REQUEST FOR PROPOSALS (RFP)

Benchmarking Microbial and Chemical Contamination in Source Water Using Hyperspectral Microscopy (5298)

Date Posted
Monday, September 9, 2024

Due Date
Proposals must be received by 3:00 pm Mountain Time on Thursday, November 14, 2024

WRF Project Contact
Sydney Samples, ssamples@waterrf.org

Project Sponsors
This project is funded by The Water Research Foundation (WRF) as part of WRF's Research Priority Program.

Project Objectives
- Develop a state of the science for hyperspectral imaging and highlight its applicability to the municipal One Water sector.
- Assess the sensitivity and accuracy of hyperspectral microscopy to detect microbial pathogens in a variety of impacted source water types (i.e., water, wastewater, reclaimed water, and stormwater) and water quality types (e.g., ranges of hardness, TOC, and alkalinity), and assess the minimum required quality assurance and quality control (QA/QC) needed to use the data for monitoring purposes. Pathogens should include but are not limited to *Cryptosporidium, Giardia,* and *E. coli.*
- Assess data cleaning, noise reduction, unmixing, and anomaly detection practices needed to refine the database produced.
- Assess the applicability of machine learning to predict microbial species based on hyperspectral imaging.
- Investigate if hyperspectral microscopy can detect chemicals and/or particles (i.e., microplastics, nanoplastics, and nanoparticles) in source water.

Budget
Applicants may request up to $250,000 in WRF funds for this project.

Background and Project Rationale
Many of the tests that utilities currently rely on to detect complex analytical microbial or chemical targets in source waters are slow, labor intensive, costly, and inefficient. They often

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require considerable sample preparation and laboratory handling, which may require highly experienced personnel. More importantly, when the targets are not regulated, these tests often generate large amounts of data that are not analyzed, compared, or trended over time, thus limiting the opportunity to use the data for evidence-based decision making. Simpler and faster alternatives are needed to provide more rapid source water monitoring. Hyperspectral microscopy is a rapidly developing technology that enables high-resolution imaging and spectral identification of a wide range of constituents in their native environment without requiring any additional staining or sample preparation. Evaluating the role of hyperspectral microscopy for rapid detection of contaminants in water and wastewater may be beneficial as an alternative monitoring technique to existing procedures.

Hyperspectral imagery works by employing a wide spectrum (i.e., hundreds of relatively narrow spectral bands, including short wave infrared [SWIR] and visible and near-infrared [VNIR]) to provide a unique and more detailed image signature than multispectral analyses. Early testing of hyperspectral imaging appears promising as a diagnostics tool and has been able to successfully differentiate a range of materials based on their unique spectral profiles in various applications (i.e., military, archaeology, forensics), including medicine (i.e., cancerous tissues) and the environment (i.e., oil spills in water, plastic refuse on land/oceans, tree disease/mortality rates). Despite hyperspectral monitoring being a powerful analytical method, remote monitoring applications (i.e., through satellites and small aircrafts) may be hampered due to analytical sensitivity challenges.

Eliminating sensitivity challenges may provide an opportunity for hyperspectral microscopy to become an alternative analytical platform for rapid and sensitive microbial contaminant monitoring in the One Water cycle. The spectral data generated through this process is generated in minutes to seconds, creating a simple and user-friendly procedure for utility personnel. While this technology is promising, additional research is needed due to existing uncertainty regarding the sensitivity and accuracy of hyperspectral microscopy for microbial contaminants. In addition, one challenge with hyperspectral imaging is extracting useful information from the high dimensional hyperspectral data that contains a vast amount of (potentially redundant) information. As a result, there is much interest in coupling this technology with artificial intelligence and machine learning to determine if pixel level spectral analyses can be applied to identify unique spectral fingerprints for different target microbials and chemicals in source waters. It should be noted that this project will not investigate hyperspectral imagery's ability to detect algal blooms because that is being addressed by WRF 5266.

Research Approach

This RFP is intentionally flexible in the research approach to encourage creativity and originality from proposers. Proposers should describe how they will conduct the research to meet the objectives listed above. The following approach is intended as a starting point.

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At a minimum, the research team must:

