

From: [Yu, Olivia, EMNRD](#)
To: [David.Bonga@ghd.com](#); [Billings, Bradford, EMNRD](#)
Subject: RE: NMOCD AP-15 - P66 East Hobbs Junction - Cool-Ox Work Plan ~RPT-075016~
Date: Tuesday, May 8, 2018 9:26:00 AM
Attachments: approved_20180402-GHD-NMOCD-AP 15-Cool-Ox Work Plan.pdf

Good morning Mr. Bonga:

Thank you for your detailed response and patience. NMOCD approves of the proposed remediation plan for AP-15. Yes; please provide microbial and water quality data, pre- and post-treatment for each application cycle.

Thanks,
Olivia

From: David.Bonga@ghd.com <David.Bonga@ghd.com>
Sent: Tuesday, May 1, 2018 11:42 AM
To: Billings, Bradford, EMNRD <Bradford.Billings@state.nm.us>
Cc: Yu, Olivia, EMNRD <Olivia.Yu@state.nm.us>
Subject: RE: NMOCD AP-15 - P66 East Hobbs Junction - Cool-Ox Work Plan ~RPT-075016~

Good Afternoon,

I'm just checking in to see if we have approval on these injections or if there is more we need to do? Could you let me know by the end of the week so I can let my subcontractors know? We are scheduled to begin on May 14, 2018.

Thank you,

David Bonga, EIT

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Please consider our environment before printing this email

From: David Bonga
Sent: Tuesday, April 24, 2018 9:18 AM
To: 'Billings, Bradford, EMNRD' <Bradford.Billings@state.nm.us>
Cc: Yu, Olivia, EMNRD <Olivia.Yu@state.nm.us>
Subject: RE: NMOCD AP-15 - P66 East Hobbs Junction - Cool-Ox Work Plan ~RPT-075016~

Brad and Olivia,

Please see our responses to your questions/concerns below:

1. We are happy to sample whatever we need to. We typically just take water quality measurements (DO and pH seem to be most valuable to assess the influence), but if you'd like additional parameters collected please let me know. DeepEarth Technologies, Inc. (DTI) said that microbial plate counts may be beneficial to collect before and after injections.

2 and 3. DTI adds a chelating agent to the formulation that stabilizes the iron availability during the reaction. Most problems with residual iron come from the traditional Fenton practice of injecting iron with hydrogen peroxide. DTI has found that sufficient iron can be attained from the soil by simply adding a chelating agent.

4. If you are concerned about the residual, the best thing to do is to take baseline samples for microbial plate counts. We will treat the site and then we can take the same samples 60 days after, if you prefer. According to DTI, It is not unusual for them to see increases of 10^6 to 10^7 within 60 days post application

5. The main reason metals may be mobilized in most technologies is because the pH is less than 7 (acidic). The Cool-Ox® process optimizes at a pH of 8.5. The pH sends the drift upward with the calcium technology rather than downward with the persulfate technology.

6. DTI overcomes the issue of radius of influence by calculating the volume of reagent it takes to saturate the whole area. I have attached write-ups on ChemHydro-Infusion and Clay Injectability.

DTI has treated a ConocoPhillips site in San Juan County and another at Kirtland AFB in Albuquerque, so you may be able to look into that information to help build your database.

Please let me know if you would like additional information and we will work to get it to you.

Thank you,

David Bonga, EIT

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From: Billings, Bradford, EMNRD <Bradford.Billings@state.nm.us>

Sent: Thursday, April 19, 2018 1:57 PM

To: David Bonga <David.Bonga@ghd.com>

Cc: Yu, Olivia, EMNRD <Olivia.Yu@state.nm.us>

Subject: RE: NMOCD AP-15 - P66 East Hobbs Junction - Cool-Ox Work Plan ~RPT-075016~

Hi David,

Have discussed this with Olivia in District I, we have the following thoughts, and I will paraphrase Olivia's notes herein,

