accelerating the acceptance of improved and sustainable technologies that address water issues. The goal is to provide sustainable technology and approaches to utilities (communities) that can be used to reduce risk and protect public and ecological health. This includes healthier water at lower cost involving easier treatment operation and maintenance and lower environmental impact. Factors affecting the deployment of solutions will also be addressed, including public acceptance, policy, and regulatory drivers/barriers. To conduct adequate sustainability assessments for drinking water and wastewater systems, a great deal of information is needed such as the system design and characteristics, chemistry of the treated water and residual streams, health impacts, new ways of assessing risk and environmental/ecological impacts,

including energy consumption and the extent to which it generates greenhouse gases directly or indirectly.

Measure of Success

We expect that the science and engineering developed in this project will directly lead to near term (3-5 years) technological solutions. The outcomes of this project will be directly used by communities, states, regions, program offices, consulting firms and others to solve real water problems. The success of the project will be based on the number of users of the project products (e.g., downloads, readers, manuscripts, licenses, technologies adopted, etc.). More importantly, success will be based on the feedback from the stakeholders and acceptance of the technological advances by state regulatory agencies, communities and others, and the development and adoption of commercially viable solutions. Success can also be measured by tools, methods, and approaches moving from the development stage in Project 6.02 into the use and implementation stage in Project 6.01.

Stakeholders (outside ORD):

All research undertaken by ORD is designed to answer stakeholder needs. The principal internal stakeholders for the SSWR program are the Office of Groundwater and Drinking Water (OGWDW), the Office of Science and Technology (OST), the Office of Wastewater Management (OWM), the Office of Chemical Safety and Pollution Prevention (OCSPP)/Office of Pollution Prevention and Toxics (OPPT) and the Regions. External stakeholders include consumers of drinking water and users of community wastewater systems, particularly in underserved communities, state and local regulatory and public health agencies and officials, technology and system developers, vendors, and the scientific community. Multi-sector partnerships with these stakeholders will be leveraged to accelerate innovation, foster technology transfer, address regulatory/policy barriers, streamline adoption, and promote business and economic development opportunities.

Output(s)

Topic 6 includes four integrated outputs (listed below) for Project6.0 2 as well as Project 6.01 - Current Systems and Regulatory Support and Project 6.03 - Transformative Approaches and Technologies for Water Systems. A brief explanation of anticipated work within Project 6.02 for each of these Outputs follows.

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2018)

Brief Description: While the immediate OW information needs focus on water quality for direct potable reuse (DPR), Project 6.02 research in this area will cover treatment, monitoring, and risk assessment for fit-for-purpose water. This research will feed into Output 1 by providing water quality data on treated water for a wide variety of finished water types including irrigation, industrial, and other non-potable reuse categories. Project 6.02 will also examine next-generation systems and technologies for fit-for-purpose water treatment.

Delivery Date: 2018

Intended user and audience: OW, Regions, States, and communities

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk

Brief Description: Project 6.02 contributes to Task 6-Output 2 through the identification and testing of novel analytical methods for the analyses of emerging contaminants of concern. The Project will lead to the development of new and innovative approaches to measuring and monitoring human health risks from individual and groups of contaminants.

Delivery Date: 2018

Intended user and audience: OW, Regions, States, and communities

Output 3. Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment, and distribution of water and the recovery of resources (2019)

Brief Description: Project 6.02 will include research in support of Topic 6-Output 3 that addresses the use of novel technologies for the treatment of water and wastewater, and water quality in distribution systems. This work will leverage existing ORD partnerships and programs such as the Water Technology Innovation Cluster and Small Business Innovation Research efforts. Emphasis will be placed on systems and approaches which reduce energy consumption (e.g. low dissolved oxygen biological processes for wastewater treatment/reuse). Project 6.02 research under this Output will range from bench to pilot-scale and field demonstrations. Whenever practical, field research will be conducted in communities that have been historically underserved and disproportionately impacted by environmental hazards.

