

Field Testing of In-Situ Passive Samplers for Monitoring Mercury Methylation Dynamics During Remediation and Long-Term Recovery of a Mercury-Impacted Site (Maine, USA)

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Background and Project Description

This **Research Initiation** proposal asks for **\$49,000** (approx.) over three years to develop field methodologies for monitoring the ecological effectiveness of sand caps for remediation of mercury-impacted sites. Sand caps are currently under pilot scale (< 10 acres) development in the United States for remediation of contaminated sediment for locations in which dredging is not an economically viable; ecologically warranted; and/or community supported approach to aquatic ecosystem remediation. With respect to MEIF-SCI, this proposed research aligns with **Aquaculture and Marine Technology** as well as **Environmental Technology** sectors.

In specific, this proposal requests funding to field test the use of **in-situ thin films** for monitoring and quantifying the microbial generation of hydrogen sulfide (H₂S) and associated methylation of inorganic mercury (Hg) within the sediments of the **Penobscot River estuary in Maine**. The Penobscot River estuary is currently undergoing the first stage of a **federally-mandated multi-stage remediation** resulting from the historical discharge of mercury from a chlor-alkali facility that operated in Orrington, ME¹. The initial stage of the remedy entailed the August- September 2026 placement of a 6-acre pilot sand cap in the intertidal and low marsh of an Orrington cove in which sediment enrichment with legacy mercury contamination is evident. If proven successful as a low-impact remedy, a further 150+ acres of mercury-impacted sediment may be capped within the Penobscot River estuary to facilitate system recovery while also eliminating or limiting the ecological and community impacts of a dredge-focused remedy.

Maine DEP (MEDEP) and Greenfield Environmental Trust Group² are committed to a 3-year monitoring program to **evaluate the stability and efficacy of the sand cap**; this research proposes to improve upon standard compliance and functional monitoring methods by **developing tools for time-integrated, in-situ monitoring of methylmercury (MeHg) generation in contaminated sediments**. With respect to the microbial generation of H₂S, preliminary research suggests that a thin film developed from silver gelatin photographic paper successfully allows for rapid determination of sulfide depth profiles in coastal sediments (Merritt 2026³). Likewise, preliminary research (Taylor et al. 2019⁴) suggests that polyphenylene sulfide (PPS) polymer thin films effectively sorb both inorganic Hg and MeHg. With relevance to monitoring ecological impacts of sand cap placement for mercury-impacted sites, sorption of

¹ <https://www.penobscotriversremediation.com/settlementoverview>

² <https://greenfielddenvironmental.com/getg-trusts/penobscot-trusts>

³ Merritt, K. 2026. Silver Gelatin Photo Paper as a Tool for Characterizing Microbially-Mediated Redox Dynamics in Saturated Sediments. In preparation for submission to *Biogeochemistry*.

⁴ Taylor, V. Buckman, K.L. and Burgess, R.M. 2019. Preliminary Investigation of Polymer-Based In Situ Samplers for Mercury and Methylmercury. *Chemosphere*. 234: 806-814.

MeHg to PPS polymer films also appears to correlate with MeHg accumulation by *Leptocheirus plumulosus*, an estuarine amphipod employed in USEPA-approved biotoxicity assessments.⁵

For this research, thin film deployments are proposed for summer 2027 and summer 2028 to evaluate the **evolution of mercury biogeochemistry under, within and through the emplaced Orrington sand cap**. The goal of this research is to assess whether the minimally disruptive monitoring technique described in this proposal can provide cost-effective monitoring data for sand cap performance, including assessment of laboratory-modeled (but not yet field-evaluated) concerns that in-situ remedies such as sand caps increase the rate of mercury methylation in the sediments under the emplaced cap.

For the mercury-impacted and pilot-scale capped cove along the Orrington shoreline, thin film deployments in 2027 will focus on optimizing thin film emplacement technique and duration, as well as confirmation of sampling resolution within the thin film. That is, based on thin film exposure duration and rates of in-situ microbial processes (i.e., sulfate reduction to sulfide and associated methylmercury generation in the presence of inorganic mercury), 2027 deployments will evaluate the possibility of sectioning films to allow distinguishing of processes in water overlying the cap; within the sand cap itself; and in the underlying mercury-contaminated sediment. With the objective of collecting **field-based, proof-of-concept data for use of analyte-specific thin films in environmental remediation monitoring**, deployments in 2028 will be conducted as 3-4 transects across the 6-acre pilot cap, with 4-5 sampling locations per transect oriented from the high- to the low-intertidal zone.

A specific additional goal of this research is **student opportunity at MMA**, with funds proposed for student involvement in research planning; field sampling; evaluation and interpretation of results; and presentation of project outcomes at at least one research conference. In addition, as a significant portion of the analytical budget for this project will be allocated to an academic laboratory at Dartmouth College for analysis of the mercury-specific thin films, the opportunity exists for one or several MMA students to participate in a summer laboratory research experience/opportunity at Dartmouth within the timeframe of this study.

