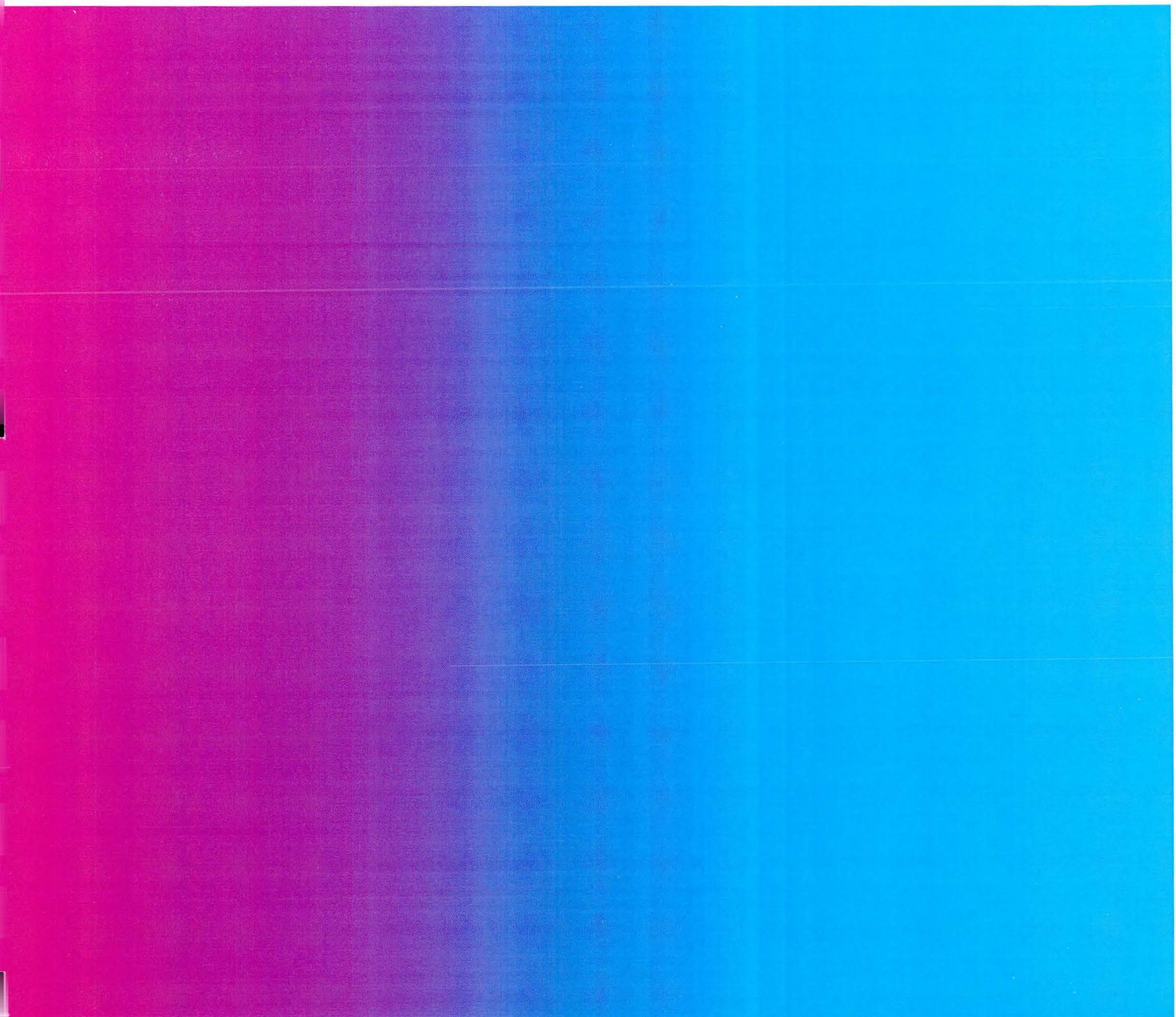




Environment

Underground Injection Control (UIC) Approval Request





Environment

Underground Injection Control (UIC) Approval Request

Reedsburg Cleaners
349 East Main Street
Reedsburg, WI 53959

WDNR BRRTS No. 02-57-001682



AECOM
11425 W. Lake Park Drive, Suite 100
Milwaukee, WI 53224

414 359 3030 tel
414 359 0822 fax

November 16, 2009

Mr. Hank Kuehling, P.G.
Wisconsin Department of Natural Resources
3911 Fish Hatchery Road
Fitchburg, WI 53711-5397

Subject: Underground Injection Control (UIC) Approval Request for Groundwater Remediation - Reedsburg Cleaners, Reedsburg, WI, BRRTS# 02-57-001682, AECOM Project No. 60139948

Dear Mr. Kuehling:

As a follow-up to the Wisconsin Department of Natural Resources (WDNR) e-mail regarding the Reedsburg Cleaners site dated November 5, 2009, AECOM (formerly STS) has prepared this Underground Injection Control (UIC) Approval Request for groundwater remediation associated with the Reedsburg Cleaners site in Reedsburg, Wisconsin. If you have any questions, please feel free to contact us at your convenience. Thank you very much for your assistance with this matter.

Yours sincerely,

Mark M. Mejac, P.G., CGWP
Senior Project Hydrogeologist

Jeanne M. Tarvin, P.G., CPG
Senior Principal Hydrogeologist

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1.0 Introduction

This Underground Injection Control (UIC) Approval Request has been prepared by AECOM (formerly STS) on behalf of Reedsburg Cleaners to address impacted groundwater in the vicinity of the Reedsburg Cleaners property in the central portion of Reedsburg, Wisconsin (Figure 1). The Reedsburg Cleaners facility, hereinafter referred to as the subject property, is located at 349 East Main Street in Reedsburg, Wisconsin.

Pursuant to a Wisconsin Department of Natural Resources (WDNR) e-mail regarding the Reedsburg Cleaners site dated November 5, 2009, this UIC Approval Request was prepared to meet the requirements under Wisconsin Administrative Code (WAC) Chapter NR 140, NR 700 and NR 800 Rule Series.

1.1 Background Information

The subject property is located at 349 East Main Street in the City of Reedsburg, Wisconsin in the southwest quarter of the northeast quarter of Section 10, T12N, R4E, Sauk County (Figure 1). The geographic coordinates of the site are N 43° 31' 56.7" W 90° 0' 17.5". The site's Sauk County parcel ID number is 276-0935-00000.

Based on Sanborn Map information, the site operated as a gasoline station in 1944. The site was reportedly converted from a gasoline station to a dry cleaning facility in 1976, and has been in use as a dry cleaner since that date. Prior to 1976, three 1,000-gallon leaded gasoline underground storage tanks (USTs) located in the northeast portion of the site (Figure 2) were abandoned in-place and filled with sand. Prior to 1992, one 500-gallon fuel oil UST was removed from the northeast portion of the site. Tetrachloroethene (PCE) was previously stored in a 100-gallon aboveground storage tank (AST) in the northeast portion of the site. Approximately 10 to 15 gallons of PCE were reportedly spilled from the AST in early 1994. The AST has not been used since 1995.

In December 1994, PCE was detected in a groundwater sample from a monitoring well located adjacent to Reedsburg Cleaners during a petroleum hydrocarbon site investigation conducted at Spellman Monument (403 East Main Street). In a November 1995 letter, the WDNR requested that Reedsburg Cleaners investigate an apparent release of PCE from the on-site AST. Petroleum hydrocarbon contamination was detected at the Reedsburg Cleaners site in May 1996, as part of a site investigation conducted by Advent Environmental. In a July 1996 letter, the WDNR requested that Reedsburg Cleaners investigate the petroleum hydrocarbon contamination.

Site investigation activities were conducted between 1999 and 2001, which were documented in a November 2001 "Remedial Investigation Report" prepared by Vierbicher Associates, Inc. (Vierbicher) of Reedsburg, Wisconsin. Soil impacted with PCE had been identified within an approximate 3,000-square foot area within the eastern portion of the site. Detected concentrations of PCE in soil within this area in 1999 ranged between 270 micrograms per kilogram ($\mu\text{g}/\text{kg}$) and 330,000 $\mu\text{g}/\text{kg}$. Groundwater impacted with PCE has been identified beneath and to the southwest of the site. Detected concentrations of PCE in groundwater have been detected as high as 14,000 micrograms per liter ($\mu\text{g}/\text{L}$). Based on groundwater quality information obtained from piezometers near the site, the vertical extent of PCE-impacted groundwater is approximately 30 feet below ground surface (bgs).

An interim action investigation of the Reedsburg Cleaners site was conducted by AECOM between November 2005 and January 2006. This interim action investigation included installation of four hydraulic probes, installation of new monitoring well MW-10, and collection of groundwater samples from new and existing monitoring wells. The results of the interim action investigation were documented in an AECOM Interim Action Investigation Report dated February 27, 2006.

AECOM subsequently recommended a soil source removal action to address volatile organic compound (VOC) impacted soil and groundwater, as described in the WDNR "Approval of Consultant Selection, Scope of Work and Bid Costs for Remedial Action" letter, dated November 6, 2006. The soil excavation was intended to remove the vadose zone source of VOCs to reduce further contaminant mass flux to the groundwater. The VOC-impacted soil at the site was excavated, transported off-site for disposal, and replaced with clean compacted backfill material. A total of 459.76 tons of impacted soil was excavated from the site between November 6, 2006 and November 9, 2006 and transported to Veolia Cranberry Creek Landfill, Wisconsin Rapids, Wisconsin, for disposal.

