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** pre-proposal asks for **$40,000** (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.

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 (H_2S) 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, ME[1]. 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 Group[2] 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 H_2S, 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 2026[3]). Likewise, preliminary research (Taylor et al. 2019[4]) 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 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]

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[1] https://www.penobscotriverremediation.com/settlementoverview
[2] https://greenfieldenvironmental.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.
[5] https://archive.epa.gov/water/archive/polwaste/web/pdf/guidancemanual.pdf

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.

It is expected that results from this proof-of-concept study will be of interest in the regulatory sphere 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. 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 conduct the mercury and methylmercury analyses at Dartmouth.

Dr. Karen Merritt has worked for 15+ years as an environmental engineering consultant on the characterization of legacy contamination in aquatic environments and has published on the development of reactive gels for evaluation of mercury bioavailability and use of sand caps to enhance ecological recovery in estuarine environments. She serves as Assistant Professor in Arts & Sciences at MMA and continues to consult on remediation strategies for mercury-impacted sites. For the research proposed herein, Dr. Merritt will conduct the sulfur chemistry analyses and will be responsible for dialysis sampler deployments and field sampling requirements.