

TECHNICAL MEMORANDUM

To: Nevada Environmental Response Trust

Cc: Dan Pastor, David Bohmann

From: Arul Ayyaswami

Date: June 28, 2018

Subject: Unit 4 Source Area In-Situ Bioremediation Bench-Scale Treatability Study Work Plan Modification No. 1

This Technical Memorandum presents Tetra Tech's recommended Treatability Study Modification No. 1 to the scope of work for the September 12, 2017 Unit 4 Source Area In-Situ Bioremediation Bench-Scale Treatability Study Work Plan. Bench-scale studies are currently in progress to support design and implementation of the Unit 4 Source Area In-Situ Bioremediation Treatability Study at the Nevada Environmental Response Trust (NERT or the Trust) site (Site) located in Clark County, Nevada. Based on the initial findings of the initial bench-scale testing and input provided by the Nevada Division of Environmental Protection (NDEP) and Dr. Batista at the University of Nevada Las Vegas (UNLV), Tetra Tech recommends continuation of existing bench-scale testing, and additional bench-scale testing as detailed below. The recommended scope addendum will supplement and support the original bench-scale study objectives and is necessary to obtain data for use in the Unit 4 In-Situ Source Area Bioremediation Treatability Study.

Continuation of Bench-Scale Testing

Bench-scale testing is currently being conducted by UNLV consistent with the approved Unit 4 Source Area In-Situ Bioremediation Bench-Scale Treatability Study Work Plan to support the Unit 4 Source Area In-Situ Bioremediation Treatability Study design and implementation. As of May 2018, bench-scale testing results are summarized as follows:

- UNLV has utilized several carbon substrates and combinations of carbon substrates to evaluate their effect on the biodegradation of chemicals of potential concern (CPOCs), including emulsified oil substrate (EOS), EOS and acetate, and molasses.
- The use of bioaugmentation, the process of enhancing biodegradation by the addition of biomass, appears necessary to degrade chlorate and perchlorate in the samples tested.
- At very high total dissolved solids (TDS) (20,000 - 25,000 mg/L), with bioaugmentation:
 - Hexavalent chromium is fully degraded.
 - Chlorate is fully degraded by EOS and acetate.
 - Perchlorate concentrations were reduced ~75% with EOS and acetate.
 - Molasses is performing slower than EOS and acetate; however, this might be due to drop in pH; therefore, future microcosms will be buffered with NaHCO₃.

- At ultra-high TDS (>50,000 mg/L), with bioaugmentation:
 - Hexavalent chromium is degrading very slow with EOS and acetate, but was fully degraded by molasses.
 - Chlorate degradation is delayed with EOS and acetate, but degraded 23% with molasses.
 - Perchlorate degradation is delayed with EOS and acetate, but degraded 15% with molasses.

As outlined in the September 12, 2017 Bench-Scale Work Plan, the planned bench-scale testing was anticipated to be completed within approximately six months. Based upon the current bench-scale testing results, extending the duration of the existing bench-scale studies is required to allow sufficient time for completion of the microcosm testing and planned column studies based on the observed slower degradation rates. This extension is not expected to lengthen the duration of the overall treatability study.

Additional Bench-Scale Testing

Based on the current bench-scale testing results, as well as input from NDEP, Dr. Batista, and Tetra Tech's technical team, additional bench-scale studies are recommended. The recommended additional bench-scale testing will supplement the current bench-scale tests and will be designed to meet the following specific objectives:

- 1) Examine the impact of nano-scale zero-valent iron (ZVI) on the reduction of hexavalent chromium and other COPCs, and evaluate the degradation kinetics of a selected organic carbon source with and without the addition of ZVI to determine if the addition of ZVI influences biological reduction of COPCs. The addition of nano-scale ZVI is expected to accelerate reduction of hexavalent chromium, thus accelerating the biological processes toward reduction of perchlorate and other COPCs.
- 2) Determine the rate at which chloroform is degraded along with other COPCs; evaluate potential chloroform toxicity to microorganisms; and identify intermediate and final degradation products associated with biodegradation of chloroform. One objective identified in the Unit 4 Source Area In-Situ Bioremediation Treatability Bench-Scale Work Plan was to evaluate the impacts of volatile organic compound (VOC) concentrations (specifically chloroform) on the biodegradation of perchlorate and other COPCs. The initial bench-scale tests included checking for chloroform degradation but not evaluating the kinetics or any by-products formed. Based on recent discussions with UNLV, it is important to begin to investigate and understand chloroform degradation in terms of toxicity, rate and sequence with respect to the biodegradation of the high concentrations of perchlorate and chlorate involved with the bench-scale studies. With some additional analyses, these parameters can be evaluated during the same microcosm tests being conducted as part of the initial bench-scale tests.
- 3) In response to comment #2 of NDEP's December 29, 2017 comments on the Unit 4 Source Area In-Situ Bioremediation Treatability Study Work Plan, evaluate the effectiveness of citric acid as a carbon source for in-situ bioremediation in the source area relative to molasses or EOS.

In order to meet the additional bench-scale testing objectives, UNLV will conduct additional microcosm testing as detailed below:

- ZVI Microcosm Testing: Nano-scale ZVI will be added to microcosms containing groundwater from Unit 4 wells. Microcosms will contain either ZVI alone or ZVI combined with an organic carbon source and nutrients. Prior to initiating the detailed microcosm testing, a set of preliminary microcosms will be run using various ZVI dosages to determine a range of ZVI concentrations to be used in the bench-scale study.
- Chloroform Batch Microcosm Testing: The rate of degradation of chloroform present in groundwater collected from the Unit 4 area will be evaluated using microcosms. The degradation will be monitored by analyzing for chloroform and dichloromethane.

- Citric Acid Batch Microcosm Testing: The degradation of perchlorate and reduction/degradation of co-occurring contaminants (i.e., chromium, nitrate, chlorate, and chloroform) will be investigated using citric acid as an electron donor and carbon source. To determine the impact of citric acid on the pH of the system, a titration curve will be generated using groundwater collected from the Unit 4 area. In addition, a 1:1 dilution ratio of the Unit 4 groundwater will be used for the first set of tests. Additional microcosm tests using other dilution factors will be performed based on the results of the preliminary microcosm tests.

Tetra Tech personnel will periodically collect groundwater from existing monitoring wells as necessary for use in the batch microcosm tests. Tetra Tech personnel also retained soil samples collected during the preliminary well installations performed in May 2018 as part of the Unit 4 Source Area In-situ Bioremediation Treatability Study for use in the additional batch microcosm tests. The addition of this additional bench-scale testing is not expected to lengthen the duration of the overall treatability study.

CERTIFICATION

Unit 4 Source Area In-Situ Bioremediation Bench-Scale Treatability Study Work Plan Modification No. 1

**Nevada Environmental Response Trust Site
(Former Tronox LLC Site)
Henderson, Nevada**

Nevada Environmental Response Trust (NERT) Representative Certification

I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of NERT. Based on my own involvement and/or my inquiry of the person or persons who manage the systems(s) or those directly responsible for gathering the information or preparing the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Office of the Nevada Environmental Response Trust

Le Petomane XXVII, not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Signature: Jay A Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

not individually, but solely as Pres. Trust

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date: 6/28/18

CERTIFICATION

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been prepared in a manner consistent with the current standards of the profession, and to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

Description of Services Provided: Unit 4 Source Area In-Situ Bioremediation Bench-Scale Treatability Study Work Plan Modification No.1, Nevada Environmental Response Trust Site, Henderson, Nevada



Kyle Hansen, CEM
Field Operations Manager/Geologist
Tetra Tech, Inc.

June 28, 2018

Date

Nevada CEM Certificate Number: 2167
Nevada CEM Expiration Date: September 18, 2018