A total of seven groundwater monitoring events at the Reedsburg Cleaners site were conducted by AECOM between January 2006 and May 2009. Based on WDNR review of the resulting groundwater monitoring data, the WDNR issued an e-mail regarding the Reedsburg Cleaners site dated November 5, 2009. The November 5, 2009 WDNR e-mail indicated the following: "It is clear that groundwater quality has improved in the immediate vicinity of the source and soil excavation area. But it is also clear that groundwater is significantly contaminated with volatile organic compounds (VOCs) from the Reedsburg Cleaners property near the south property line and beyond to the southwest to the south side of Main Street. Remedial actions must be taken to improve this groundwater quality".

1.2 Project Contacts and Emergency Procedures

The proposed in-situ enhanced anaerobic biodegradation program will be performed on behalf of B&B Inc., under the direction of AECOM and the oversight of the WDNR. The project contact personnel for the enhanced anaerobic biodegradation program are as follows:

Regulating Agency: Wisconsin Department of Natural Resources

- Hank Kuehling, WDNR Project Manager: 608/275-3286

Responsible Party's Environmental Consultant: AECOM

- Jeanne M. Tarvin, Project Principal, Direct: 414/577-1304, Cell: 262/385-1751
- Mark M. Mejac, Project Manager, Direct: 414/577-1364, Cell: 262/391-7835

Electron Donor Injection Contractor: Moraine Environmental, Inc.

- Thomas C. Sweet, Project Manager: 262/377-9060

Local community questions or concerns should be directed to the attention of Ms. Tarvin of AECOM. In the event of an emergency, the primary contact is Mr. Mejac of AECOM and the secondary contact is Ms. Tarvin of AECOM.

2.0 Application Components

2.1 Description of Proposed Remedial Technology

2.1.1 Enhanced Anaerobic Dechlorination (EAD) Processes

Chlorinated volatile organic compounds (CVOCs) can be degraded to non-toxic daughter products by anaerobic microbes known as reductive dechlorinators. Such biodegradation requires reducing conditions to stimulate anaerobic microbes to dechlorinate the CVOC. A carbon or electron donor source is used in this approach to create reducing conditions. The EAD process has been successful and well documented at a wide variety of sites, and guidance documents are available that describe the process in detail (AFCEE, 2004).

The anaerobic microbes use CVOCs during dehalorespiration via reductive dechlorination. There are a variety of bacteria that dehalorespire only on PCE or TCE, producing toxic cis-1,2-dichloroethene (cDCE) in the process. In contrast, the dechlorinating microorganism *Dehalococcoides ethenogens* (DE) is the only known microorganism capable of further dechlorination to non-toxic ethene. Although DE microorganisms are widely distributed in the environment, research indicates that they are not ubiquitous. If DE is absent from a site, incomplete dechlorination and accumulation of cDCE is anticipated to occur, or extended acclimation periods will be required to allow low concentrations or poorly distributed DE populations to achieve functional cell densities. If the results of groundwater monitoring during EAD system operations indicate insufficient DE bacterial populations, then the EAD systems are often combined with bioaugmentation using commercially-available DE microbes.

Under this remedial approach, the naturally adapted microbes sequentially dechlorinate the CVOCs and gain energy in each step while utilizing the substrate as a carbon source and the CVOC as an electron acceptor. The adapted microbes respire using the CVOCs in place of other electron acceptors such as oxygen. The areas in which substrate is delivered become anaerobic due to the uptake of available electron acceptors to support respiration of the microbes, which provides the environment required for the EAD process to take place. This process has been shown to be more effective than other treatment processes, such as physical and chemical removal.

2.1.2 Selection of Electron Donor

In order to effectively bioremediate a particular area using EAD technology, it is critical to:

- Select the optimal chemical additives;
- Bioaugment (if necessary) the site with dechlorinating microbes;
- Properly distribute the chemical and biological additives to stimulate the dechlorination process within the contaminated area; and,
- Maintain the enhanced subsurface conditions for sufficient time to fully dechlorinate the dissolved and adsorbed CVOCs.

The goal of the EAD system is to inject electron donor at a sufficient rate such that amendments are distributed in the area of interest prior to "consumption" of the added electron donor. The electron donor that is added is consumed by the CVOCs in dechlorination reactions, as well as naturally-occurring electron acceptors in methanogenic reactions (plus sulfate reduction, nitrate reduction etc.). The design of the EAD injection system is based on delivery of sufficient amendments to the impacted aquifer within a finite time period. The empirically determined guidance for the injection of electron donor design includes maintenance of total organic carbon (TOC) concentrations in groundwater within the injection zone within a range of 10 milligrams per liter (mg/L) to 200 mg/L.

Batch injections of relatively low solubility electron donors, such as emulsified vegetable oils, are slowly released and can offer electron donor that can subsequently travel with the groundwater and be distributed downgradient of the injection point. Many other organic materials have been demonstrated to be applicable for creating reducing conditions that support reductive dechlorination. Based on the results of a literature review of case studies of similar sites, AECOM recommends the use of dairy whey as a relatively slow-acting and inexpensive electron donor to implement EAD at the Reedsburg Cleaners site. Whey is a water soluble byproduct of the food industry, and contains lactose and several mineral nutrients (including nitrogen, phosphorous, potassium, sodium and calcium). Literature concerning the application of whey for EAD of CVOC-impacted groundwater is provided in Appendix A.

2.1.3 Request for Pilot Test Variance

As indicated in WAC NR 169.23(6)(d), a pilot test is required for active groundwater remediation systems, "unless the consultant can justify to the department's satisfaction that a pilot test is not necessary." AECOM's justification that a pilot test is not necessary is largely based on groundwater monitoring results obtained to date after pilot-scale and full-scale injections where whey electron donor was also used at a similar dry cleaner site (Butz Cleaners & Laundry) located in nearby (20 miles distant) in Mauston, Wisconsin.

At both the Reedsburg and Mauston sites, the water table is situated within sandstone bedrock, such that at both sites the whey injection zone is situated entirely within a sandstone bedrock matrix. However, two factors favor the application of whey electron donor at the Reedsburg site over the Mauston site: (1) the average measured aquifer hydraulic conductivity at Reedsburg is 1.0×10^{-2} centimeters per second (cm/s), while the average measured aquifer hydraulic conductivity at Mauston is 1.1×10^{-3} centimeters per second (cm/s); and (2) the vertical treatment zone at Reedsburg is 10 feet, while the vertical treatment zone at Mauston is 30 feet. The average measured sandstone aquifer hydraulic conductivity at Reedsburg is approximately one order-of-magnitude greater than at Mauston, which should facilitate subsurface distribution of whey electron donor. At long screened intervals substrate may preferentially enter the formation at the top of the screened interval due to increases in vertical hydrostatic pressure with depth. This preferential substrate distribution is therefore less likely to occur at the Reedsburg site than at the Mauston site.

In terms of geochemistry, ambient groundwater pH values at the Reedsburg site are similar to those measured at the Mauston site (the average May 2009 pH is 6.8 at Reedsburg and at 6.7 Mauston). Dissolved oxygen and oxidation-reduction potential values in May 2009 averaged 3.6 milligrams per liter (mg/L) and -45 millivolts (mV) at Reedsburg, and 4.4 mg/L and +154 mV at Mauston, respectively. The somewhat more anaerobic conditions evidenced by these data at Reedsburg are favorable for the implementation of anaerobic dechlorination. The only available sulfate and nitrate data from the Reedsburg site were obtained by AECOM in 2006. The average sulfate concentration was 51 mg/L, and the average nitrate concentration was 1.1 mg/L. The 2006 sulfate and nitrate concentrations at the Mauston site averaged 43 mg/L and 4.9 mg/L, respectively. Lower sulfate and nitrate concentrations

are generally more favorable for the implementation of anaerobic dechlorination. The available sulfate and nitrate data do not favor either the Reedsburg or Mauston sites relative to one another in terms of the applicability of anaerobic dechlorination.

In summary, hydrogeologic, vertical treatment zone, and geochemical conditions at the Reedsburg site appear to be comparable to the Mauston site in terms of the applicability of anaerobic dechlorination. AECOM e-mail communications to the WDNR dated August 20, 2009 and November 2, 2009 provide evaluations of two rounds of groundwater monitoring conducted at the Mauston site associated with the May 2009 pilot test injection and October 2009 full-scale injection of whey substrate. These e-mail communications indicate that the available groundwater monitoring data demonstrate that reductive dechlorination of PCE is occurring in response to the anaerobic conditions that have been created by the May and October 2009 injections of whey. Moreover, the scale of the recommended electron donor injection program at the Reedsburg site is not substantially larger than that associated with the Mauston pilot test. Based on the foregoing, AECOM concludes that a pilot test is not necessary and requests WDNR approval to implement the recommended whey electron donor injection program at the Reedsburg site without completion of a pilot test.

2.1.4 Recommended Implementation of EAD at Reedsburg Cleaners Site

The preliminary design of the electron donor injection system for the Reedsburg Cleaners site is based on estimated aquifer hydraulic parameters and target injection zone dimensions. The site lithology below the site vicinity consists of sandstone bedrock to the remediation target depth, which ranges from 20 feet to 30 feet bgs. Aquifer hydraulic conductivities greater than approximately 3×10^{-4} cm/sec are generally suitable for injection of soluble electron donor. The estimated average hydraulic conductivity of the sandstone aquifer near the subject site is 1×10^{-2} cm/sec, or approximately 30 times the 3×10^{-4} cm/sec value.

The amount of substrate amendment needed to complete groundwater remediation of the site was estimated based on the total mass of inorganic and organic compounds that would be reduced during the EAD process. The total impacted aquifer volume is first estimated and used to estimate the total hydrogen demand due to the inorganic and organic contaminant compounds. The total hydrogen demand is the amount of reductant needed for reductive dechlorination of the CVOCs, as well as the reduction of inorganic species such as dissolved oxygen, sulfate and nitrate, and iron oxides within the aquifer matrix.

