TETRA TECH

TECHNICAL MEMORANDUM

To:	**Steve Clough**
Cc:	Eric Klink, Dan Pastor
From:	Carl Lenker
Date:	May 15, 2019
Subject:	**NERT Unit 4 Source Area In-Situ Bioremediation Treatability Study Modification 1, Addendum 1**

This memo was prepared by Tetra Tech, Inc. (Tetra Tech) as directed by the Nevada Environmental Response Trust (NERT). The memo provides a summary of the citric acid testing performed by the bench-scale testing laboratory, the University of Nevada, Las Vegas (UNLV), as part of the Unit 4 Source Area In-Situ Bioremediation Treatability Study Modification 1 and proposes an Addendum to Modification 1 to eliminate further citric acid testing.

In the Nevada Department of Environmental Protection's (NDEP's) December 29, 2017 comments on the Unit 4 Source Area In-Situ Bioremediation Treatability Study Work Plan (Work Plan), NDEP noted that American Pacific Corporation (AMPAC) had previously conducted an in-situ bioremediation pilot test from November 2002 through May 2003 that had operational issues due to biological and chemical fouling of the injection and extraction wells. NDEP requested that NERT review AMPAC's May 2003 report, "Pilot Test for In Situ Bioremediation of Perchlorate-Impacted Groundwater" prepared by GeoSyntec Consultants in order to understand the facts surrounding well fouling, including a recommendation in the AMPAC pilot test report that "citric acid should be used as an electron donor rather than ethanol, in order to avoid issues related to mineral precipitation and materials handling safety (i.e., flammability)".

Tetra Tech and UNLV reviewed the AMPAC report and subsequently, on behalf of NERT, prepared Modification No. 1 to the Work Plan to perform additional microcosm testing to evaluate the effectiveness of citric acid as a carbon donor. NDEP approved Modification No. 1 in a letter dated July 10, 2018.

In accordance with Modification No. 1, UNLV completed initial tests using citric acid, including evaluating the chemical oxygen demand (COD) of citric acid and generating titration curves using water collected from M-251-100, a monitoring well located within the Unit 4 treatability study area. Groundwater from M-251-100 was selected for the initial citric acid testing as the water is well characterized and has been used in several on-going microcosm tests being conducted as part of the bench-scale studies. COD is often used as an indirect indicator of the amount of organic carbon that a specific compound can generate and can be roughly considered as a measure of the "strength" of the donor. Based on solubility limits, UNLV determined that the maximum COD for citric acid is expected to be approximately 444 g/L, compared to approximately 1,000 g/L for molasses and approximately 2,000 g/L for emulsified vegetable oil. As such, molasses and emulsified vegetable oil are much

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more effective in biological treatment processes which is why they were originally specified in the NDEP-approved Work Plan.

Maintaining a neutral pH within the aquifer is necessary to promote in-situ bioremediation, thus UNLV also generated titration curves to evaluate the amount of buffering solution (i.e., sodium bicarbonate) that would be required to maintain a neutral pH as citric acid is added to the groundwater. The titration curves, which are plots of the pH of the solution versus the volume of titrant (citric acid or sodium bicarbonate) added to a solution, indicate that the addition of just 0.1 mL of citric acid solution results in lowering the pH of the Unit 4 groundwater sample from approximately 7.5 to 3.2 (See attached **Figure 1**, Citric Acid Titration Curve) and that for every 100 mL of impacted water and 0.5 mL of citric acid solution, about 10 mL of 1M sodium bicarbonate solution is required to bring the pH back to neutral (See attached **Figure 2**, Sodium Bicarbonate Titration Curve). Based on these results, the volume of sodium bicarbonate needed to maintain a neutral pH during the Unit 4 treatability study would represent approximately 10% of the total pore volume. This would significantly add to the total volume of solution required to be injected into the aquifer during the implementation of the treatability study and would increase the already high concentrations of total dissolved solids (TDS) present in the aquifer.

As noted in Tetra Tech's response to NDEP's December 29, 2017 comments, in contrast to the AMPAC pilot study, the planned Unit 4 Source Area In-Situ Bioremediation Treatability Study will not involve recirculation and re-injection of impacted groundwater with donor amendment. The Unit 4 Source Area In-Situ Bioremediation Treatability Study will utilize groundwater extraction to assist in distributing donor and reducing TDS concentrations, but extracted groundwater will be conveyed to the GWETS for on-site treatment rather than recirculating and re-injection. While biofouling and chemical precipitation must be managed in any in-situ biological treatment approach, Tetra Tech anticipates that the amount of well fouling will be significantly reduced by not re-injecting impacted groundwater with donor amendment.