It is expected that results from this proof-of-concept study will be of interest at the state level (such as at MEDEP) with the goal of **improving the cost-effectiveness and efficacy of environmental monitoring**. In addition, it is expected that results will be valuable in seeking additional larger-scale funding for continued research on low-impact and cost-effective tools for confirming successful implementation of remedial strategies at contaminated sediment sites.

Team/Institutional Merit and Commitment

Dr. Karen Merritt has worked for 15+ years as an environmental engineering consultant on the characterization of legacy contamination in aquatic environments in the U.S., Canada, Latin America and the E.U. Her work includes chemical fate and transport analysis, design of field sampling programs, evaluation of industrial histories, particularly with respect to mercury cell chlor-alkali production, and contaminant bioavailability on salt marshes and mudflats. She has published on the development of reactive gels for evaluation of mercury bioavailability and use

⁵ <https://archive.epa.gov/water/archive/polwaste/web/pdf/guidancemanual.pdf>

of sand caps to enhance ecological recovery rates in estuarine environments. Her current research is focused on the development of reactive sulfur gels. In addition to serving as Assistant Professor in Arts & Sciences at MMA and Affiliate Faculty in Ocean Studies, she continues to consult on remediation strategies for mercury-impacted sites. For the research proposed herein, Dr. Merritt will conduct the required sulfur chemistry analyses at MMA and will be responsible for dialysis sampler deployments, field sampling requirements and access permissions.

Dr. Vivien Taylor is a Research Associate Professor in the Earth Sciences Department at Dartmouth College. Dr. Taylor has published extensively on the environmental cycling and bioavailability of contaminants including mercury in coastal aquatic ecosystems; the potential utility of thin films for mercury monitoring, and the development and refinement of laboratory analytical methods for analysis of mercury and methylmercury in water, sediment, and biological tissue. For the research proposed herein, Dr. Taylor will run the required mercury and methylmercury analyses at Dartmouth. The instrumentation required for these analyses is not currently available at Maine state academic institutions.

Relevance to Stated Funding Targets

With a focus on **MEIF-SCI** investments in:

- Increasing research capacity + activity with potential for follow-on funding;
- Supporting new technologies and commercialization of those technologies; and
- R&D workforce development, including student research learning opportunities

and aligned with **State Economic Development Plan** objectives and strategies to:

- Promote collaboration across public, private, non-profit, and educational sectors;
- Expand educational and career opportunities to build a skilled local workforce (A);
- Promote Maine's community colleges, colleges, and universities as attractive options for students, boosting enrollment and retaining graduates in the local workforce (B.5);
- Foster research, development, and entrepreneurship to drive innovation (C); and
- Facilitate connections between educational institutions, nonprofits, and hubs to promote innovation + skill development (G.2)

and **Maine Economic Recovery Committee (ERC)** commitments regarding:

- Strategic investment in INNOVATION and ENTREPRENEURSHIP; and
- TALENT DEVELOPMENT with a focus on investing in higher education programs and increasing degree attainment; preparing workers for Maine's innovative sectors; and expanding internship opportunities and pathways linked to Higher Education.

this research proposal is significantly aligned with relevant Maine Economic Improvement Fund (MEIF) targets. In addition, this proposed research is aligned with **Federal Priority** goals to:

- Build capacity to translate scientific discovery into technological implementation;
- Expand hands-on technical learning; and
- Invest in basic and use-inspired research for emerging science and engineering technologies.

Timeline	Cost Category	Cost Estimate	Details
2027	Supplies	\$ 3,000	PPS ¹ films; lab needs
	MMA Student Stipend	\$ 2,000	\$25 hr × 40 hr × 2 wks
	Field Work	\$ 2,000	Small boat rental and incidental field needs
	Laboratory (MMA)	\$ 2,000	Porewater analyses
	Sub-Contract (Dartmouth)	\$ 6,000	Laboratory analyses (Hg ² and MeHg ³)
2028	Supplies	\$ 3,000	PPS films; lab needs
	MMA Student Stipend	\$ 3,000	\$25 hr × 40 hr × 3 wks
	Field Work	\$ 6,000	Includes MMA vessel and Waterfront staff time ⁴ (2 days)
	Laboratory (MMA)	\$ 2,000	Analytical support
	Sub-Contract (Dartmouth)	\$ 12,000	Laboratory analyses (Hg and MeHg)
2029	Supplies	--	--
	MMA Student Stipend	\$ 2,000	\$25 hr × 40 hr × 2 wks
	Field Work	\$ 1,000	Incidental field needs
	Laboratory (MMA)	--	--
	Sub-Contract (Dartmouth)	\$ 4,000	Laboratory analyses (Hg and MeHg)
	Conference + Publications	\$ 1,000	TBD; includes Maine Sustainability and Water Conference
Total		\$ 49,000	45 % - Dartmouth Lab Subcontract

1. PPS: polyphenylene sulfide

2. Hg: total mercury

3. MeHg: methylmercury

4. MMA Waterfront fees: \$300/hr (Gemini + small boat) x 8 hrs x 2 days + \$50 fuel surcharge/day x 2 days