Delivery Date: September 2019

Intended user and audience: OW, Regions, States, and communities

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

Brief Description: Project 6.02 will inform this output through the development of new methods and tools for measuring human health risks from chemicals (individual and mixtures) and pathogens. Project 6.02 research will focus on advances in cell-based assays and genomics to assess human health risks from priority contaminants. Contaminants will be prioritized based on OW input and ongoing toxicology modeling studies in CSS. Results from this research will place an emphasis on communicating these results to communities that have been historically underserved and disproportionately impacted by environmental hazards.

Delivery Date: September 2019

Intended user and audience: OW, Regions, States, and communities

Key Products Identified

The following are potential Key Products. These products need to be evaluated relative to the resources associated with Project 6.02 prior to implementation; however, they serve to indicate direction and emphasis within the Project. All example products identified below could be used in combination with the products developed for both this Project and with the Products developed in Projects 6.01 and 6.03 to provide the Outputs.

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2019)

Example of Key Products that could feed into this output

Key Product Title: Definition of health risks and treatment requirements for waters fit for purpose depending on source water quality.

Description: Report providing information on health risks and treatment requirements for targeted end-use of treated wastewater. End-uses include direct potable reuse, agricultural irrigation, industrial (e.g. cooling towers), and other non-potable use. Specifically, the product will identify chemical and biological parameters to be monitored in such systems that would be representative indicators of risk. In addition, contaminant monitoring locations, monitoring protocols, and issues associated with measuring limits will be identified. Lastly, the treatment (e.g., filtration, disinfection, etc.) effectiveness of accepted and innovative approaches to reduce contaminants of concern and minimize health risk in such systems will be examined. The work will help update existing guidance (e.g. California Title 22 water quality requirements for end-use) and broadened to include other state issues.

Delivery Date: 2018

Intended Users: Office of Water, Regional Offices, States, Utilities, and Municipalities.

OW/Regional needs which may be met (wholly or in part) include:

- Adapt water reuse technology to multichemical and pathogen treatment for small system application.
- Development of guidelines for “acceptable” drinking water treatment plant source water quality to serve as a target for alternative sources such as reclaimed wastewater effluents, harvested stormwater, produced water, etc.

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk (2019)

Example of Key Products that could feed into this output

Key Product Title: Analytical and monitoring tools for future UCMR, CCL, and emerging contaminants.

Description: This product will cover analytical tools that would be helpful to drinking water and wastewater utilities with regard to future contaminants of concern including microbial and chemical contaminants.
Delivery Date: 2018
Intended Users: OW, States, and utilities

Output 3. Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment, and distribution of water (drinking water and wastewater), and the recovery of resources (2019)

Example of Key Products that could feed into this output

Key Product Title: Development and demonstration of novel technologies for improved water and wastewater treatment and distribution systems (Output 3)

Description: Reports/journal articles on next generation technologies for drinking and wastewater treatment/reuse. This product will consider novel technologies and approaches that are currently at a relatively late stage of development but not yet to the point where they are used or widely accepted. The product will include technology pilot and full-scale treatment demonstrations to address specific contaminants of concern. Technology advances will apply to drinking water, wastewater and distribution/conveyance systems. Resource recovery and reuse approaches from drinking water and wastewater will also be addressed in this product. Advancements could include:

A. Application of a holistic approach to address water distribution and collection system issues (e.g. biofilms and corrosion);
B. New resource recovery and reuse approaches that encompass the new generations of technologies available for creating fit-for-purpose waters and other resources with acceptable costs
C. The development of innovative techniques for reducing organic matter in water to address multiple problems associated with treatment, disinfection, and disinfection byproducts.

Delivery Date: FY19

Intended Users: Office of Water, Regional Offices, States, Municipalities, Utilities

OW/Regional Needs which may be met (wholly or in part) include:

- Research on fate and transport of emerging contaminants (including trace organics, nanoparticles and pathogens) in wastewater, surface water, and biosolids, and development of cost effective test methods and management/treatment options to inform risk assessment and potential future wastewater treatment regulations.
- Innovative and cost-effective nutrient removal technologies to meet very low limits (below current limit of technology) with minimal carbon footprint. (This could also include R8 input on nutrient treatment in lagoons/ponds in R8 and on consequences (e.g. GHG emissions) from more stringent nutrient removal requirements).