For the anaerobic bioremediation program at the Reedsburg Cleaners site, conservatively high estimates of native and chlorinated volatile organic compound electron acceptor mass (based on the results of previous Reedsburg Cleaners site groundwater monitoring data and an estimated groundwater treatment volume of 300,000 gallons) are as follows:

Initial Electron Acceptor Demand

Aqueous Phase native electron acceptors	Concentration	Mass	Stoichiometric Hydrogen Demand	Total Demand
Oxygen	4 mg/L	10 lbs	7.9	1.3 lbs
Nitrate	1 mg/L	2.5 lbs	10.2	0.25 lbs
Sulfate	50 mg/L	125	10.6	11.8 lbs
Carbon dioxide (as methane produced)	10 mg/L	25 lbs	5.5	4.5 lbs
Soluble competing electron acceptor demand				17.8 lbs
Solid phase native electron acceptors	Concentration	Mass	Stoichiometric Hydrogen Demand	Total Demand
Iron (III) estimated as Fe (II) produced	50 mg/L	125 lbs	55.9	2.2 lbs
Manganese estimated as Mn (II) produced	10 mg/L	25 lbs	27.5	0.91 lbs
Solid phase competing electron acceptor demand				3.1 lbs
Soluble contaminant electron acceptor	Concentration	Mass	Hydrogen Demand	Total Demand
Tetrachloroethene	4 mg/L	10 lbs	20.6	0.5 lbs

Sorbed contaminant electron acceptor	Concentration	Mass	Stoichiometric Hydrogen Demand	Total Demand
Tetrachloroethene	5.3 mg/kg	21.0 lbs	20.6	1.0 lbs
Total native electron acceptor demand				20.9 lbs
Total contaminant electron acceptor demand				1.5 lbs

Electron Acceptor Flux (per year) - Stoichiometric

Aqueous Phase native electron acceptors	Concentration	Mass	Stoichiometric Hydrogen Demand	Total Demand
Oxygen	4 mg/L	10 lbs	7.9	1.3 lbs
Nitrate	1 mg/L	2.5 lbs	10.2	0.25 lbs
Sulfate	50 mg/L	125	10.6	11.8 lbs
Carbon dioxide (as methane produced)	10 mg/L	25 lbs	5.5	4.5 lbs
Soluble competing electron acceptor demand				17.8 lbs
Soluble contaminant electron acceptor	Concentration	Mass	Stoichiometric Hydrogen Demand	Total Demand
Tetrachloroethene	4 mg/L	10 lbs	20.6	0.5 lbs
Total annual electron acceptor demand				40.7 lbs

The total estimated hydrogen demand is approximately 40.7 pounds. The estimated hydrogen demand with a commonly-applied safety factor of 10 totals 407 lbs of hydrogen. The proposed whey electron donor contains approximately 3 percent lactose. One 5,000-gallon truck load contains 41,000 lbs of whey, including 1,200 lbs of lactose. Each pound of lactose produces 0.047 lb of hydrogen through fermentation reactions, such that each truck load of whey can result in the production of approximately 56 lbs of hydrogen. Therefore, the recommended anaerobic bioremediation program at the Reedsburg Cleaners site includes injection of two 5,000-gallon truck loads of whey substrate for each injection event

at intervals of approximately 4 months. The actual amount of required substrate may be greater than this estimate due to the potential amount of iron oxides present in the formation and the extent of methane production. If this situation is in fact the case, the quantity of the substrate injected could be increased to off-set non-productive consumption.

Measured values of groundwater pH are generally less than 7, which indicates that the local sandstone aquifer may not be well buffered. Organic acids generated through subsurface fermentation of whey will likely further reduce groundwater pH values. DE microbes that are necessary for complete dechlorination of PCE to harmless ethene begin to become inhibited at pH values less than 6.3. A sodium bicarbonate buffer is therefore recommended to be added to the whey substrate prior to each injection event. At the desired neutral pH range, 1.8 mol (or 152 grams) of sodium bicarbonate is estimated to neutralize acids generated by 1 mol (or 342.3 grams) of lactose. Therefore, approximately 500 lbs of sodium bicarbonate is recommended to be added to each 5,000-gallon truck load of whey substrate prior to injection.

The proposed EAD injection system will consist of a network of six injection wells. These injection wells are identified as IW1 through IW6 on Figure 2. The locations of the six injection wells are designed with a distance of approximately 20 feet between each injection well, perpendicular to groundwater flow. Based on an assumed aquifer porosity of 30 percent, an injection volume of 1,260 gallons of whey electron donor through each injection well (with screen lengths of 10 feet) should achieve a target radius of influence of 10 feet (AFCEE, 2004). The recommended injection of 10,000 gallons of whey through six injection wells will result in the injection of an average of 1,670 gallons of whey through each injection well. As such, the recommended distance of approximately 20 feet between each injection well should allow for adequate subsurface distribution of injected whey within the treatment zone.

Based on information contained in AFCEE (2004), an optimal spacing of injection wells parallel to the direction of groundwater flow for plume-wide treatment is equivalent to a 100-day substrate travel time distance. The estimated groundwater flow velocity at the Reedsburg Cleaners site is approximately 0.8 feet per day, such that the 100-day substrate travel time distance is approximately 80 feet. The recommended locations of injection wells IW1 and IW2 are therefore approximately 70 to 80 feet from injection wells IW3 through IW6, as shown on Figure 2.

The existing groundwater monitoring well network present at the site will be used for monitoring the effectiveness of the EAD injection program. The six injection wells will be 2-inches in diameter. The injection wells will be installed to approximate depths of 30 feet bgs, and screened from 20 to 30 feet bgs. The tops of the injection well screens will be approximately 2 feet below the water table, to avoid preferential flow at the top of the well screens. Otherwise, absence of hydrostatic pressure at the top of the well screens would likely result in injected electron donor to preferentially flow on top of the water table, significantly limiting the effectiveness of the injection event. Injection well fouling will be reduced through the use of 0.020 slot high-flow screens. AECOM assumes that soil cuttings generated from well installation activities will be disposed of off-site as non-hazardous solid waste.

AECOM has identified a local supplier of whey electron donor (Muscodia Protein Products of Muscodia, Wisconsin). The whey is proposed to be delivered in bulk (approximate 5,000-gallon capacity tanker truck), and injected through a portable manifold system into the six injection wells. AECOM recommends injection of one batch of whey every four months. Each batch is anticipated to consist of approximately 10,000 gallons of injected whey. Ongoing groundwater monitoring data will be evaluated to document the progress of remediation and modify the electron donor injection program as appropriate. Based on the results of future groundwater monitoring, the EAD injection program may be combined if necessary with bioaugmentation using commercially available DE microbes.

2.2 Notifications and Permits

The following sections identify the permits and notifications that are anticipated to be required to conduct the proposed injection of electron donor.

2.2.1 Underground Utility Clearance

Prior to injection well advancement activities, AECOM will contact Digger's Hotline for the location of public utilities within the injection areas and will also review maps and other available information regarding the locations of private utilities. AECOM will request notification of the type and location of all private utilities within the injection areas.

2.2.2 City of Reedsburg

Recommended injection wells IW2 and IW6 are located within the City of Reedsburg right-of-way (Figure 2). Approval for installation of these two injection wells within the right-of-way will be secured from the City of Reedsburg prior to commencement of injection well installation.

2.2.3 Wisconsin Department of Natural Resources

Under WAC Chapter NR 812.05(2), the use of a well or borehole for injection is prohibited unless it is to be conducted for the purpose of remediation of contaminated soil, groundwater or an aquifer. Information concerning the proposed soil and groundwater remediation of the subject site is provided in Section 2.1. An "Inventory of Injection Well Form 3300-253 (5/01)" is provided as Appendix B.

2.3 Remedial Action Implementation

A quarterly groundwater monitoring program will be initiated approximately 3 months after the initial whey electron donor injection event. The monitoring wells to be sampled as part of the groundwater monitoring events are as follows: MW-2, MW-3R, MW-4, MW-5, MW-6, MW-7, MW-8, MW-10, P-1 and P-2 (Figure 2). The groundwater samples from these monitoring wells will be submitted for laboratory analysis of VOCs. In addition, field instruments will be used to measure geochemical parameters, including pH, specific conductivity, temperature, dissolved oxygen and oxidation-reduction potential. In accordance with the WDNR April 2003 guidance document "Understanding Chlorinated Hydrocarbon Behavior in Groundwater" (WDNR Publication RR-669), groundwater samples from monitoring wells MW-3R, MW-4, MW-5, MW-6, MW-7 and MW-10 will also be analyzed for the following natural attenuation parameters by a Wisconsin-certified laboratory: alkalinity, dissolved iron, ethene/ethane/methane, total organic carbon, nitrate+nitrite, and sulfate.

The injection zones will encompass six approximately 30-foot deep injection wells at the locations shown on Figure 2. The injection points will consist of 2-inch diameter schedule 40 PVC injection wells that will be screened from approximately 20 to 30 feet bgs. Based on CVOC concentrations and aquifer geochemistry, approximately 10,000 gallons of whey will be injected through six injection wells as part of each injection event. The whey is proposed to be delivered in bulk (approximate 5,000-gallon capacity tanker truck), and injected through a manifold system into the injection wells.

Vapor monitoring will be conducted by AECOM during the electron donor injection events. A photoionization detector (PID) with an 11.7eV lamp or equivalent will be used to monitor concentrations of organic gases. The PID will monitor the breathing zone within the area of oxidant injection, and will be equipped with an alarm system. The alarm will be set to sound if PID readings exceed 15 PID units within the breathing zone, and PID readings will be recorded on an hourly basis during working hours. If PID readings exceed 15 PID units within the breathing zone for a period of 10 minutes, then site

conditions will be re-evaluated for possible personnel protection upgrade to Level C (including the use of an air purifying respirators and Tyvek suits). If PID readings exceed 50 PID units within the breathing zone for a period of 10 minutes, then the site will be evacuated until PID readings are less than 50 PID units. Site safety procedures to be implemented during the electron donor injection events are further provided in the project Health and Safety Plan (Appendix C).