- Perform a literature review on hyperspectral imaging and hyperspectral microscopy for both microbial and chemical contaminants and develop a state of the science report. The report should highlight the applicability of the tool to the municipal One Water sector and distinguish the difference in capabilities at the micro versus the nano scale.
- Conduct laboratory testing to determine the sensitivity and accuracy of hyperspectral microscopy to detect microbial pathogens. A variety of impacted source water types should be used, including different sources of drinking water, wastewater, reclaimed water, and stormwater. The testing should explore different water quality types, such as waters with different levels of hardness, total organic carbon (TOC), and alkalinity. Testing practices should include minimum required QA/QC to ensure the data can be used for monitoring purposes. The proposal should include, but is not limited to, the following pathogens: *Cryptosporidium, Giardia,* and *E. coli.* The exploration of any assays that allow distinguishing viable, infective pathogens from non-infectious targets by hyperspectral microscopy are encouraged. A clear rationale should be provided for the contaminants selected as part of the study. The team should also assess what data cleaning, noise reduction, unmixing, and anomaly detection practices are needed to refine the database produced using the tool.
- Assess the applicability of machine learning to generate fingerprints for test microbial contaminants.
- Perform an exploratory study on hyperspectral microscopy's ability to detect chemicals and/or particles (i.e., microplastics, nanoplastics, and nanoparticles) in source water. The same level of sensitivity and accuracy is not needed on this portion of the study. The team should evaluate IF hyperspectral microscopy can detect chemicals or particles in source water. The proposers should develop a framework for this testing as well. Potential high interest chemicals and particles to investigate include 1,4-dioxane, 6DDP, microplastics, nanoplastics, and nanoparticles.
- Develop testing recommendations that utilities can use to establish their own hyperspectral microscopy testing programs. This resource guide should help utilities determine: the minimum features required to operate the technology, the minimum testing frequency, the types of samples that can be evaluated, the level of training required to operate the technology and read the results, and how to validate the results.
- Develop a decision tree that highlights when hyperspectral microscopy can be informative in addition to or instead of standard methods.

Expected Deliverables

- Research report (must use WRF's *Research Report Template*)
- Literature review
- A decision tree
- Webcast
- Conference presentation

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Communication Plan

Please review WRF's *Project Deliverable Guidelines* for information on preparing a communication plan. Conference presentations, webcasts, peer-reviewed publication submissions, and other forms of project information dissemination are typically encouraged.

Project Duration

The anticipated period of performance for this project is 24 months from the contract start date.

References and Resources

The following list includes examples of research reports, tools, and other resources that may be helpful to proposers. It is not intended to be comprehensive, nor is it a required list for consideration.

- Bukhari, Z. In Progress. *Determining the Role of Spectral Imaging as an Early Warning System for Presence/Significance of Algal Blooms.* Project 5266. Denver, CO: The Water Research Foundation. https://www.waterrf.org/research/projects/determining-role-spectral-imaging-early-warning-system-presencesignificance-algal.
- Bartrand, A., T. Hargy, R. McCuin, Z. Rodriguez del Rey, I. Douglas, J. Elliot, R. Andrews, and R. McFadyen. 2017. *Using QMRA to Estimate Health Risks of Pathogens in Drinking Water*. Project 4598. Denver, CO: The Water Research Foundation.
- Raucher, R., K. Setty, S. Cline, T. Bartrand, J. Bartram, and G. O'Flaherty. 2020. *A Risk Management Framework for Managing Source Water Risks in the United States*. Project 4748. Denver, CO: The Water Research Foundation.
- Jaiswal, G., R. Rani, H. Mangotra, and A. Sharma. 2023. Integration of Hyperspectral Imaging and Autoencoders: Benefits, Applications, Hyperparameter Tunning and Challenges. *Computer Science Review*, 50 (C): 100584.
- McKibben, S. M., S. Schollaert Uz, and S. L. Palacios. 2024. Testing a Hyperspectral, Bio-Optical Approach to Identification of Phytoplankton Community Composition in the Chesapeake Bay Estuary. *Earth and Space Science*, 11 (5): e2023EA003244.
- Peng, Y., J. Zhang, W. Wang, Y. Li, J. Wu, H. Huang, X. Gao, and W. Jiang. 2011. Potential Prediction of the Microbial Spoilage of Beef Using Spatially Resolved Hyperspectral Scattering Profiles. *Journal of Food Engineering*, 102 (2): 163-169.
- Gowen, A. A., Y. Feng, E. Gaston, and V. Valdramidis. 2015. Recent Applications of Hyperspectral Imaging in Microbiology. *Talanta*, 137: 43-54.
- Foca, G., C. Ferrari, A. Ulrici, G. Sciutto, S. Prati, S. Morandi, M. Brasca, P. Lavermicocca, S. Lanteri, and P. Oliveri. 2016. The Potential of Spectral and Hyperspectral-Imaging Techniques for Bacterial Detection in Food: A Case Study on Lactic Acid Bacteria. *Talanta*, 153: 111-119.
- Soni, A., Y. Dixit, M. M. Reis, and G. Brightwell. 2022. Hyperspectral imaging and machine learning in food microbiology: Developments and challenges in detection of bacterial, fungal, and viral contaminants. *Comprehensive Reviews in Food Science and Food Safety,* 21 (4): 3717-3745.

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- Qiu, R., Y. Zhao, D. Kong, N. Wu, and Y. He. 2023. Development and Comparison of Classification Models on VIS-NIR Hyperspectral Imaging Spectra for Qualitative Detection of the Staphylococcus Aureus in Fresh Chicken Breast. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 285: 121838.
- Soni, A., M. Al-Sarayreh, M. M. Reis, and G. Brightwell. 2021. Hyperspectral Imaging and Deep Learning for Quantification of Clostridium Sporogenes Spores in Food Products Using 1D-Convolutional Neural Networks and Random Forest Model*. Food Research International,* 147: 110577.