- Affordable and effective technologies to retrofit existing types of municipal wastewater treatment systems for nutrient removal to achieve ecoregion-based reference criteria. Can it be sustainably accomplished while withstanding the peak flow impacts of climate change?
- Research on pathogen and BOD removal performance for wet weather management approaches and on innovative technologies for handling peak wet weather flows.
- Innovative and sustainable wastewater treatment technologies for small systems (particularly those facing new stringent regulatory requirements).
- Detection, identification, and quantification of individual and groups of contaminants in drinking water sources. There is an urgent need for tools and methods to detect and identify contaminants for future rule development, regulatory reviews, and revisions.
- Temperature and Flow: How vulnerable are designated uses to warmer waters and low streamflows expected to result from a changing climate?

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

Example of Key Products that could feed into this output

Product Title: Improved assessment of risk posed by individual and emerging contaminants, groups of contaminants and pathogens associated with water systems.

Description: Will focus on next generation assessment and monitoring tools for advancing our understanding of human risks associated with water systems. The Key Product will also leverage advances in computational biology and adverse outcome pathway research conducted within the Chemical Safety and Sustainability Research Program and is envisioned to provide a synthesis report on progress and advancements made in the following areas;

A) Predictive models for effect of established and emerging contaminants, groups of contaminants and pathogens
B) Advances in exposure and effects monitoring technologies targeting groups of contaminants based on mode of action or bioactivity
C) Advances in methods for assessment and prediction of multi-route exposure potential of contaminants of engineered water systems
D) Improved methods to group chemicals based on integration of information on occurrence, exposure and health associated with water systems
E) Approaches to evaluate human health response to groups of waterborne contaminants associated with changes in drinking water quality

Delivery Date: FY19

Intended Users: Office of Water, Office of Chemical Safety and Pollution Prevention, Regional Offices, States, Utilities

OW/Regional Needs which may be met (wholly or in part) include:

- Development of bioactivity/bioassay measures for monitoring of chemical contaminants to support screening assessments and criteria development based on adverse outcome pathways.
- Development of bioactivity/bioassay measures for monitoring and criteria development to permit estimation of multichemical effects due to common adverse outcome pathways.
- Develop a risk-based process to select chemicals for development of new or revised water quality criteria (toxicity, frequency and magnitude of occurrence, persistence, bioaccumulation, cumulative risk)
- Develop new and revised criteria based on risk-based selection process
- Animal and in vitro-based dose response models for pathogens to support criteria and MCLG development for pathogens.
- Develop and refine the scientific tools available for screening risks for chemical and microbial pollutants from various matrixes

Assumptions and Constraints

The proposed research assumes adequate institutional support and funding. Collaborative efforts with the Chemical Safety for Sustainable will be assumed, particularly for next generation modeling and monitoring for human health risk assessment. The development of project-specific, multi-sector collaborations through the Water Technology Cluster, STAR and other ORD partnerships and collaborative programs and cooperation with other Agencies such as DoD and USGS will be needed for developing the next generation of treatment and monitoring systems.

SSWR Project Charter
Water Systems – Project 3 (6.03)

Project Title: Transformative approaches and technologies for water systems

Project Lead (PL): Jay Garland, PhD (NERL), Evelyn Hartzell (Deputy Project Lead-NRMRL)

Project Development Team Members: Jay Garland (NERL), Cynthia McOliver (NCER), Sid Hunter (NHEERL), Kate Sullivan (NERL), Christopher A. Impellitteri (NRMRL), Ardra Morgan (NERL), Cissy Ma (NRMRL), Phil Zahreddine (OW-OWM), Bob Bastian (OW-OWM), Jennifer Cashdollar (NERL), Evelyn Hartzell (NRMRL), Tim Wade (NHEERL), Al Dufour (NERL), Scott Keely (NERL), Michael Nye (NERL)