- 1) Maybe some benefit in having samples taken nominally immediately prior to application of the oxy releasing material? And then perhaps 24 hrs. later? Would this initial evaluation help in determining if initial application was sufficient, and perhaps change schedule of nominally planned applications?
- 2) Does the geology/soils in treatment zone have conflicts with potential Fe^{+2} interactions, with sulfides/sulfates and depending on adsorption/desorption rates and calcium ions?
- 3) If not known, per se, perhaps should test initially for $\text{Fe}^{2+}/\text{Fe}^{3+}$, arsenic, sulfate/sulfide compounds to evaluate any potential issues. Don't want to "create" an issue with something else while remediating the hydrocarbon, as has happened on/at other sites. Maybe an Fe phase diagram would help as well.
- 4) Would it be beneficial to evaluate DOC as well as DO? Indication of microbe potential. Not really sure how much is the oxygen itself doing the work, per se, or in supplying oxygen for indigenous microbes. Has analysis been done on this question?
- 5) Although a pH in the range of 8 is not particularly worrisome, I have had issues with sites in the past wherein, a significant pH shock had resulted in some metals issues. Do we have a good understanding yet of this as a potential issue?
- 6) Have you calculated a dispersal estimate in the groundwater? I have had sites that end of with, shall we say, a swiss cheese look from a surface view. Meaning, the immediate area about a given injection point was "cleaned" but the oxy really did not get dispersed well. What might lead you to believe it would disperse adequately?

This is a bunch of questions, but we need to understand, and also build data bases and evaluations of remedial options for those who follow. As this one is in the "new" approach category we may need additional information and data collection that may be useful or not in future.

So, not a bad idea in and of itself, but I think we need some more info to get to decision. Stay in touch with both Olivia and I on email as much as possible. If we eventually need to talk, let us know.

Thanks for your efforts.

Brad Billings
EMNRD/OCD
Santa Fe

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ChemHydro-Infusion[™]

Although reagent volume and pressure play an important part in fracture or fissure of site penetration wherever the Cool-Ox[®] process is applied, oxidative conversion of fuel hydrocarbons to surfactants plays a key role. May we explain!

The generation of foam at the surface of the site during Cool-Ox[®] injections gives us an indication of what is happening below. A study of surfactant chemistry reveals that three (3) components are necessary to produce foam. These are water, a surfactant and a gas. In partially oxidizing hydrocarbons, an amphiphilic (hydroxylated hydrocarbon – i.e., surfactant) molecule is formed. Gas (carbon dioxide) is generated by the mineralization of a portion of the contaminants. This gas, forced through the surfactant/water mixture creates foam.

In the subsurface, carbon dioxide is continuously produced during the reaction of Cool-Ox[®] with the contaminants. The pressure caused by the generation of this gas will attempt to escape the reaction zone (continuously producing carbon dioxide). This reaction gas will seek out any pathway it can find to dissipate the reaction pressure. In this manner, it will travel through fractures (where available), regardless of the orientation (horizontal or vertical) of the fracture in the formation.

Because the carbon dioxide is formed in the reaction media, it will attempt to escape in any direction to any area of lower pressure. Thus, as the gas migrates it will push Cool-Ox[®] with it thereby, distributing reagent into any fissures or fractures that may be harboring contaminants which in turn, will react to produce more gas and as this gas migrates....and thus, the cycle continues.

This dynamic mixing process underpins the success of the Cool-Ox[®] technology in any media where it may be applied. When treating halogenated organics (abiotic reductive dichlorination), the carbon dioxide gas is generated by the conversion of the contaminants directly to carbon dioxide. Thus, the infusion process is promoted with both the oxidation of hydrocarbons and reductive processes of halogenated organics depending upon the contaminant type.