2.4 Post-Injection Groundwater Monitoring Reporting

Ongoing groundwater monitoring data will be evaluated to document the progress of remediation and modify the electron donor injection program as appropriate. Based on the results of future groundwater monitoring, the electron donor injection program may be recommended to be combined with bioaugmentation using commercially available DE microbes. After completion of each post-injection groundwater monitoring events, a brief report will be prepared that will provide an evaluation of the groundwater monitoring data, and provide recommendations for future project activities to be conducted.

2.5 Level of Contaminated Groundwater Pre-Treatment Prior to Re-infiltration

The proposed whey injection at the subject property will not involve re-infiltration or reinjection of contaminated groundwater.

2.6 Types and Concentrations of Substances Proposed for Injection

AECOM has identified a local supplier of de-proteinized whey electron donor (Muscoda Protein Products of Muscoda, Wisconsin). The proposed whey electron donor contains approximately 3 percent lactose.

2.7 Volume and Rate of Injection of Remedial Material

Approximately 10,000 gallons of whey substrate will be injected through six injection wells as part of each injection event. The injection rate for the whey substrate is not anticipated to exceed 15 gpm at each injection well location. The injection pressure for the cheese whey is not anticipated to exceed 20 psig at each injection well location. At the relatively low pressures and flow rates identified above, experience at similar sites indicates that secondary permeability features should not be created.

2.8 Locations Where Remedial Material will be Injected

The electron donor injection events will involve the six injection well locations shown on Figure 2, at injection depths that range between approximately 20 and 30 feet bgs.

2.9 Project Schedule

Pursuant to the WDNR e-mail dated November 5, 2009 regarding the Reedsburg Cleaners site, AECOM is prepared to complete the injection well installation during the week ending November 27, 2009, and initial whey injection during the week ending December 4, 2009.

3.0 Site Investigation Information

3.1 Regional and Local Geology and Hydrogeology

The Reedsburg Cleaners site is situated at an elevation of approximately 898 feet relative to mean sea level. The regional geology of the area is characterized by silty sand soils overlying sandstone bedrock. The results of previous site investigations revealed the presence of silty sand with trace gravel within the upper 10 feet of the subsurface. This silty sand unit is underlain by weathered sandstone bedrock from 10 to 15 bgs, followed by competent sandstone bedrock below 15 feet bgs. The water table is present within the competent sandstone bedrock, at a depth of approximately 17 feet bgs. The direction of shallow groundwater flow is toward the southwest, at a horizontal hydraulic gradient of 0.008 ft/ft, and the vertical hydraulic gradient near the site ranges from 0.02 ft/ft to 0.04 ft/ft upward. The estimated hydraulic conductivity of the sandstone aquifer (based on in-situ hydraulic conductivity testing of site monitoring wells) is 1.0×10^{-2} cm/s. The estimated groundwater flow velocity is 0.8 feet per day.

3.2 Detected VOC Concentrations in Groundwater Samples

Based on laboratory results of previously-collected groundwater samples, PCE is the most widely detected CVOC in the vicinity of the subject property. PCE was detected in ground water samples collected from 10 of the 12 monitoring wells or piezometers in the site vicinity, at concentrations as high as 14,000 micrograms per liter ($\mu\text{g/L}$). The area of PCE-impacted groundwater extends approximately 200 feet to the southwest of the site (Figure 2).

3.3 Potential Migration Pathways and Potential Receptors

Potential exposure pathways associated with impacted soil at the site include direct contact (ingestion, inhalation of particulate matter, inhalation of vapors, and dermal absorption), and migration to groundwater. Groundwater impacts present in the vicinity the subject property do not intersect any underground utility lines, as the water table is present approximately 17 feet bgs (which is below the bedrock surface). The property in closest proximity to the subject site is a veterinary clinic to the west (Figure 2).

The subject site is served by City of Reedsburg municipal water, the source of which is six municipal water supply wells. These wells are identified as follows:

1. "Granite Pump", located 2,100 feet to the northwest of the Reedsburg Cleaners site;
2. "Lucky Pump House", located 1.1 miles to the southeast of the Reedsburg Cleaners site;
3. "Myrtle Pump House", located 3,700 feet to the northeast of the Reedsburg Cleaner site;
4. "Nishan Pump House", located 5,000 feet to the northeast of the Reedsburg Cleaners site;
5. "Power House", located 2,000 feet to the southwest of the Reedsburg Cleaners site; and,
6. "Well #7", located 1.7 miles to the north-northwest of the Reedsburg Cleaners site.

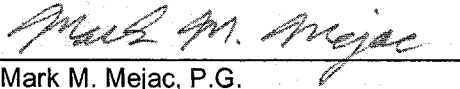
The surface water body in closest proximity to the Reedsburg Cleaners site is the Baraboo River, which is located approximately 1,800 feet to the southwest of the site.

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5.0 Certification

I, Mark M. Mejac, hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. 700 to 726, Wis. Adm. Code.

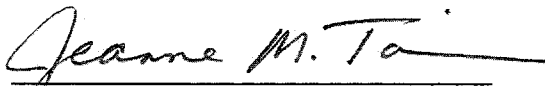


Mark M. Mejac, P.G.
Senior Project Hydrogeologist

November 12, 2009

Date

I, Jeanne M. Tarvin, hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. 700 to 726, Wis. Adm. Code.



Jeanne M. Tarvin, P.G.
Senior Principal Hydrogeologist

November 12, 2009

Date

5.0 Certification

I, Mark M. Mejac, hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. 700 to 726, Wis. Adm. Code.



Mark M. Mejac, P.G.
Senior Project Hydrogeologist

November 16, 2009

Date

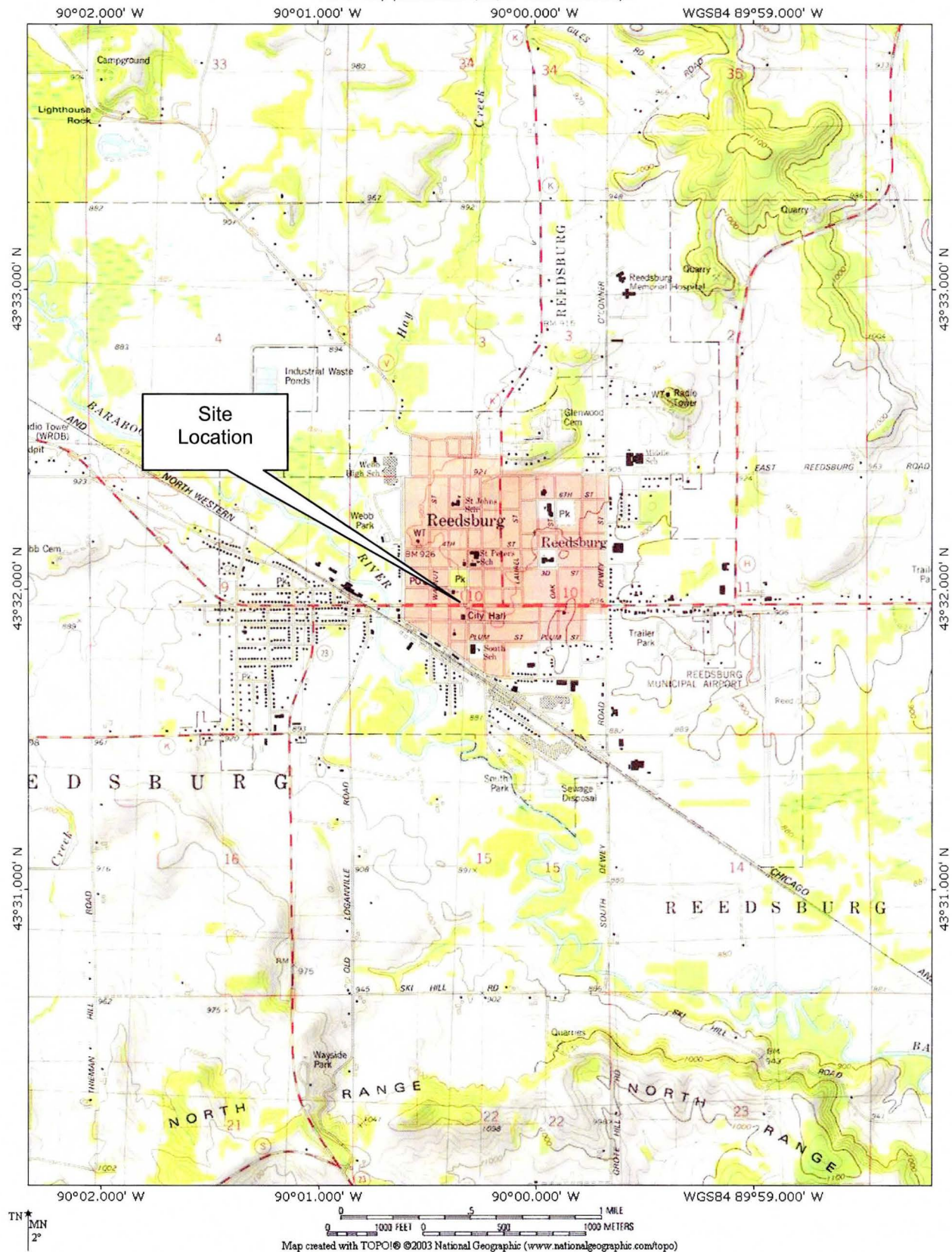
I, Jeanne M. Tarvin, hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. 700 to 726, Wis. Adm. Code.