Project Start Date: 10/01/2015

Project End Date: 09/30/2019

Executive Summary

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

Research Project Description

In the future, increasing stresses on water resources will impact water supply and demand. Stressors include population growth and density, climate variability, energy consumption, contaminants, and deteriorating infrastructure (Kiparsky, 2013). The American Society of Civil Engineers predicts a funding gap of 84 billion dollars for water and wastewater infrastructure needs by the year 2020 with an increase in the funding gap to 144 billion dollars by 2040 (ASCE, 2011). Transformative, sustainable approaches to water systems will be necessary in order to meet future demands on water quality and quantity. The previous Safe and Sustainable Water Resources Strategic Research Action Plan for 2012-2016 included topics that focused on the design, life cycle analysis and best management practices for sustainable water infrastructure systems (USEPA, 2012). This project aims to build on previous SSWR research by providing a

framework for holistically advancing water systems that encompasses the entire water cycle: from source to tap and back to the source. This project directly addresses EPA Program and Regional Office needs for water research (see Key Products section). The project also supports EPA's National Water Program Climate Change Strategy Priority 9: Facilitating Next Generation Water Reuse to Build Climate Resilience of Public Water Supplies.

Relevant current science in this area is emerging from research groups such as ReNUWIt (http://www.renuwit.org/). ReNUWIt is an engineering research center whose focus is on re-inventing US urban water infrastructure. Similarly, this project will contribute to the re-invention of not only urban water systems, but systems that serve small communities. The project will include targeted field-scale pilot systems that can contribute to the transformation of water treatment systems as we know them by providing safe, affordable technologies that treat water to fit-for-purpose levels while recovering energy and other resources (e.g. nutrients). Additionally, the project will include innovative transformative methods for risk assessment and monitoring.

This research project involves four main efforts corresponding to the integrated outputs for Topic 6 (see Table 1 below). The first effort develops an integrated sustainability assessment framework based on linkages among drinking water, wastewater, stormwater, and natural infrastructure contained within a watershed. The framework will integrate various complimentary system-based tools, such as life cycle assessments, life cycle costs, advanced water foot printing approaches, emergy analyses, and resiliency to climate-induced events to quantitatively evaluate alternative, innovative water system approaches. 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 places emphasis on 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/surrogates to assess the efficacy of water reuse systems and evaluation of the potential role of waterborne exposures in triggering diabetes and other autoimmune disorders.

Project Impact

This project will supply stakeholders with information on how to most effectively transform water systems. Specifically, the project will assess and demonstrate the performance of innovative wastewater treatment, water reuse, and resource recovery technologies. Development of an integrated, systems-based framework will enable utilities to apply innovative changes to the way that they manage water by providing cost/benefit, system efficiency, human health, and environmental impact information on different aspects of water management. The effort will employ multi-sector collaborations with communities, businesses, economic development organizations and other stakeholders to foster innovation, improve technology transfer, streamline adoption, and accelerate the deployment of commercially viable technologies and systems. Lastly, research on innovative approaches to risk

measurements will provide improved tools for screening and monitoring the efficacy of water systems.

Project Scope

The scope of the performance assessments and the integrated systems-based framework for transformative water systems encompasses cost/benefits and tradeoffs involved with alternative treatment and reuse strategies (e.g. treatment for fit-for-purpose water) at different scales. This includes the collection, treatment, and discharge of wastewater and stormwater and the supply, treatment and distribution of drinking water. The demonstration effort for this research will focus on field pilot-scale systems for energy and resource recovery and will leverage the NetZero initiative between DoD and EPA and multi-sector collaborations through the Water Technology Innovation Cluster and NCER. High throughput toxicity screening will be linked with EPA-ORD's Chemical Safety for Sustainability Research Program to help identify and prioritize key chemical contaminants in water treatment and water reuse/resource recovery systems. Innovative monitoring methods will also focus on prioritized contaminants from existing lists of chemicals (e.g. ToxCast).

Project Structure and Rationale

The project structure is fully integrated with Projects 6.01 and 6.02 as described in Table 1.