Based on the laboratory testing and evaluation completed as part of the approved Modification No.1 activities, citric acid is not considered a suitable carbon substrate for the Unit 4 treatability study due to the low COD compared to other carbon substrates currently being evaluated at UNLV, the low pH conditions it creates (which could be detrimental to perchlorate reducing bacteria), and the significant amount of buffering solution (sodium bicarbonate) required to keep the water at a neutral pH, which would also increase the already high concentration of TDS in the aquifer. Based on the evaluation completed, Tetra Tech and UNLV recommend not completing the citric acid microcosm testing that was included in Modification No. 1.

CERTIFICATION

NERT Unit 4 Source Area In-Situ Bioremediation Treatability Study Modification 1, Addendum 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

Not Individually, but Solely
as President of the Trustee

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

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: 5/16/19

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: Prepared NERT Unit 4 Source Area In-Situ Bioremediation Treatability Study Modification 1, Addendum 1.

Kyle S. Hansen

May 15, 2019

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

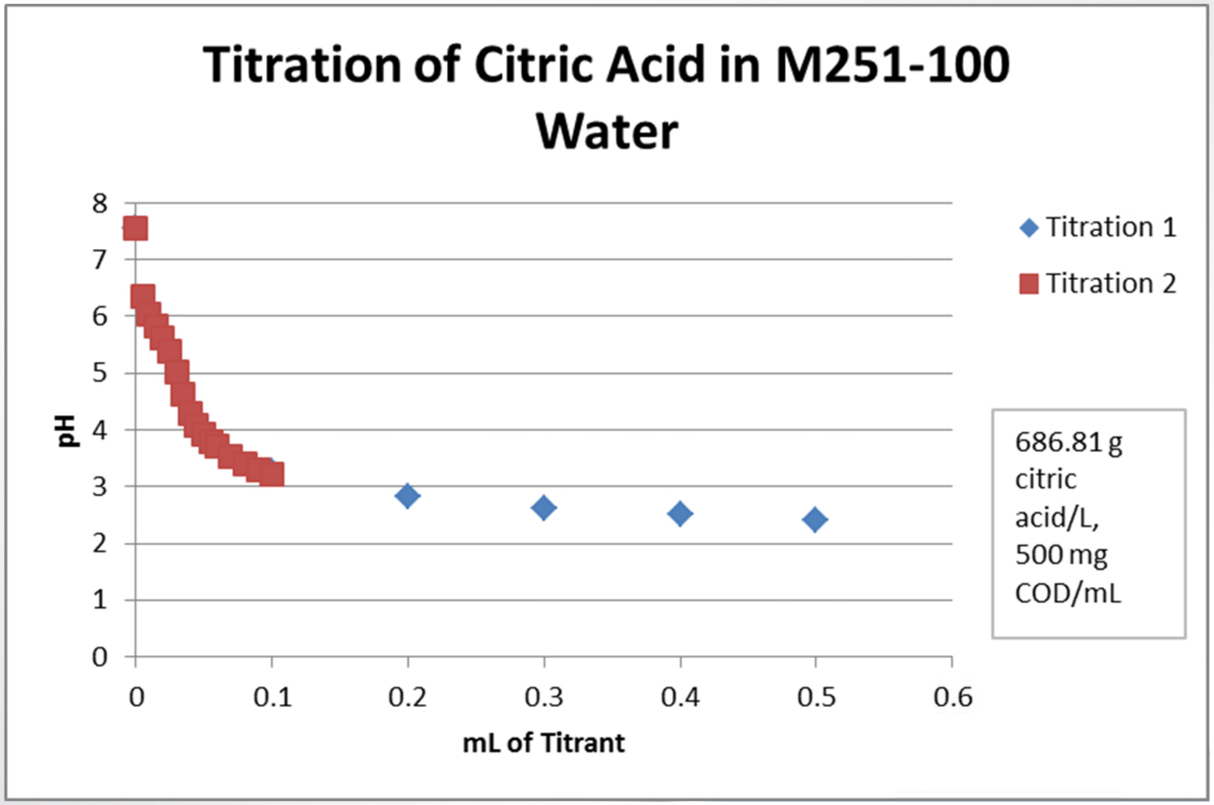
Date

Nevada CEM Certificate Number: 2167
Nevada CEM Expiration Date: September 18, 2020

Citric Acid

Figure 1

1. Addition of just 0.1 mL of citric acid solution (50 mg COD) results in a pH of 3.2



Citric Acid

Figure 2

1. For 0.5 mL of citric acid in 100 mL of 251 well water, about 10 mL of 1M sodium bicarbonate solution is required to bring the pH back to neutral