Jeanne M. Tarvin, P.G.
Senior Principal Hydrogeologist

November 16, 2009

Date



11425 W. Lake Park Drive
 Suite 100, Milwaukee, WI 53224
 T 414.359.3030
www.aecom.com

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Site Location

Reedsburg Cleaners
 Reedsburg, Wisconsin

Drawn: CAS 11/11/2009

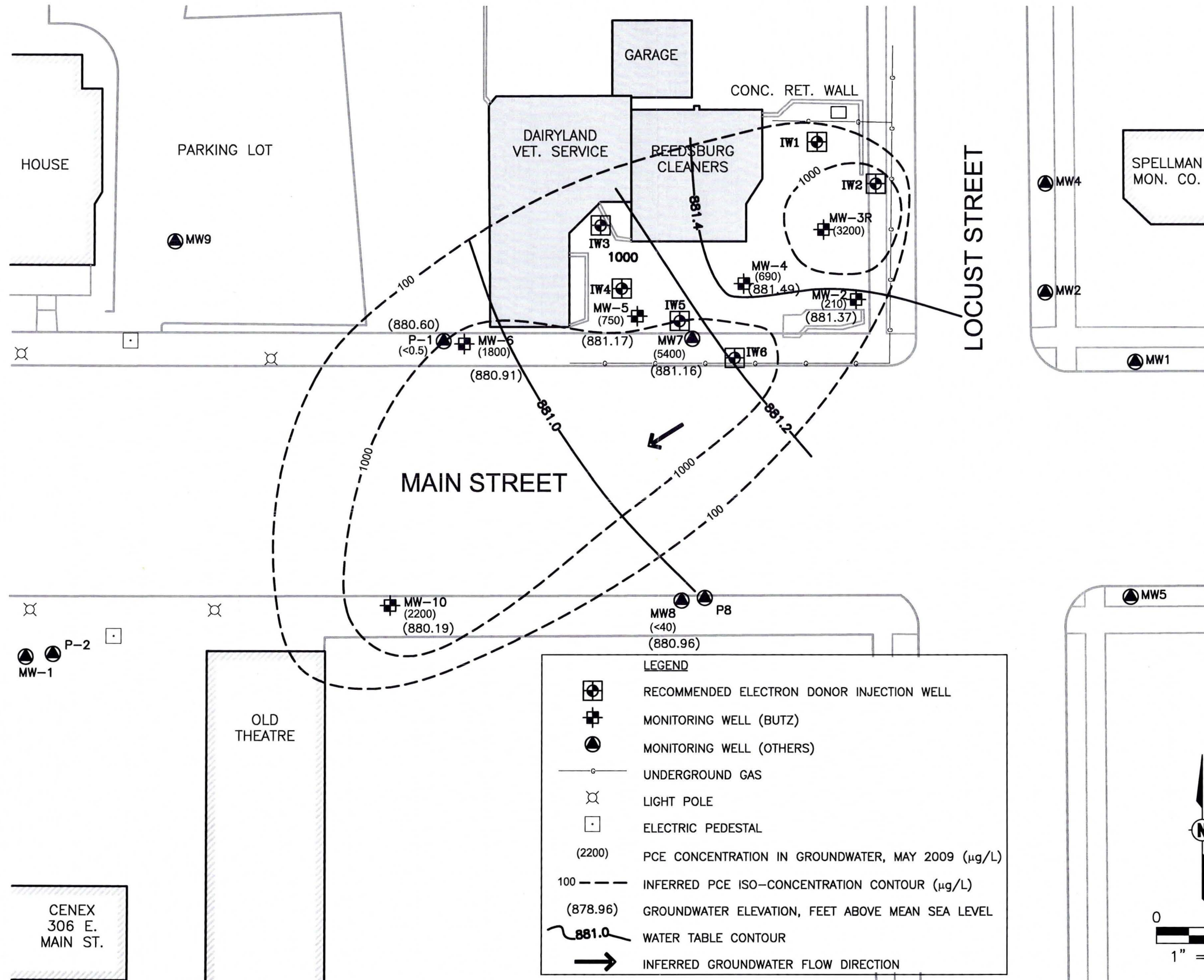
Checked: MOM 11/11/2009

Approved: JMT 11/11/2009

PROJECT NUMBER 60139948

FIGURE NUMBER 1

X:\Projects\200606852\dwg\G60139948-INJECTION WELL.dwg; 11/11/2009 3:05:01 PM; HEINTZ, CHARLES



RECOMMENDED ELECTRON DONOR INJECTION WELL LOCATION MAP

REEDSBURG CLEANERS
 349 E. MAIN STREET
 REEDSBURG, WISCONSIN

Drawn: CJH 11/11/2009
 Checked: MMM 11/11/2009
 Approved: MMM 11/11/2009

PROJECT NUMBER 60139948

FIGURE NUMBER 2

Appendix A

Literature Concerning the Application of Whey for Groundwater Remediation

Effects of PCE Biodegradation on Mass Transfer from Entrapped DNAPL

Ann R. Kaplan, *Kent C. Glover*, Junko Munakata Marr (jmmarr@mines.edu), and Tissa H. Illangasekare (Colorado School of Mines, Golden, Colorado, USA)

Tetrachloroethene (PCE) entrapped in the subsurface as a DNAPL dissolves slowly into flowing groundwater and is a long-term source of contamination, posing significant remediation challenges. Recent studies in homogeneous porous media at relatively low DNAPL saturation have shown that dechlorinating bacteria can accelerate dissolution rates. However, effectiveness of bioremediation in DNAPL source zones that are heterogeneous combinations of residual-saturation zones and high-saturation pools is less understood. The overall goal of our studies is to characterize and model mass transfer of PCE during bioremediation of heterogeneous DNAPL source zones. Our approach combines results of controlled experiments at bench- and intermediate-scales to develop methods for scaling models of biologically enhanced mass transfer to multi-dimensional flow conditions encountered in the field. Specific objectives of this presentation are to identify the influence of biodegradation on mass transfer of PCE at laboratory-bench scales with DNAPL saturations that range from residual to high saturation pools and under various flow regimes.

Column and flow-cell studies were conducted using neat PCE as DNAPL. In each column or flow cell, a DNAPL source zone was created and tracer tests were conducted to characterize system hydraulics. Columns were prepared with DNAPL at residual saturation of approximately 0.20 throughout the column or in only the first quarter of the column. Flow cells were prepared by creating a DNAPL pool in the lower part of the flow cell and quantifying spatial variability in DNAPL saturation by x-ray attenuation techniques. Resulting vertical profiles of DNAPL saturation were used to determine thickness of a hydraulically active transition zone at pool interfaces. A series of dissolution experiments was conducted for each DNAPL configuration and chlorinated ethene composition of influent and effluent was determined by gas chromatographic analysis. Dissolution experiments were conducted at several flow rates under abiotic conditions and following inoculation with a KB-1 microbial consortium capable of reductive dehalogenation of PCE to ethene.

Biological activity enhanced dissolution of entrapped DNAPL in all experiments. However, dissolution characteristics of column studies differed from those of flow cells, reflecting differences in flow patterns and source-zone configurations. Enhanced dissolution in column experiments was caused by degradation of PCE to more soluble daughter products as well as increased PCE concentrations relative to abiotic conditions. Effluent PCE from biologically active columns was consistently higher than PCE aqueous solubility expected in abiotic systems, suggesting effects of bio-surfactants. Differences in surface tension measured in influent and effluent were consistent with this hypothesis. Biologically enhanced mass transfer in flow-cell experiments was caused by degradation of PCE to more soluble daughter products with minimal PCE in effluent, suggesting that biodegradation acted as a reaction sink near the DNAPL-water pool

interface to increase the PCE concentration gradient. The degree of biological enhancement was proportional to thickness of pool transition zones and suggests that significant biological activity occurred within transition zones. In flow-cell experiments where electron-donor flux was not limiting, biological activity enhanced dissolution by a factor of 7 to 32. At low electron-donor flux, the ratio of degradation products to PCE declined, as did the total mass flux of chlorinated compounds.

Dissolution and Dechlorination of Chlorinated DNAPLs Stimulated by Whey Powder

Tamzen W. Macbeth (North Wind, Inc., Idaho Falls, Idaho USA)
Ryan A. Wymore and Kent S. Sorenson, Jr. (CDM, Denver, Colorado USA)

Recent field and laboratory data have shown that enhanced *in situ* bioremediation (ISB) is a viable remediation strategy for chlorinated solvent DNAPL source areas. Both biological and abiotic mechanisms have been proposed for enhanced mass transfer from DNAPLs into the aqueous phase. Given that contaminants are only degraded in the aqueous phase, these mechanisms have made ISB a feasible technology for residual source areas. A potentially important abiotic mechanism occurs when the electron donor solution itself acts to enhance dissolution of DNAPLs when injected through a residual source area. This phenomenon was first observed in the field in response to high concentration sodium lactate injections into a trichloroethene (TCE) residual source at Test Area North (TAN) located within the Idaho National Laboratory. The significance of this mechanism was investigated for several electron donors, including sodium lactate, through abiotic column studies. Whey powder performed best, with enhanced TCE DNAPL dissolution of a factor of six over baseline conditions, while sodium lactate had a much smaller impact (Wood et al, 2004).

Based on these findings, a field-scale pilot test is being conducted to examine the extent of enhanced dissolution and subsequent dechlorination from the residual source area at TAN in response to injections of whey powder as compared to sodium lactate. The pilot test is being implemented in two phases. In the first, high-resolution baseline monitoring followed routine injections of sodium lactate; samples were collected on approximately Days 2, 4, 8, 15, 22, and 36 following sodium lactate injections, which were defined as Day 1. Sodium lactate injections resulted in a two- to nine-fold increase in total chloroethenes and ethene compared to pre-injection concentrations. In addition, dramatic increases in ethene less than 24 hours after the completion of an injection event indicated rapid dechlorination of the newly bioavailable TCE.

