National Institute of Environmental Health Sciences
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Superfund Research Program

Optimizing Natural Systems for Remediation: Utilizing Innovative Materials Science Approaches to Enhance Bioremediation

The National Institute of Environmental Health Sciences (NIEHS) Superfund Research Program (SRP) funds a range of university-based research to address public health concerns arising from hazardous substances in the environment. In 2020, SRP initiated a special grant opportunity for targeted research that integrates bioremediation and materials science approaches to advance sustainable solutions for reducing hazardous substances in the environment. Grant projects funded through this program are described below. Bioremediation uses bacteria, algae, fungi, or plants to break down and remove hazardous substances from the environment. By integrating advances in materials science, research teams seek to further refine our understanding of the mechanisms of bioremediation and optimize conditions to accelerate natural degradation processes.

Through the funding opportunity announcement, RFA-ES-20-004, Optimizing Natural Systems for Remediation: Utilizing Innovative Materials Science Approaches to Enhance Bioremediation (R01), SRP provides support for the development of tools that may offer new breakthroughs to advance sustainable solutions for hazardous substances in the environment.

For more information on the National Institute of Environmental Health Sciences, visit **https://niehs.nih.gov**.

For more information on the SRP, visit **https://niehs.nih.gov/srp**.

NIEHS Contact:

Heather Henry, Ph.D.,
Program Administrator;
henryh@niehs.nih.gov; 984-287-3268

William Suk, Ph.D.,
Director Superfund Research Program;
suk@niehs.nih.gov, 984-287-3325

Legislative Authority: Section 311(a) of the Superfund Amendments and Reauthorization Act (SARA) of 1986.

R01ES032692 — Florida State University — Texas Tech University
Youneng Tang, Ph.D., ytang@eng.famu.fsu.edu; Yuexiao Shen, Ph.D., yuexiao.shen@ttu.edu

Enhancing Bioremediation of Groundwater Co-Contaminated by Chlorinated Volatile Organic Compounds and 1,4-Dioxane Using Novel Macrocyclic Materials

Scientists are evaluating a new technology to clean up groundwater contaminated with 1,4-dioxane and chlorinated volatile organic contaminants. They are designing sorbents consisting of a set of repeating cyclic macromolecules with unique geometry and internal chemistry that form specific microbe-contaminant complexes with only selected molecules, such as 1,4-dioxane. The researchers seek to understand how these sorbents can selectively adsorb hazardous substances and promote the growth of microbes on the material surface to break down contaminants.

Bacteria growing on an agar plate. The bacteria originated from a wastewater treatment site. *(Photo courtesy of Youneng Tang)*

R01ES032719 — University of Maryland, Baltimore County — Arcadis — Upal Ghosh, Ph.D., ughosh@umbc.edu, Kevin Sowers, Ph.D., sowers@umbc.edu; Amar Wadhawan, Ph.D., amar.wadhawan@arcadis.com

Leveraging the Chemo-Physical Interaction of Halorespiring Bacteria With Solid Surfaces to Enhance Halogenated Organic Compounds Bioremediation

The research team is developing carbon-based sorbent materials to enhance the ability of bacteria to break down mixtures of chlorinated organic contaminants, such as chloroethene and polychlorinated biphenyls (PCBs), in groundwater and sediments. Leveraging their previous work demonstrating that bacteria have the capability to degrade PCBs in the presence of activated carbon, the team will perform studies to evaluate the mechanisms of interaction with sorbent surfaces and integrate new findings with advanced site models to assess field-scale remedial applications.

R01ES032671 — University of Iowa — Villanova University — Timothy Mattes, Ph.D., tim-mattes@uiowa.edu; Wenqing (Vicky) Xu, Ph.D., wenqing.xu@villanova.edu

Elucidating Mechanisms for Enhanced Anaerobic Bioremediation in the Presence of Carbonaceous Materials Using an Integrated Material Science and Molecular Microbial Ecology Approach

Researchers are investigating how activated carbon can be used to enhance the performance of bacteria used to break down halogenated pollutants, such as chlorinated ethenes. By re-engineering carbon materials, they hope to influence the composition of the degrading microbial community and increase their ability to break down halogenated contaminants while also sequestering toxic chemicals that are found in mixtures with halogenated compounds. These findings will inform the team's efforts to design a bioremediation approach to reduce the amount and toxicity of halogenated pollutants in the environment.

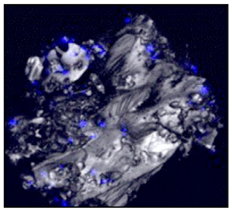

Image of bacteria attached to a black carbon particle. *(Photo courtesy of Timothy Mattes)*

PO Box 12233 • Research Triangle Park, NC 27709
Phone: 919-541-3345 • **www.niehs.nih.gov**

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R01ES032708 — Texas A&M AgriLife Research — Texas A&M University — Carnegie Mellon University
Susan Dai, Ph.D., sydai@tamu.edu, Joshua Yuan, Ph.D., syuan@tamu.edu; Gregory Lowry, Ph.D., glowry@cmu.edu

Efficient Bioremediation of Environmentally Persistent Contaminants With Nanomaterial-Fungus Framework

Scientists are designing an integrated system using nanotechnology to enhance the capacity of fungi to break down persistent organic pollutants, such as per- and polyfluoroalkyl substances (PFAS). The researchers seek to understand how modifying their nanomaterials can improve chemical adsorption and favor fungal growth. By exploring the key genes and enzymes involved, they hope to further improve the efficiency of their system. Laboratory tests are using samples collected from the Randolph Air Force Base in Texas.