Proposal Evaluation Criteria

The following criteria will be used to evaluate proposals:

- Understanding the Problem and Responsiveness to RFP (maximum 20 points)
- Technical and Scientific Merit (maximum 30 points)
- Qualifications, Capabilities, and Management (maximum 15 points)
- Communication Plan, Deliverables, and Applicability (maximum 20 points)
- Budget and Schedule (maximum 15 points)

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PROPOSAL PREPARATION INSTRUCTIONS

Proposals submitted in response to this RFP must be prepared in accordance with WRF's *Guidelines for Research Priority Program Proposals* and *Instructions for Budget Preparation*. These guidelines contain instructions for the technical aspects, financial statements, indirect costs, and administrative requirements that the applicant must follow when preparing a proposal.

Proposals that include the production of web- or software-based tools, such as websites, Excel spreadsheets, Access databases, etc., must follow the criteria outlined for web tools presented in the *Technology Deliverables Guidance.*

Eligibility to Submit Proposals
Proposals will be accepted from both U.S.-based and non-U.S.-based entities, including educational institutions, research organizations, governmental agencies, and consultants or other for-profit entities.

WRF's Board of Directors has established a *Timeliness Policy* that addresses researcher adherence to the project schedule. Researchers who are late on any ongoing WRF-sponsored studies without approved no-cost extensions are not eligible to be named participants in any proposals. Direct any questions about eligibility to the WRF project contact listed at the top of this RFP.

Administrative, Cost, and Audit Standards
WRF's research program standards for administrative, cost, and audit compliance are based upon, and comply with, Office of Management and Budget (OMB) Uniform Grants Guidance (UGG), 2 CFR Part 200 Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards, and 48 CFR 31.2 Contracts with Commercial Organizations. These standards are referenced in WRF's *Guidelines for Research Priority Program Proposals* and include specific guidelines outlining the requirements for indirect cost negotiation agreements, financial statements, and the Statement of Direct Labor, Fringe Benefits, and General Overhead. Inclusion of indirect costs must be substantiated by a negotiated agreement or appropriate Statement of Direct Labor, Fringe Benefits, and General Overhead. Well in advance of preparing the proposal, your research and financial staff should review the detailed instructions included in WRF's *Guidelines for Research Priority Program Proposals* and consult the *Instructions for Budget Preparation.*

Budget and Funding Information
The maximum funding available from WRF for this project is $250,000. The applicant must contribute additional resources equivalent to at least 33% of the project award. For example, if an applicant requests $100,000 from WRF, an additional $33,000 or more must be contributed by the applicant. Acceptable forms of applicant contribution include cost share, applicant in-kind, or third-party in-kind that comply with 2 CFR Part 200.306 cost sharing or matching. The applicant may elect to contribute more than 33% to the project, but the maximum WRF funding

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available remains fixed at $250,000. Proposals that do not meet the minimum 33% of the project award will not be accepted. Consult the *Instructions for Budget Preparation* for more information and definitions of terms.

Period of Performance

It is WRF's policy to negotiate a reasonable schedule for each research project. Once this schedule is established, WRF and its sub-recipients have a contractual obligation to adhere to the agreed-upon schedule. Under WRF's *No-Cost Extension Policy*, a project schedule cannot be extended more than nine months beyond the original contracted schedule, regardless of the number of extensions granted.

Utility and Organization Participation

WRF encourages participation from water utilities and other organizations in WRF research. Participation can occur in a variety of ways, including direct participation, in-kind contributions, or in-kind services. To facilitate their participation, WRF has provided contact information, on the last page of this RFP, of utilities and other organizations that have indicated an interest in this research. Proposers are responsible for negotiating utility and organization participation in their particular proposals. The listed utilities and organizations are under no obligation to participate, and the proposer is not obligated to include them in their particular proposal.

Application Procedure and Deadline

Proposals are accepted exclusively online in PDF format, and they must be fully submitted before 3:00 pm Mountain Time on Thursday, November 14, 2024.

The online proposal system allows submission of your documents until the date and time stated in this RFP. To avoid the risk of the system closing before you press the submit button, do not wait until the last minute to complete your submission. Submit your proposal at https://forms.waterrf.org/cbruck/-rfp-5298.

Questions to clarify the intent of this RFP and WRF's administrative, cost, and financial requirements may be addressed to the WRF project contact, Sydney Samples at 571.384.2108 or ssamples@waterrf.org. Questions related to proposal submittal through the online system may be addressed to Caroline Bruck at 303.347.6118 or cbruck@waterrf.org.

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Utility and Organization Participants

The following utilities have indicated interest in possible participation in this research. This information is updated within 24 business hours after a utility or an interested organization submits a volunteer form, and this RFP will be re-posted with the new information. **(Depending on your settings, you may need to click refresh on your browser to load the latest file.)**

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