# ITRC PROJECT PROPOSAL

## Biochemical Reactors to Treat Metals in Mining-Influenced Water

### Proposal Contact:

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### Call for Proposals Topical Area

**Primary topic area - CONT - Soil and groundwater contamination**

*Technologies and approaches for modeling, treatment, and remediation of contaminated soil and groundwater.*

**Secondary topic area – STORM - Storm water management**

*Impacts, monitoring, and mitigation of point and non-point storm water discharges.*

### Problem Statement (why is this project necessary and relevant to ITRC's purpose & mission?)

Mining influenced water (MIW) is a major environmental problem in mining districts throughout the U.S. and around the world. Water quality impacts vary from elevated suspended solids to acid mine drainage. Elevated suspended solids generally occur through erosion of mine wastes, causing increased turbidity and potential aquatic impacts following deposition. Acid mine waters are produced in mined rock masses or mining/milling waste piles containing sulfide minerals with insufficient neutralizing capacity. Oxidation of these sulfide minerals produces acid and releases metals into solution. These problems can persist for tens to hundreds of years. Over 10,000 miles of receiving waters in the United States are affected by MIW. MIW is difficult to treat cost-effectively to levels protective of human health and the environment.

A biochemical reactor (BCR) generically implies a system that cultivates microorganisms that transform contaminants or produce chemicals that can be used for remediation or treatment. The most commonly used BCRs for treating MIW are operated anaerobically, i.e. in the absence of oxygen, require a carbon source and sulfate and are often called sulfate-reducing bioreactors (SRBRs). The microbial process of sulfate reduction produces sulfide and bicarbonate. A number of target metals (e.g., cadmium, copper, nickel, lead, and zinc) in MIW will precipitate as metal sulfides at pH values above 5.0. The bicarbonate promotes an increase in pH and will promote the removal of some metals as carbonates (e.g., Iron (II) Carbonate ($FeCO_3$) and Zinc Carbonate ($ZnCO_3$)) under the appropriate conditions (e.g., specific pH and carbonate concentration). Additionally, redox active metals and metalloids (e.g., arsenic, chromium, selenium, and uranium) that form stable precipitates under neutral reducing conditions may also be targeted.

Thus, BCRs may be applicable to a broad range of metal and metalloids found in MIW. If space is not a limitation, then BCRs can be designed to address a wide range of flows, acidity and metals loading. BCRs are attractive since they can be built with local materials and often can be designed to operate without any external inputs of energy or material and require minimal maintenance. As a result, BCRs can be built to provide passive treatment and may be particularly suitable for remote and abandoned sites.

During the development of the problem-based technology and regulatory guidance for mining- waste treatment technology selection, the ITRC Mining Waste Team collected some case studies and prepared a technology overview on BCRs. The technology has been applied at mining sites but additional work is continuing to fully evaluate metrics important during deployment.

BCR design is affected by the chemistry and flow of the MIW, particularly pH and temperature as well as the kinetics of the desired microbial processes. In addition to passive systems, BCRs also include active

systems (continuous energy and chemical input). Active BCRs show the capacity to treat relatively high flows in a small areal footprint. However, these systems have only been implemented at active mining and mineral processing sites. The active systems typically employ separate tanks or zones for the bioprocesses, chemical reactions, and solids separation. The general differences between active and passive BCRs are presented below.

Active BCRs:

- accommodate reasonably high flow rates
- integrate pH adjustment into the water when needed
- allow for recovery of metal sulfides for beneficial reprocessing

In contrast, passive systems utilize designs that incorporate the bioprocesses, chemical reactions and the bulk of solids separation within an organic substrate.

Passive BCRs:

- reduce the need for intensive operation and maintenance requirements
- facilitate the use of cost-effective materials for construction
    - include the use of local materials easily obtainable for substrate media
- reduce the need for construction practices requiring advanced technologies

Hybrid systems, or semi-passive systems, have also been built. These usually provide an external carbon source (e.g. ethanol) and may also recirculate water to optimize treatment. These systems require some energy to power small chemical feed pumps and possibly recirculating pumps. For systems with just small feed pumps, solar or wind power can be used. These systems require some weekly and periodic maintenance to insure proper operation.

Based on the initial work of the ITRC Mining Waste Team, BCRs were chosen as a promising technology that needed to be further investigated and developed into a technology- based guidance. The technology is attractive and EPA has employed systems at several sites. Initial treatment has been effective but long-term performance and costs are important issues particularly since states are generally responsible for the long-term operation and maintenance at abandoned sites. BCRs generally provide treatment and can dramatically improve water quality but sometimes do not continuously meet strict numeric criteria An understanding of how and when bioreactors can be successfully used is critical. States have been reluctant to accept this technology and a guidance document is needed to facilitate acceptance and use of this innovative technology. It is important to realize that BCRs are not limited to MIW and the technology can be applied to any metal-contaminated water.

