2027 ITRC Project Team Proposal Form

ENVIRONMENTAL TOPIC:

Bioremediation update guidance document

PROJECT TITLE:

The Proposed Project Team will update ITRC guidance documents from 2002 and 2008 and develop/update/digitize the decision trees for the existing remediation tools.

PROBLEM STATEMENT:

This proposal seeks to update existing ITRC resource documents. The last ITRC in-situ bioremediation/ BioDNAPL document was in 2008 (18 years ago). This guidance will provide the reader with updated information related to site characterization, application and design criteria, process monitoring, process optimization and case studies.

Over the past 18 years continued research and technological innovation have allowed bioremediation to advance significantly. In addition to the elucidation of new biodegradation pathways for a variety of contaminants, advances in technologies include Stable Isotope Probing, next generation sequencing for microorganisms/microcosms including functional gene testing, low pH resistant strains of microorganisms, source tracking via microbial assays. Furthermore, bioremediation has recently been recognized as a viable pathway to separate and purify critical minerals from mining waste, providing reducing environmental risks while producing a new revenue stream and supporting domestic resource development

The technology that has come out since 2008 has greatly improved the success rate of bioremediation technologies and has allowed for more confident remedy selections prior to full site implementation. The newer technology provides quantification of specific contaminant degrading microorganisms and functional genes, comprehensive characterization and identification of microbial communities, and conclusive evidence of contaminant degradation. Regulators and consultants need a guidance document that summarizes these new technologies and at what concentrations amendments/microorganisms/genes/geochemistry provide confidence in bioremediation success and when bioaugmentation or additional amendment injections are beneficial.

Despite these advances, a significant gap remains between scientific capability and consistent regulatory and practitioner implementation. The problem facing the environmental community is not a lack of technology, but rather the absence of clear, standardized guidance on how to apply modern tools to support remedy selection, optimization, transition, and closure. This gap is particularly important to ITRC membership, which includes regulators, consultants, and industry practitioners who require defensible, consensus-based approaches for decision-making. Without updated guidance, there is continued variability in how bioremediation is evaluated and approved, leading to uncertainty, delayed remedies, and in some cases, underutilization of effective solutions.

In the previous bioremediation documents the focus was on regulatory acceptance and case studies to distill a general understanding from the collective information obtainable at that time. The previous documents stated that the “technology is still early in its development. There are concerns about the potential for mobilizing DNAPL during electron donor injections, and much of the “credible evidence” is based on measurements of aqueous-phase concentrations, which have inherent technical limitations. In addition, the overall impact that bioremediation of source zones can have on the restoration time frame is not clear.” 18 years since this

statement, bioremediation is no longer a technology in its early development and there are countless case studies available to show the full range bioremediation. With the new technology available we are able to quantify our answers to these questions with more confidence. Regulators and consultants need a guidance document available to describe the new technology and its applicability to answer remedy selection/remedy transition/ remedy closure options. Modern tools now allow for quantification of specific contaminant-degrading microorganisms and associated functional genes, comprehensive characterization of microbial communities, and multiple lines of evidence confirming contaminant degradation. However, specific technical and regulatory barriers remain, including: (1) lack of standardized thresholds for microbial and geochemical indicators that demonstrate effective biodegradation; (2) uncertainty in when additional amendment injections are necessary; (3) inconsistent acceptance of molecular biological data by regulators; and (4) limited integration of these tools into formal decision-making frameworks.

This effort will overcome these barriers by developing a comprehensive, updated ITRC guidance document that translates current scientific capabilities into actionable regulatory and technical guidance. The proposed solutions include defining lines of evidence and quantitative benchmarks for bioremediation performance, establishing decision frameworks for remedy selection and optimization, and providing clear guidance on when to choose natural attenuation or utilize biostimulation. In addition, the document will improve consistency in regulatory acceptance by summarizing best practices and providing scientifically defensible criteria for integrating multiple lines of evidence including advanced molecular and isotopic data.

A high-level outline of the proposed guidance document is as follows:

1. **Introduction and Background**
    a. Overview
    b. Summary of existing guidance and limitations
2. **Advances in Bioremediation Technologies**
    a. Common molecular biological tools (qPCR, NGS)
    b. Stable isotope techniques (SIP, CSIA)
3. **Lines of Evidence and Data Integration**
    a. Combining microbial, geochemical, and contaminant data
    b. Defining biodegradation
4. **Decision Frameworks**
    a. Remedy selection
    b. Remedy optimization and transition
    c. Moving to MNA and Site Closure
5. **Regulatory Considerations**
    a. Standardization of data interpretation
    b. Improving regulatory confidence and acceptance
6. **Emerging Applications**
    a. Critical minerals recovery and improved mining
    b. Challenging site conditions (e.g. low pH, complex mixtures)
7. **Case Studies**
    a. Demonstration of modern tools and decision frameworks
8. **Conclusions and Recommendations**

ADDITIONAL INFORMATION:

ITRC EMD Documents
https://microbe.com/environmental-remediation/#
https://regenesis.com/en/technology/bio-dechlor-inoculum-plus/
https://www.siremlab.com/bioaugmentation-cultures/

Suggest a guidance document and either a toolkit that with input can determine success for bioremediation at your site, and/or quick fact sheets for regulators to look at to determine if microbe populations are dense enough or have a satisfactory environment for biodegradation.

Subject matter experts and ITRC members that may be interested in joining the Project Team:

- Sara MacDonald (SC DES)
- Carl Gruszczak (CT DEEP)
- Richard Hamner (AL DEM)
- Sam Baushke (MI EGLE)
- Jen Stackhouse (CA DTSC)
- Sam Rosolina and Dora Taggart (Microbial Insights)
- Patrick McLoughlin (McLoughlin Environmental Science, LLC)