R01ES032717 — State University of New York at Buffalo — University of Pittsburgh — University of Pittsburgh
Diana Aga, Ph.D., dianaaga@buffalo.edu, Ian Bradley Ph.D., ianbradl@buffalo.edu, Nirupam Aich, Ph.D., nirupama@buffalo.edu; Carla Ng, Ph.D., carla.ng@pitt.edu

Model-Aided Design and Integration of Functionalized Hybrid Nanomaterials for Enhanced Bioremediation of Per-and Polyfluoroalkyl Substances (PFASs)

The research team is developing a two-step approach to eliminate PFAS in the environment. First, graphene-metal nanoparticles are used to break down PFAS into biodegradable forms, and then enriched bacterial cultures are used to complete the degradation process. Every step of the reaction is characterized by high-resolution mass spectrometry to determine the byproducts formed. Molecular modeling will help identify enzymes likely to break down PFAS and suggest strategies to improve their performance. Findings from this research may lead to approaches that can effectively break down PFAS without generating toxic byproducts.

R01ES032694 — Princeton University — Peter Jaffe, Ph.D., jaffe@princeton.edu, Bruce Koel, Ph.D., bkoel@princeton.edu

Enhancing Transport and Delivery of Ferrihydrite Nanoparticles via Polymer Encapsulation in PFAS-Contaminated Sediments to Simulate PFAS Defluorination by Acidimicrobium sp. Strain A6

Princeton University investigators are developing ferrihydrite nanoparticles to stimulate the activity of bacteria to break down PFAS in contaminated drinking water. The team is using laboratory studies to enhance the transport of their nanoparticles in groundwater. To test the effectiveness of their technology, the scientists will use soil samples collected from a Superfund site.

R01ES032668 — University of California, Riverside — University of California, Los Angeles
Yujie Men, Ph.D., ymen@engr.ucr.edu; Chong Liu, Ph.D., chongliu@chem.ucla.edu

Synergistic Material-Microbe Interface Towards Faster, Deeper, and Air-Tolerant Reductive Dehalogenation

The research team is exploring how nanomaterials powered by solar electricity can accelerate the activity of bacteria used to clean up halogenated contaminants and 1,4-dioxane in groundwater. The scientists are using advanced analytical tools to understand how solar electricity can allow bacteria to degrade halogenated contaminants faster, more deeply, and under more realistic conditions. They also want their system to allow bacteria to degrade halogenated compounds and other co-contaminants at the same time.

R01ES032707 — Oregon State University — Lewis Semprini, Ph.D., lewis.semprini@oregonstate.edu, Willie Rochefort, Ph.D., rochefow@oregonstate.edu, Michael Hyman, Ph.D., mrhyman@ncsu.edu

Development of Passive and Sustainable Cometabolic Systems to Treat Complex Contaminant Mixtures by Encapsulating Microbial Cultures and Slow-Release Substrates in Hydrogels

Researchers are developing a strategy to use bacteria encapsulated with a slow-release compound in hydrogel beads to break down complex mixtures of contaminants, such as VOCs and 1,4-dioxane. Using materials science and laboratory studies, the team aims to improve the ability of bacteria to stay active in encapsulated systems and to determine how to produce hydrogel beads that maintain mechanical integrity for extended periods. Results from this project may inform long-term bioremediation solutions to treat a broad range of contaminants.

R01ES032712 — Yale School of Public Health — University of Minnesota — Connecticut Agricultural Experiment Station
Vasilis Vasiliou, Ph.D., vasilis.vasiliou@yale.edu, Christy Haynes, Ph.D., chaynes@umn.edu, Jason White, Ph.D., jason.white@ct.gov

Understanding and Enhancing PFAS Phytoremediation Mechanisms Using Novel Nanomaterials

Researchers are designing nanomaterials customized to bind and take up PFAS from contaminated soil and water into hemp plants. Their nanomaterials are based on silica nanoparticles with high porosity and surface area, and on carbon dots known for their small size and fluorescence. The carbon dots' ability to emit light will allow the team to visually track the PFAS movement into and throughout the plants. They will also test the affinity of their nanomaterials to bind a mixture of two legacy and two new PFAS.

R01ES032686 — University of Massachusetts — Om Parkash Dhankher, Ph.D., parkash@umass.edu, Venkataraman Dhandapani, Ph.D., dv@umass.edu, Baoshan Xing, Ph.D., bx@umass.edu, Jason White, Ph.D., jason.white@ct.gov

A Novel Strategy for Arsenic Phytoremediation

Scientists are genetically engineering plants to take up arsenic from soil and store it in their tissues. The research team is modifying the expression of genes that control the transport, oxidation state, and binding of arsenic. By adding nanosulfur to the plant, they aim to improve plant growth, enhance the extraction process, and increase the plant's arsenic storage capacity. Insights from this study will enable efficient and effective phytoremediation approaches to minimize or remove arsenic from contaminated croplands.