	Project 6.01. Current Systems and Regulatory Support	Project 6.02. Next Steps: Technology Advances	Project 6.03. Transformative Systems and Approaches
Output 1. Integrated Sustainability Assessment Tool for Water Systems and Resource Recovery	Task(s)	Task(s)	Task(s)
Output 2. Advanced Monitoring and Analytical Tools	Task(s)	Task(s)	Task(s)
Output 3. Performance Data on Technologies and Integrated Systems	Task(s)	Task(s)	Task(s)
Output 4. Advanced Approaches for Measuring Health Risks	Task(s)	Task(s)	Task(s)

Table 1. Topic 6-Water Systems Project Structure

Measure of Success

We expect to achieve completion of a systems-based framework for assessing transformative processes and technologies in water management, evaluations of innovative technologies for treating water to fit-for-purpose levels and resource recovery, high-throughput toxicology assessments for priority contaminants in water systems, and the identification of novel methods for monitoring contaminants in water systems.

We expect to develop multi-sector collaborations with communities, businesses, economic development organizations and other stakeholders to foster innovation, improve technology transfer, streamline adoption, and accelerate the deployment of commercially viable technologies and systems. We hope to develop cooperative research and development agreements (CRADAs) and patent licensing agreements with the private sector to foster the development and deployment of promising technologies. We hope to achieve the implementation of these tools by stakeholders and partners for advancing the sustainability of water resources in the future. Outcome success will be determined based on stakeholder and partner feedback.

Stakeholders (outside ORD):

EPA Program and Regional Offices, Water Reuse Research Foundation, Water Research Foundation, Water Environment Research Foundation, State Governments, Municipalities, Utilities, other Federal agencies, water technology clusters, private sector developers, academia

Output(s)

Topic 6 includes four integrated outputs (listed below) for Project 6.03. These outputs are closely linked with Projects 6.01-Current Systems and Regulatory Support and 6.02-Next Steps: Technology Advances. A brief description of anticipated work within Project 6.03 for each of these Outputs follows.

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2018)

Output Description: While previously siloed approaches to water services (i.e., water resource management, drinking water, wastewater, and stormwater) have led to great improvements in public health protection, sustainable solutions for growing service communities facing increased resource constraints demand advanced holistic management to maximize the use and recovery of water, energy, nutrients, and materials. These approaches are needed to evaluate the tradeoffs of decision alternatives in a systems context. The tool will allow communities to consider holistic water management that includes connections between various subsystems at multiple levels (i.e. niche technology, regulatory regime, existing technical systems, and meta-forces such as climate change).

The initial output of Project 6.03 will be to develop and test a suite of integrated system-based tools, including life cycle assessments, life cycle costs, advanced water footprinting approaches, emergy analyses, and resiliency assessment. Sustainable water system planning requires a

comprehensive understanding and assessment of the integrated source-drinking-wastewater-stormwater systems over their life-cycles at various scales. The analyses will provide a fundamental understanding of key relationships in a typical water system, such as energy expenditure, emerging and esoteric health risks, impact distributions and water-energy issues.

An improved database, inventory, and library of flows, contaminants, and processes in various water subsystems, particularly the transformative alternatives and geographically detailed data, will be developed for future system evaluations and decision guidance. A comprehensive database, including a number of water system elements such as centralized/decentralized system configurations, fit-for-purpose water quality, sewer collection systems, resource recovery (carbon and thermal energy recovery, N/P nutrient recovery, water reuse), and natural/green infrastructure elements, will be developed in order to enable scenario comparisons at various scales. Transferability and scalability of alternatives will be evaluated as well. The open source database will provide transparent, sound bases and user friendly interfaces for stakeholders.

Data from SSWR Topic 6 Project 6.02 (Next Steps: Technology Advances) and Topic 5 Project 5.01 (Green infrastructure tools and modeling approaches) will also contribute to the database and library in this task.

System-level modeling of a range of virtual alternatives will be explored to gain knowledge of key relationships and system net benefit that can inform sustainability assessments and more sustainable design options for future communities. Linkage to specific case studies of community decision making is feasible, potentially through the Sustainable Community Water Management element in SHC Project 4.6.1, Integrated Solutions Sustainable Communities.