Phase two of the pilot test involves three cycles of whey powder injections followed by the same high-resolution groundwater monitoring described above beginning in August 2004. Preliminary results show that the total mass of contaminants liberated and subsequently degraded to ethene during a whey powder injection cycle is approximately 3 times greater than that observed during a sodium lactate injection cycle. These data indicate that whey powder enhances dissolution of chlorinated ethenes more than sodium lactate, and also stimulates complete dechlorination. Therefore, whey powder will be used for long-term ISB operations. The increased liberation and subsequent degradation of contaminants from the residual source area is expected to result in a dramatic reduction of the remediation timeframe at TAN. In addition, documentation of these significant effects of enhanced ISB on DNAPL degradation at a field scale using different electron donors has profound implications to electron donor selection and injection strategy for DNAPL sites across the country.

Evaluation of Enhanced Mass Transfer of Chlorinated DNAPLs during Bioremediation

Tamzen W. Macbeth, Kevin Harris, and Joe Rothermel

(North Wind, Inc., Idaho Falls, Idaho USA)

Kent S. Sorenson Jr. (CDM, Denver, Colorado USA)

Lee O. Nelson (Idaho Completion Project, Idaho Falls, ID, USA)

Enhanced in situ bioremediation (ISB) using high concentration electron donor injections has facilitated enhanced mass transfer of trichloroethene (TCE) from a residual phase to the aqueous phase where it is subsequently degraded in the deep, fractured rock aquifer beneath the Test Area North (TAN) site of the Idaho National Laboratory. Three potentially important mechanisms are thought to contribute to enhanced mass transfer at TAN. The first two are associated with the biological removal of contaminants:

1) maximized concentration gradient due to removal of contaminants from the aqueous phase and 2) maximized loading to the aqueous phase due to the generation of degradation daughter products that are more soluble than the parent compound. The third mechanism is abiotic, and occurs when the electron donor solution itself acts to enhance mass transfer of DNAPLs. This phenomenon was first observed in the field in response to high concentration sodium lactate injections at TAN. Abiotic column studies confirmed that the dissolution of TCE DNAPL was enhanced during amendment with high concentrations of some electron donors. Of these, whey powder enhanced TCE DNAPL dissolution by a factor of six over that observed during potable water amendment, while sodium lactate had a much smaller impact. Based on these findings, a field-scale pilot test was conducted to examine the extent of enhanced mass transfer and subsequent dechlorination of TCE from the residual source area at TAN in response to injections of whey powder as compared to sodium lactate.

The pilot test was implemented in two phases, the first of which involved high-resolution monitoring following two injections of sodium lactate conducted in March and May of 2004. Following these injections, spikes in TCE and cis-DCE concentrations from near 0 $\mu\text{g/L}$ to 300-400 $\mu\text{g/L}$ at the injection well, and to 25-75 $\mu\text{g/L}$ 25 feet downgradient were observed. In addition, there were dramatic increases in ethene concentrations within 48 hours, indicating rapid dechlorination of the newly bioavailable TCE. Phase two of the pilot test involved three cycles of whey powder injections conducted August and October 2004, and January 2005. These injections resulted in spikes in TCE and cis-DCE concentrations from near 0 $\mu\text{g/L}$ to 400-600 $\mu\text{g/L}$ within the injection well, and to 250-400 $\mu\text{g/L}$ 25 feet downgradient. In addition, the total chloroethene and ethene molar areas were evaluated during these injection cycles in order to compare the total mass of contaminants liberated and subsequently degraded to ethene. The total molar areas were approximately 3 times greater during a whey injection cycle compared to sodium lactate. In addition, the rate at which the molar area increased (indicator for mass removal rate) was 50-250% higher during a whey powder injection cycle than for sodium lactate. These data indicate that whey powder enhanced mass transfer and degradation of TCE to a greater degree than sodium lactate. The use of whey powder for long-term ISB

operations is expected to increase the rate of contaminant destruction, ultimately resulting in a reduction of the remediation timeframe at TAN. The application of these techniques to evaluate mass transfer at other DNAPL sites will have profound implications for future electron donor selection and injection strategies.

Field Use of Cheese Whey for Enhanced Reductive Dehalogenation of Chlorinated Ethenes

Jirina Machackova (jirina.machackova@earthtech.cz), Ferdinand Hercik, Lubomir Soukup, Monika Stavelova, and Pavel Machek
(Earth Tech CZ, Prague, Czech Republic, EU)
Kvetoslav Vlk and Jaroslav Zima
(Ministry of Environment, Prague, Czech Republic, EU)

ABSTRACT: Many sites with chlorinated solvent contamination have been remedied during the last fifteen years in the Czech Republic (CR). Achieving the treatment goals by pump-and-treat has been shown to be infeasible at many sites. A failure of this traditional treatment method has led to testing and implementation of novel approaches to the clean-up of chloroethenes (CAH). Biodegradation of chloroethenes via reductive dechlorination (ERD) has proved an effective method and a number of different substrates were tested to support this technology. The Earth Tech CZ Company tested field application of enhanced *in situ* reductive dechlorination using cheese whey as a substrate on five sites. Cheese whey supported complete reductive dechlorination on all tested sites.

INTRODUCTION

Chlorinated aliphatic hydrocarbons (CAHs), namely chloroethenes, are common soil and groundwater contaminants in the Czech Republic. Perchloroethylene (PCE) and trichloroethylene (TCE) were widely used in the second half of the 20th century as industrial degreasing and extracting substances. Due to a lack of understanding of the environmental hazards connected with these materials and generally low attention given to environmental issues in communistic society, many sites in the Czech Republic have extensive soil and groundwater pollution from uncontrolled releases of CAHs.

After the so-called velvet revolution in 1989, change of ownership of industrial facilities (privatization) had taken place. A part of privatization was conducting due diligence assessments of privatized facilities, which revealed many contaminated sites. For new owners, the Czech State granted financing of the clean-up of these so-called “old environmental burdens.” The Czech Ministry of Environment created a register of contaminated sites with their characteristics and priority evaluation. Of the 800 polluted sites in the ministry database, 407 have subsurface chloroethene contamination. A process of risk assessment and site-specific clean-up goal setting and approval, was employed in remediation of old burdens’ removal. The Czech Ministry of Environment defined a methodology for risk assessment in 1996 (updated in 2005), which consists of criteria for evaluation of soil and groundwater contamination content (the ABC list). Czech ABC criteria for chloroethenes, together with Czech drinking water standards and surface water standards are provided in Table 1.

Many sites with chlorinated solvent contamination had been remedied in the CR after 1990, primarily with pump-and-treat chosen as the remediation method. However, reaching clean-up target limits and acceptable environmental conditions using a

pump-and-treat approach was shown to be infeasible on many sites during the period 1990-2000. The failure in this traditional treatment method has led to testing and implementation of new approaches to chloroethenes' clean-up in the last six years.

TABLE 1. Czech standards for chloroethenes' concentrations in environment.

Chloroethene	Surface Water (µg/L)	Drinking Water (µg/L)	Groundwater A** value (µg/L)	Groundwater B value (µg/L)	Groundwater C value (µg/L)
PCE	0,5	10	0,1	10	20
TCE	1	10	0,1	25	50
1,1 DCE		*	0,1	10	20
1,2 DCE (cis+trans)	10	50	0,1	25	50
VC	2	0,5	0,1	10	20
AOX	30				

* rare substance, if present, limit is set individually by state authority

** A value – background, B value – indication of contamination, further evaluation needed, C value –risk assessment necessary

BIOLOGICAL REDUCTIVE DECHLORINATION

Enhanced *in situ* biological reductive dechlorination (ERD) of CAH belongs to one of the most promising and effective methods. [3] The basic principle of ERD involves the delivery of an organic substrate into the subsurface for stimulating microbial growth and creating an anaerobic groundwater treatment zone and generating hydrogen through fermentation reactions. Hydrogen serves as source of energy to dehalorespiring bacteria, which are capable to use CAHs as an alternate electron acceptor in their metabolism and through sequential dechlorination transform CAHs to harmless substances. In some cases, organisms may need to be added, but only if the natural microbial population is incapable of performing the required transformations. [2], [3]

The key task, which determines effectiveness of ERD, is ability to operate the clean-up technology in way to achieve conditions favorable for complete dechlorination and remove CAHs quantitatively. A common problem in chloroethenes' ERD is so-called *cis*-DCE or VC stall, which is an informal term used to describe sites that exhibit anaerobic dechlorination of PCE and TCE to *cis*-DCE, but where the degradation of *cis*-DCE stalls out. This "stall" can have several reasons: (i) lack of the necessary microbiological communities required to degrade *cis*-DCE to VC; (ii) conditions sufficiently anaerobic to support the conversion of PCE to TCE and TCE to *cis*-DCE, but not sufficiently anaerobic (i.e., sulfate-reducing to methanogenic) to support the conversion of *cis*-DCE to VC via anaerobic dechlorination—this may simply be due to a lack of sufficient electron donor; [3] and (iii) high substrate dosing, which creates deep methanogenic conditions, when methanogens can overgrow dehalorespirators. [4]

On many sites a temporary increase of *cis*-DCE concentrations occurs, which is caused due to kinetic disparity, where parent compounds degrade at a faster rate than dechlorination products and concentrations of dechlorination products increase (apparent

stall). As parent CAHs are depleted over time, degradation of dechlorination products may be sufficient to reduce concentrations and the reverse the apparent stall. [3]

Many organic materials have proven applicable for creating reductive conditions, which support dechlorination. ERD was implemented on more than 500 sites worldwide through 2004. [2], [3],[6] Based on a literature review of laboratory studies [1], [5] cheese whey was selected in 2000 by Earth Tech CZ as a complex and inexpensive substrate. This material was tested for its ability to enhance the natural biodegradation process under field conditions. Cheese whey, a water soluble byproduct of the food industry, contains about 5 – 6 weight percent of organic substances (mainly lactose and lactic acid) and a wide range of mineral nutrients (N, P, K, Na, Ca, and others). It is a food-grade product and for this reason it is acceptable for regulatory approval for subsurface applications.