**Proposed Scope to Address Problem (what is the approach for this project?)**

The ITRC Mining Waste Team will build from the existing case studies and literature research included in the existing BCR Technology Overview. The team will conduct a critical review of existing and additional case studies and use new data and research from the U.S. EPA, U.S. Department of the Interior, Colorado School of Mines and the ITRC Industry Affiliates Program (IAP) members to evaluate the following:

- the microbial and chemical processes occurring in BCRs,
- a detailed comparison of the different types of BCRs
- the parameters and concentrations that can be treated
- required site characteristics
- flow and chemical loading requirements
- treatment life
- costs

The lessons learned and engineering concerns identified in the BCR Technology Overview will be incorporated and addressed in the Technical and Regulatory Guidance. Some of the questions and issues to be addressed include:

- Is a BCR appropriate for a given site and how is this determined?
- What are the BCR design requirements and what are the constraints?
    - What modifications are needed for treatment during winter months?
- How are fluctuating flows and water quality managed?
- What are the requirements to prevent the system flow from short circuiting?
- How can systems be designed to reduce or minimize maintenance?
- How can treatment be optimized or improved?

- How long will treatment last and when will the substrate media need to be replaced or replenished?
- Where and how is the substrate media from the BCR disposed?

## Targeted Users (who will use products generated by this project?)

Primary users for BCRs will be practitioners and consultants and state and federal regulators responsible for the remediation of MIW at abandoned or active mining sites. Responsible parties for MIW include the commercial mining industry, the U.S. Department of the Interior including the Bureau of Land Management and the U.S. Forest Service, EPA Superfund through Fund-lead response actions, U.S. Department of Defense, U.S. Department of Energy, and state mined-land and water-resource programs. Universities such as the Colorado School of Mines, Pennsylvania State University, the University of Georgia, and the University of Nevada, Reno are currently interested and conducting research on the biochemical treatment of MIW.

**According to the ITRC SE needs assessment:**

- Five states have noted that mining related problems are a number-one (#1) state priority. These are Missouri, Oklahoma, West Virginia, Wyoming, Alaska,
- Four states have noted that mining related problems are a number-two (#2)state priority. These are Colorado, Georgia, Missouri, and Wyoming
- Three states have noted that mining related problems are a number-three (#3) state priority. These include Colorado, Maine, Utah,
- Two states have noted that mining related problems are a number-four (#4) state priority. These include Colorado and Pennsylvania.

Please refer to the Mining Specific needs assessment at http://www.itrcweb.org/planning.asp for further information.

During preparation of the *Mine Waste Issues in the United States: A White Paper* and the guidance, the ITRC Mining Waste Team state members identified Acid Mine Drainage (AMD), which is included in MIW, as a priority. These states include:

- Alaska
- California
- Colorado
- Idaho
- Maine
- Minnesota
- Missouri
- Oklahoma
- Pennsylvania
- Utah
- Vermont

## Summary of Deliverables (primary project product(s))

A Technology Overview of Biochemical Reactors has been completed by the ITRC Mining Waste Team and can be found on http://www.itrcweb.org/teamresources_56.asp The Mining Waste Team will use the information, case studies and literature referenced in the Technology Overview of Biochemical Reactors, plus additional information that becomes available, to prepare a Technical and Regulatory Guidance for the application of BCRs to treat metal-contaminated water. This will be accompanied by the required Internet Based Training. This is the final product development phase in the ITRC Project Lifecycle. This will be followed by Implementation. All products will follow the guidance provided in the ITRC Framework for Developing a Quality ITRC *Technical and Regulatory Guidance Document.*

## Impact (how will this project result in more effective environmental decision making?)

This Technical and Regulatory Guidance will enhance the user's ability to treat MIW on site and improve the water quality of hundreds of watersheds throughout the U.S. Designed and maintained properly, BCRs can treat nearly any volume of flow and concentration of metals. BCRs can be sustained over the long term, can achieve passive metal removal, and can be deployed remotely in many instances. Combined with other technologies and applied in tandem, BCRs can improve water quality in watersheds that are ecologically impacted by high metal contamination resulting from current and historic mining practices.

This guidance will support the ITRC mission by offering and information resource in the form of a guidance that helps break down barriers to the acceptance and use of a technically sound solution to a widespread environmental challenge through an active and existing network of diverse professionals in the mining industry, consulting industry and regulatory community.

## Project Schedule

Team work will begin in January 2011. Activities to be completed and a timeline are as follows:

1) Case study review and update, plus collection of addition case examples will be completed by July 2011.
2) The decision protocol for a BCR Tech-Reg document (active and passive) will be completed by the ITRC Fall 2011 meeting along with the outline and first full draft of the guidance.
3) Internet based training development will begin in January 2012.
4) External review (see ITRC Framework for Developing a Quality ITRC *Technical and Regulatory Guidance Document*) will begin in June 2012.
5) Final Posting of the Tech-Reg document and delivery of the dry-run internet-based training will be completed in December 2012.
6) Implementation will begin in January 2013 and extend through 2014.