Injectability of Clay Sites

DeepEarth Technologies, Inc. (DTI) has been employed on numerous occasions, to perform In-Situ injections at sites impacted with hydrocarbons, halogenated organics, MGP artifacts and other contaminants where the lithology was primarily tight clays. Fortunately, DTI discovered early on that each site presents unique challenges that must be understood and addressed so that a successful project can be delivered. Although no two sites are exactly the same and the nature of the clay can vary (type, density, homogeneity/stratification, ground water saturation, etc.), depending upon circumstances, the most important factor to note is that DTI (as a field services company) has specialized in learning how to "read" each site and to understand the optimum injection method needed. This know-how allows DTI's field application specialists to adjust our injection techniques in the field, (as site variations are encountered), to ensure the most effective delivery of *Cool-Ox[®]* while at the same time, minimizing daylighting, and ensuring maximum contact with the contaminants.

DTI's field personnel are highly experienced at injecting clay sites and have the equipment and knowledge necessary to ensure a successful application. For example, it has often been the practice for a client to conduct an injectability study using fresh water as a baseline to determine how well the contaminated soil will accept liquid. However, DTI has found that fresh water injection does not compare evenly to an injectability study utilizing *Cool-Ox[®]* technology. There are several notable differences;

Water: Water is non-reactive, and because it is not miscible with hydrocarbon fuels, it will actually be rejected from soils (especially clays) highly contaminated with hydrocarbons (it is important to remember the simple concept that "oil-and-water-don't-mix"). This mixture of soil and fuel hydrocarbons is quite hydrophobic and actually creates a solubility barrier that will quickly reject water back to the surface. This phenomenon often gives the wrong impression that aqueous liquids cannot be injected.

Cool-Ox[®]: Although *Cool-Ox[®]* is an aqueous liquid, it is a reactive oxidation reagent that readily reacts with hydrocarbons, especially in soil. These oxidation reactions produce oxygenated compounds that are soapy-like in nature. These soapy-like (amphiphilic) compounds bridge the solubility barrier between the oily hydrocarbons and the aqueous based *Cool-Ox[®]* and allow expanded penetration of the oxidizer thus, beginning the remediation of the site.

Example: DTI was called upon to attempt to inject a site where the soil (a combination of sandy-clay, clay, and silty-sand) was heavily impacted with gasoline range organics (GRO) and diesel range organics (DRO) to the extent that the soil contained a sheen when exposed to sunlight. Having failed several attempts by others, to inject water, the site was considered by the consultant to be impossible for application by DPT injection. However, having worked with the consultant on other projects, DTI was called upon to perform a final attempt.

DTI inspected the site soils and conducted an on-site "beaker study" with *Cool-Ox[®]* (conducted by the field operations personnel to "tell" them how to treat the site). An application formulation was designed, and injection activities initiated employing our AMS-9500 DPT track mounted rig. This is where DTI know-how prevailed. At first, (based upon the beaker study) a very shallow injection point (4" to 6") was placed in the area of highly contaminated soil. A small amount of *Cool-Ox[®]* reagent (maybe a pint) was injected, and everyone waited. After approximately two (2) minutes, foam was observed issuing from the shallow injection point. After the formation of a foam "donut" around the injection tooling, penetration of an additional six to twelve inches was initiated, and a small amount of additional *Cool-Ox[®]* was applied. This process was repeated until the full depth (18 ft-bgs) was accomplished.

This methodology, although appearing tedious (the first injection point took approximately 25 minutes), provided the information necessary to penetrate and treat the site without excessive daylighting and boisterous reactions. The process also revealed a radius of influence (ROI) of four (4) feet to be optimum. It was also noted that below three (3) feet, carbon dioxide gas produced by the reaction could penetrate the formation laterally thus, opening up the strata and aiding in the distribution of the *Cool-Ox[®]* reagent (see *Cool-Ox[®] ChemHydro-Infusion[™]*). One-hundred four (104) injection points were completed in slightly less than four days.

It should be noted that in addition to the oxidative characteristics of the *Cool-Ox[®]* technology, DTI employed its specially designed *Soil-Slicer[™]* end tooling for increased penetration.

For additional information see: www.deepearthtech.com or call toll free; 1-877-COOL-OX1