ERD with cheese whey as a substrate has been applied by Earth Tech at five sites in the CR so far, as well as several sites in the US. Detailed information about the Czech sites is given further.

CASE STUDIES

Initially, ERD supported by application of cheese whey was used to solve the problem of rebounding, following remedial action using pump and treat. **Site 1** was an electrical component production facility, where PCE was used as a metal parts degreaser. Site 1 was underlain by granite bedrock, which weathered to sandy-gravel eluvium. The shallow aquifer was contained within the eluvium and the upper portions of the fractured bedrock.

The site was treated by **pump-and-treat** for three years (1995–1998) with input PCE groundwater contamination levels (3–5 mg/L) declining to treatment goal (0.2 mg/L) (see Fig. 1). In the last year of operations, a biodegradable surfactant was applied to enhance PCE solubilization. This application also slightly supported reductive dehalogenation, as an increase in levels of cis-DCE were documented in 1998 (Fig. 1). When PCE concentrations were below the clean-up goal (0.3 mg/L) for several months, clean-up was stopped. But significant **rebound** occurred within a month after pump-and-treat shutdown and PCE concentrations rose above 1 mg/L in four groundwater monitoring wells. To address this rebound, cheese whey was applied as an electron donor to promote biological **reductive dechlorination**. Fresh, undiluted cheese whey was applied to an area of 600 m², to the depth interval 5 – 15 m below ground surface (bgs) in four doses over a three month period. Total applied volume was 20 m³.

The efficiency of EDR was evaluated by chloroethene concentration and ratio changes. A substrate content and in groundwater was observed as COD_{Cr} monitoring and changes of geochemical conditions were evaluated by monitoring of selected parameters (redox potential, dissolved oxygen, methane and sulphite content, iron and manganese ions content, nitrate, nitrite and sulfite ion contents). An increase in concentrations of less chlorinated ethene (TCE, cis-DCE), as markers of the dechlorination process, was observed shortly after the first injection of whey, followed by a rise in vinyl chloride (VC) concentrations. Concentrations of all CAHs declined twelve months from initial ERD injections. The treatment goals were reached across the whole site and cleanup was confirmed during two post-treatment monitoring events. Afterwards, a regulatory approval for the site closure was obtained.

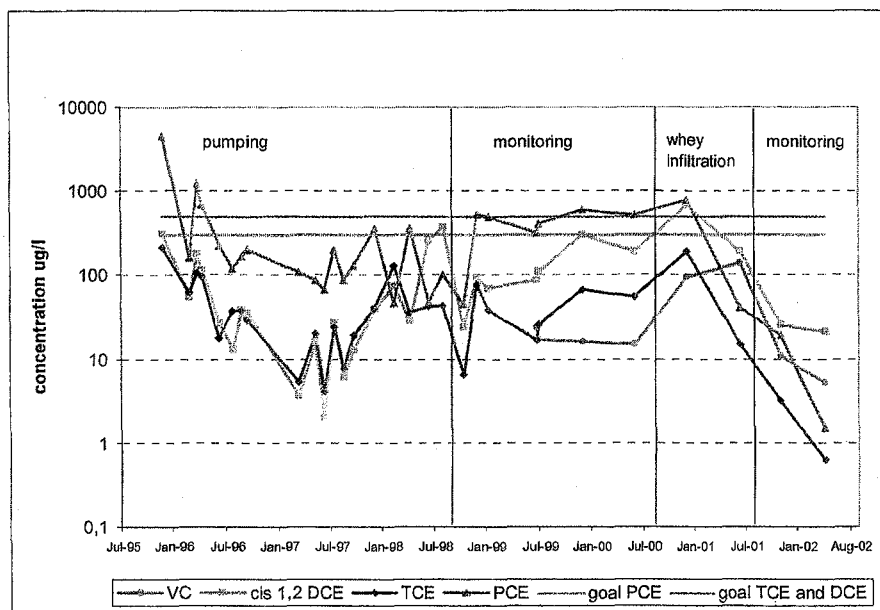


FIGURE 1. Site 1 – chloroethene concentration changes in the well EP-11.

At site 2, where cheese whey was used for ERD stimulation at a textile factory, PCE was used for cleaning of looms and produced linen. Site 2 was situated on the river bank, where fractured Permian–Carboniferous siltstones are overlain by a Quaternary river terrace formed of clayey sands. A long-term pump-and-treat system was operated on the Site 2 for 9 years with negligible influence on CAH groundwater concentrations (see Fig. 2). ERD was proposed as an alternative remedial strategy in 2001, mainly because of observed evidence of a reductive attenuation process (high cis-DCE concentrations, Fig. 2).

Cheese whey was applied to an area about 2,600 m² with a contaminated aquifer thickness of 2 m and groundwater level (GWL) of 2 – 6 m bgs. Two systems were used for dosing – infiltration at the groundwater table through venting system and injection to the aquifer bottom through injection wells. A total volume of 32 m³ of fresh, undiluted cheese whey was applied to the site subsurface during an 18-month period. A rapid decrease in CAH concentrations in groundwater was observed after stimulation of biological degradation and clean-up goals were achieved, as confirmed by two-year post-treatment monitoring.

Site 3 was a former drycleaning facility with similar natural conditions to Site 1— fractured granodiorite bedrock overlain by sandy-gravel eluvium. GWL was about 2 m bgs and thickness of the contaminated aquifer, contained in eluvium and the upper

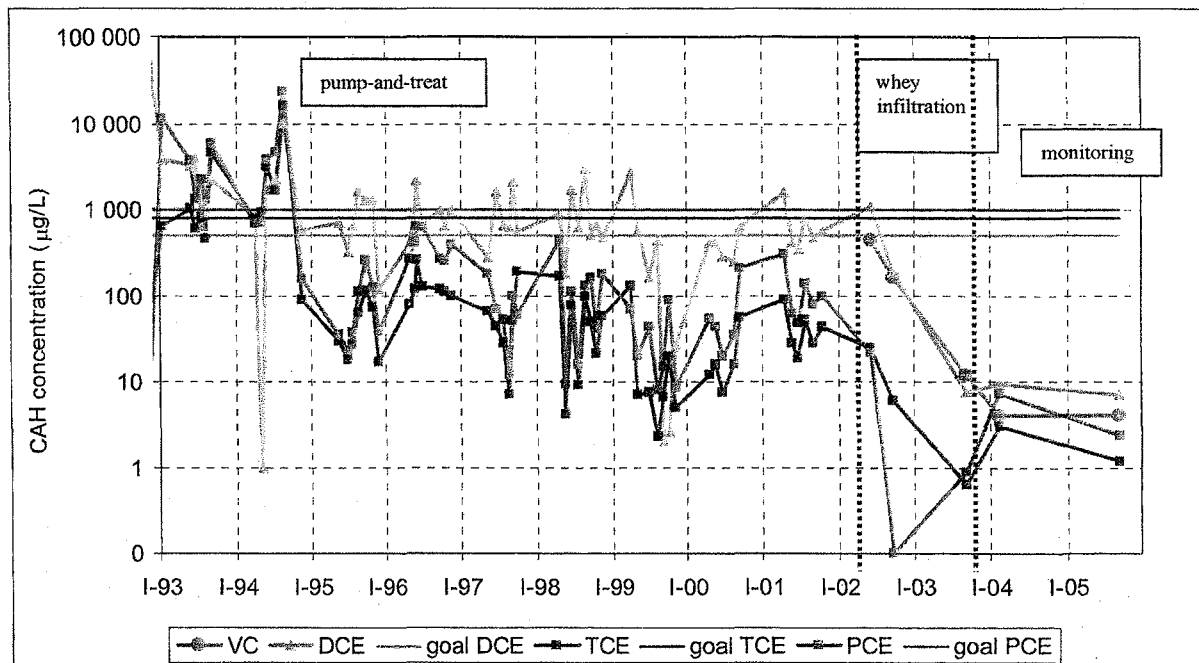


FIGURE 2. Site 2 – chloroethene concentration changes in the well LT-2.

fractured bedrock, varied between 6–10 m. EBRD was implemented in an area of 2,500 m², where undiluted fresh cheese whey was applied to three depth intervals: at the GWL via horizontal pipeline, and at the middle and bottom of the contaminated aquifer through injection wells. Application was performed in four doses, where a volume of 50 m³ was injected over a period of twelve months.

Characteristic curves of chloroethene concentrations and ratio changes were observed at the site (Fig. 3), indicating that EBRD had successfully taken place in the subsurface. A decreasing trend of CAH concentrations, observed in autumn 2005, indicates that most of the CAH in subsurface was removed. Post-treatment monitoring is about to start at the site. To prove that clean-up goals were met, it is necessary to perform monitoring after the added substrate has been depleted and natural geochemical conditions have been restored in the aquifer.

Chloroethenes are relatively hydrophobic and, as a result, are typically bound to organic carbon, which is a part of the soil matrix. Because they are relatively small molecules, CAHs also are susceptible to sorption to the clayey portion of soil, which can be more significant than sorption to organic matter. Groundwater concentrations of CAHs are driven by the equilibrium between CAHs dissolved in water and sorbed to soil (and in form of DNAPL, if present). When aqueous phase CAHs are being removed by biological reductive dechlorination with high efficiency (especially sites with lower CAH content), very low groundwater CAH concentrations can be observed. This early success can lead to premature termination of substrate dosing and, after the substrate is depleted, rebound can occur as sorbed CAH is released from the soil matrix. This is why it is necessary to perform post-treatment monitoring to demonstrate that the clean-up target has been reached under normal geochemical conditions.