Delivery Date: 2018

Intended user and audience: Office of Water, Regional Offices, States, Utilities

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk (2018)

Output Description: Future health monitoring of source, potable and processed water will increasingly rely on evaluations of biological activity and less on the determination and assessment of individual and multiple chemicals in water. Applying the tenets of Toxicology in the 21st Century, as described by the National Academy (NAS, 2007), perturbation of mechanistic, molecular initiating or key events that are linked to adverse health outcomes will serve as the basis for evaluating the biological activity and health monitoring evaluations. This chemically agnostic approach is predicated on determining biological activity in a test system following exposure to the complex mixtures present in water. The challenge is to develop mechanistically linked biosensors that can, in real time, determine health hazards and quantitatively establish the magnitude of exposure.

A biologically-based effects monitor will be developed that senses and responds to chemical exposures that could result in adverse health effects. This monitor will respond to chemical exposures that trigger molecular initiating or key events that are linked to adverse health outcomes. These molecular initiating or key events will be selected based on putative, formal and quantitative adverse outcome pathways linked to selected health effects, e.g. bladder cancer. The monitor will be tested against a comprehensive profile of "conventionally" measured POTW constituents and developed such that a detection technology can be used to assess response without the aid of expensive laboratory procedures and instrumentation.

Delivery Date: A prototype model will be available August 2017

Intended Users: Researchers evaluating potential health effects of complex mixtures of source, potable or waste waters. Developers of new technologies for water treatment or processing to evaluate the potential health consequences.

Output 3. Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment, and distribution of water (drinking water and wastewater), and the recovery of resources (2019)

Output Description: This output will focus on case studies and demonstrations of transformative technologies, with an emphasis on mapping pathways to successful mainstreaming of niche technologies and the potential for system optimization through redefining wastewater treatment as a resource recovery process, including water reuse, nutrient recovery, and energy generation. Particular emphasis will be placed on case studies involving, 1) integrated approaches for small systems which couple treatment, resource recovery, and economic benefits in different contexts, 2) innovative and sustainable nutrient removal technologies to produce effluent levels below the current limits of technology, 3) low energy treatment processes which minimize aeration and greenhouse gas emissions, including anaerobic treatment approaches, short-cut N removal, and novel membrane systems and materials, and 4) water reuse treatment and monitoring technologies which address key research gaps identified within the recent National Research Council (NRC) report on "Potential for Expanding the Nation's Water Supply Through Reuse of Wastewater" (NRC, 2012). Demonstrations and case studies may be conducted at various scales (building, community, regional). Given the large number of potential case studies relative to available resources, the project will leverage existing ORD partnerships and programs such as the Water Technology Innovation Cluster, Net Zero/Net Positive, and Science to Achieve Results (STAR) programs to the maximum extent possible in order to advance the state of the science and foster earlier adoption of next generation technologies. Although the case studies will focus on specific innovative treatment mechanisms and technologies, the pathways work will account for social, economic, regulatory and other contextual factors that accelerate or hinder the ability of promising innovative technologies to become mainstream. The case studies and pathways will be constructed collaboratively with businesses, communities, economic development organizations, and other stakeholders.

Delivery Date: 2019

Intended user and audience: Office of Water, Regional Offices, States, Utilities

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

Output Description: Health risk research in Project 6.03 will focus on transformative approaches involving either new contaminants of concern or defining alternative measures of risk. For several years, the Centers for Disease Control and Prevention (CDC), with input from US EPA scientists and others, has been developing national estimates of the burden of waterborne disease. Health risk research in Project 6.03 will complement the CDC work by focusing on the shifting nature of waterborne disease in the United States. One example of this shift in the focus of risk research is evaluating the potential role of waterborne pathogens as triggers for novel health outcomes such as diabetes and other autoimmune disorders. The magnitude of the association between environmental/waterborne exposures and diabetes is not well understood. Given the massive economic and health care burden of Type 1 diabetes, better understanding the associations with waterborne and environmental exposures could lead to very impactful approaches to reduce and control this disease.