## Proposed Personnel

**Potential Team Membership/Needs**

**Co-Team Leader:** Cherri Baysinger, Missouri
Cherri is the Chief of the Bureau of Environmental Epidemiology, Missouri Department of Health and Senior Services. She has worked for Missouri Department of Health and Senior Services or Missouri Department of Natural Resources for 19 years. Ms. Baysinger has a B.A. in Biology and an M.S. in Forestry, Fisheries, and Wildlife, both from the University of Missouri-Columbia. Cherri has been the Co-team Leader of the ITRC Mining Waste Team since 2007 and the team received the Team of the Year award in 2009.

**Co-Team Leader:** Paul Eger, Minnesota
Paul is a principal engineer for the Minnesota Department of Natural Resources, Division of Lands and Minerals, where for over 30 years he has worked with environmental issues related to mining. Much of his work has focused on the development of successful passive systems to control and prevent mine drainage problems. He has also been a leader in the development of cost-effective and environmentally safe reclamation using waste products, including biosolids and dredged material.

Paul was a member and internet instructor for the ITRC Wetlands Team, was a co-team leader and instructor for the ITRC Mitigation Wetlands Team and has been co-team leader of the ITRC Mining Waste Team since it began in 2007.

The proposed team includes some of the leading U.S. researchers, consultants, federal agencies and states in this area and the resulting guidance will draw upon their experiences and skills. The team will include numerous regulators from a variety of states and from the federal government who bring varying regulator perspectives on this topic that are essential to incorporate in any characterization technical regulatory document.

**States interested in participating in this project and why.**

- Alaska
- Colorado
- Maine
- Minnesota
- Missouri
- Oklahoma
- Pennsylvania
- Utah
- Vermont

All have reported to have serious MIW problems resulting from active or historic mining practices. Many of these sources of MIW are continuous and require economical methods of water treatment to protect human health and restore stream and watersheds to an ecologically healthy condition. Since the states are often responsible for long-term operation and maintenance costs, they are particularly interested in the feasibility of applying innovative passive systems like BCRs.

Other organizations that have expressed interest in participating as team members for this project are:

**Federal Agencies:**

- U.S. EPA Office of Research and Development (ORD), National Risk Management Research Laboratory (NRMRL), Cincinnati, Ohio
- U.S. EPA Office of Solid Waste and Emergency Response (OSWER), Office of Superfund Remediation and Technology Innovation (OSRTI)
- U.S. EPA Regions 8 and 9

The U.S. EPA has and continues to conduct research on BCRs in conjunction with practioners and various universities (e.g. Colorado School of Mines, University of Oklahoma). There are a number of

large Superfund sites throughout the United States (e.g. Bunker Hill, Tar Creek, Standard Mine, etc.) that result from historic mining and where BCRs have been installed.

- The U.S. Department of the Interior

The U.S Department of the Interior administers 253 million acres of land in the US. Much of this land is in the western US. There are thousand of abandoned mines on or adjacent to Bureau of Land Management (BLM) land that is impacting surface and groundwater. The BLM Abandoned Mine Lands program is charged to enhance public safety and improve water quality by reducing or eliminating effects of past hard rock mining in the western United States. Currently their inventory includes over 12,000 mining sites; 80% of these still require attention.

- U.S. Fish And Wildlife Service

The U.S. Fish and Wildlife Service has responsibility to maintain a healthy environment for aquatic species on and near superfund sites. This agency has a critical interest to see that surface waters are restored to healthy conditions and can support a functional aquatic ecosystem.

- U.S. Department of Defense (including the Air Force Center for Engineering and the Environment (AFCEE), the Navy, the Strategic Environmental Research and Development Program (SERDP) )
- U.S. Department of Energy
- Center for Protection of Sustainable Technologies (CPTS) La Paz Bolivia

Christian Romero of CPTS has been an active member of the ITRC Mining Team since it beginning and has been a significant contributor and author of the current web based Tech-Reg. CPTS is funded by USAID and the Denmark Embassy. CPTS has a signed agreement with Universidad Mayor de San Andrés" – UMSA (Mayor Saint Andrews University – MSAU) and includes German cooperation through Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in order to conduct research on bioreactor technologies, including high altitude and low temperature operation.

**IAP companies (Environmental Consultants and industry)**

Arcadis
ERM
Western Research Institute
Freeport McMoMoran
DOE Run
Golder and Associates
JRW Bioremediation, LLC
Kleinfelder
BP Corporation
Shaw Environmental
Northwind, Inc

**Academia**

- Colorado School of Mines
- University of Georgia
- Pennsylvania State University
- University of Nevada Reno

The team provides a forum in which academics can bring their research and network with practitioners from both the private and public sectors.

- The skill mix of team members includes but is not limited to: hydrogeology and water chemistry, environmental, civil, and bioengineering, treatment system design, site characterization, regulatory issues, geology, chemistry, and bioremediation.
- For sectors of team members required, this will be the same as the existing ITRC Mining Waste Team which was well represented in all sectors.

**Proposed In-Kind/Direct Project Funding**

- At this time, in-kind or direct project funding has not been identified.

## Related Work

The ITRC Mine Waste Team has prepared the following:

- Mine Waste Issues in the United States: A White Paper 2008
- Mining Waste Treatment Technology Selection 2010