Another significant, transformative view of waterborne health risk involves the development of alternative surrogates of wastewater treatment efficacy through high-throughput sequencing of the extremely diverse and abundant community of phage (i.e., viruses which infect bacteria) associated with wastewater. Phages represent an abundant (i.e., 10^8-10^9 ml^{-1}) and relevant (more analogous to viral pathogens) biological target for evaluating the efficacy of wastewater treatment. Analysis of the abundance of phage sequences and functional diversity of associated genomes (i.e., "phageome") in wastewater would provide new insight into potential surrogates for performance monitoring which would be particularly relevant to wastewater reuse applications. Identification of abundant, commonly occurring phage sequences could be linked to subsequent studies evaluating their removal in advanced treatment systems for water reuse relative to commonly employed viral spikes (i.e., MS2). The end product would be validated, endogenous markers of treatment efficacy, and concomitant opportunities for more real time monitoring.

Delivery Date: 2019

Intended user and audience: Office of Water, Regional Offices, States, Utilities

Key Products Identified

All products identified below will be used in combination with the products developed for monitoring both in this Project and with the Products developed in Projects 6.01 and 6.02.

Output 1. Integrated assessment tool to define optimal resource recovery-based water systems including water fit for purpose at various scales (2019)

Example of Key Products that could feed into this output

Key Product Title: Multi-criteria decision support tool and associated peer-reviewed support documents.

Description: LCA framework for assessing costs/benefits of innovative technologies and transformative processes for water treatment and resource recovery
Delivery Date: 2017

Intended Users: Office of Water, Regional Offices, States, Utilities

OW/Regional needs which may be met (wholly or in part) include:

- Innovative energy conservation and recovery technologies and approaches for WWTP energy self-sufficiency.
- Integrated wastewater management approaches for small systems that provide an optimal balance between treatment/environmental protection, productivity (e.g. agriculture, aquaculture), and resource recovery (e.g. water, nutrients). (Could also include costs/benefits for decentralized WW management approaches for large and small systems).

Output 2. Advanced monitoring and analytical tools (multiple parameters) for effective integrated water system management to minimize human and ecological risk (2019)

Example of Key Products that could feed into this output

Key Product Title: Report on development, testing, and evaluation of near real time biosensors.

Description: This key product contains two separate products: The first is the creation of a biosensor tool and the second is development of a deployable tool to measure the cellular response readout.
Delivery Date: 2018
Intended Users: Office of Water, Regional Offices, States, Utilities

OW/Regional needs which may be met (wholly or in part) include:

- Evaluate well construction and design, monitoring technologies, modeling and evaluation tools used for Area of Review delineation.
- NPDES Multi-Sector General Permit: Analyzing and recommending a strategy for industrial and storm water monitoring.

Output 3. Develop and demonstrate individual technologies and integrated systems to optimize the collection, treatment, and distribution of water (drinking water and wastewater), and the recovery of resources (2019)

Example of Key Products that could feed into this output

Key Product Title: Report on the development and demonstration of integrated net positive water systems at various community scales. Reports on water/resource recovery technologies in the NetZero Program.

Description: Information on innovative approaches for fit-for-purpose treatment of wastewater and resource recovery.
Delivery Date: 2019
Intended Users: Office of Water, Regional Offices, States, Utilities

OW/Regional needs which may be met (wholly or in part) include:

- Next generation advanced wastewater treatment designs that minimize aeration and GHG emissions.

Output 4. Communication of technological advancements of technologies for measuring health risks in current and future systems (2019)

Example of Key Products that could feed into this output

Product Title: Report determining whether a fraction of Type 1 diabetes may be preventable by controlling exposures and infections with environmental pathogens.

Description: Compilation of results from peer-reviewed manuscripts describing the influence of environmental factors (including sources of drinking water) on the association between microbial antigens and antibody response to selected pathogens (*Mycobacterium avium,* subspecies *paratuberculosis* and Coxsackievirus) in type 1 diabetes subjects.

Delivery Date: 2018
Intended Users: Office of Water, Regional Offices, States, Utilities

OW/Regional needs which may be met (wholly or in part) include:

- Protect human health from chemical and microbial contaminants

Assumptions and Constraints

The proposed research assumes adequate institutional support and funding. Field work will be contingent on continued cooperation with DoD through the NetZero program and the development of project-specific, multi-sector collaborations through the Water Technology Cluster, STAR and other ORD partnerships and collaborative programs.

References

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