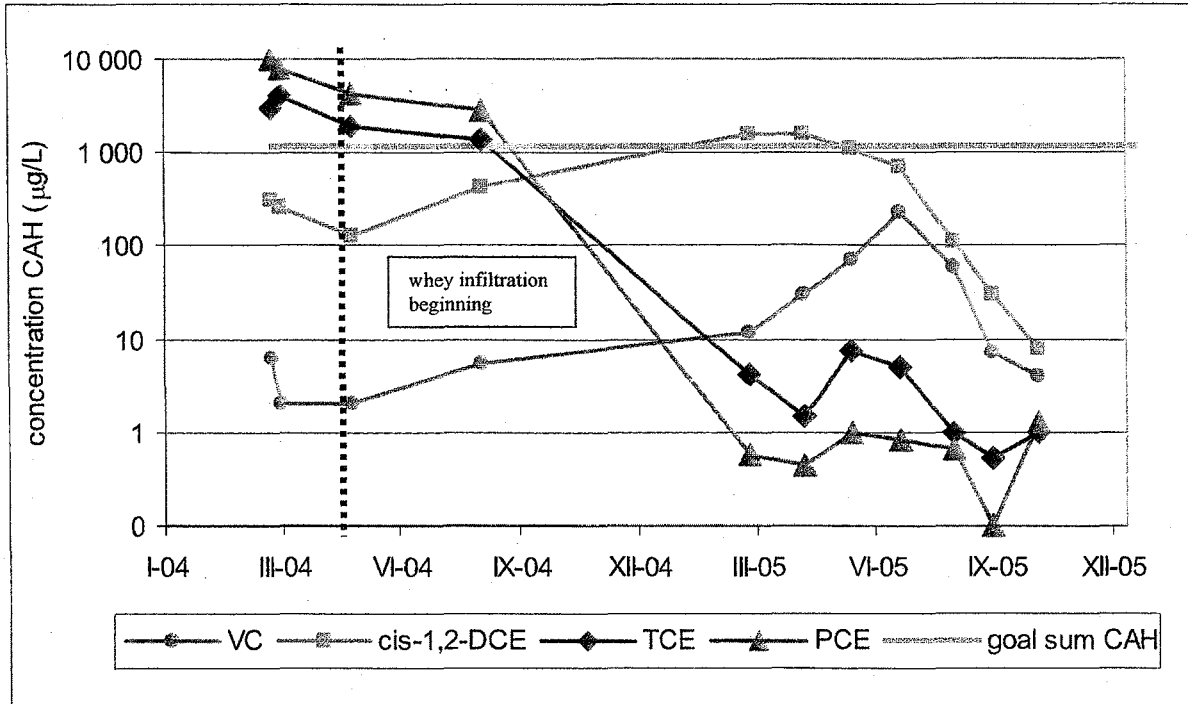


FIGURE 3. Site 3 – chloroethene concentration changes in the well S-1.

Site 4 was an automotive company with natural conditions similar to the Site 1 with fractured granite bedrock overlain by elluvium and anthropogenic debris. A pilot test of EBRD was conducted at the site in an area of 3000 m². GWL in the area of the pilot test is about 2 m bgs and the thickness of the contaminated aquifer is about 12 m. The test started in April 2005 and, after six months, data indicate a significant shift in CAH ratios towards daughter CAHs (Fig. 4) with complete dechlorination demonstrated by production of ethene (Fig. 5).

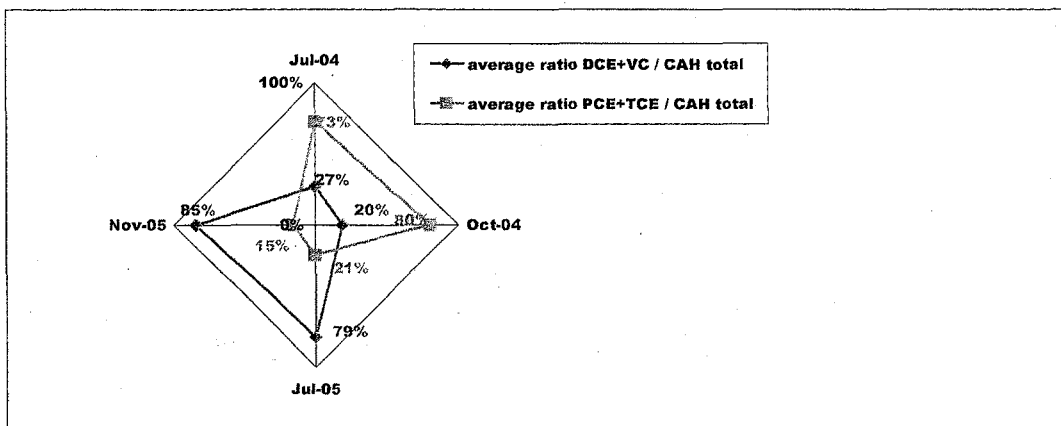


FIGURE 4. Site 4 – chloroethene ratio changes in groundwater.

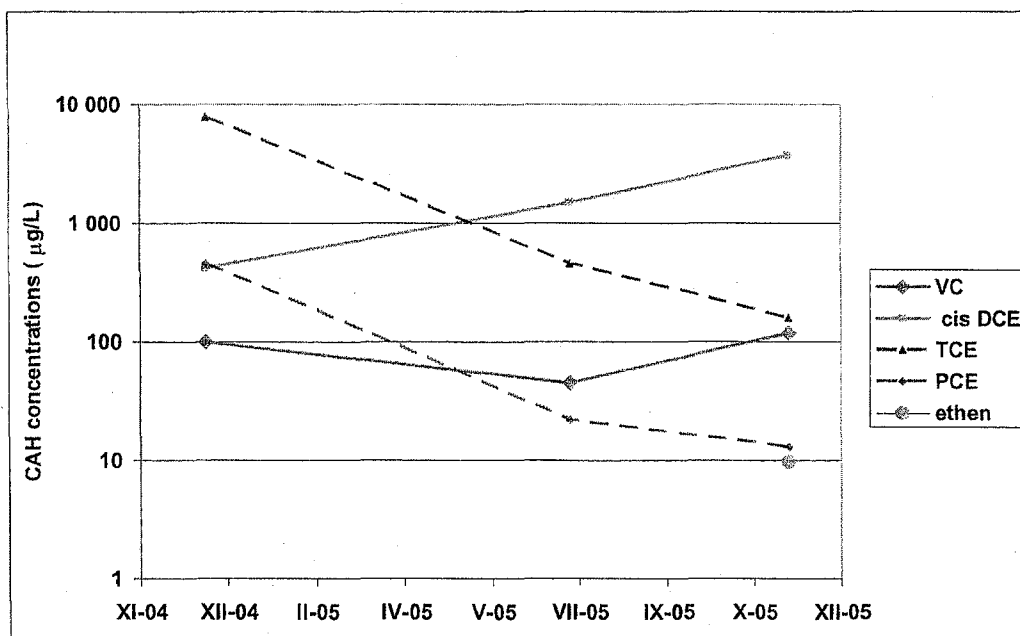


FIGURE 5. Site 4 – concentration changes in the well HM-15.

Site 5 was an automotive company, situated on a river bank. The site was underlain by a Quaternary river terrace, consisting of sandy-gravel deposits with high clay fraction. The base of the river terrace was deposited onto a Cretaceous claystone, which weathers to a clay aquitard.

The core zone of contamination was remedied by **air sparging** (AS) and soil vapor extraction (SVE). Initial groundwater concentration was 100 - 500 mg/l TCE in the source area. Air sparging removed a significant mass of TCE, but the decline in concentration was exponential and the system was not effective enough to reach the clean-up goal. Enhanced anaerobic reductive dechlorination was performed as a final step in the clean-up. Beet molasses and whey were used as substrates. When biodegradation was initiated, the maximum concentration of TCE was 20 mg/l in the source area.

The periodic substrate injection lasted for 18 months: during the first 12 months, molasses was used and during the last 6 months whey was used. Biodegradation efficiency was evaluated by chloroethene concentration and ratio changes. The concentration of cis-DCE rose far above the initial TCE concentration during treatment, with a maximum detected concentration of 160 mg/l cis-DCE. Production of VC and ethene was observed. Concentrations of DCE and VC started to decline after 10-15 months of biological treatment and the remediation goal (0.5 mg/L for TCE and DCE, 0.2 mg/L for VC and PCE) was ultimately reached. Additionally, significant decrease of Cr^{VI} concentration in groundwater was observed during treatment (from 0.4 mg/L below 0.005 mg/L).

SUMMARY AND DISCUSSION

Fresh cheese whey was used as a substrate for support of biological reductive dehalogenation of PCE and TCE on five sites. Results of groundwater monitoring confirmed that fresh cheese whey effectively supported ERD on all sites. Whey was applied via developed injection wells/or infiltration drains periodically over 3–6 months. Frequency of dosing and amount of substrate applied was driven by results of groundwater monitoring. Higher amounts of substrate and shorter dosing frequency were needed initially to establish anaerobic conditions. Restoration of natural conditions (i.e. depletion of added substrate and re-equilibration of redox potential to pre-treatment values) had taken about 8 – 12 months after termination of substrate injections. Table 2 provides basics pros and cons of whey as a substrate for ERD.

TABLE 2. Pros and cons of fresh cheese whey as a substrate for ERD.

Characteristics	Pros	Cons
Economics	Inexpensive (2 USD/m ³ in CR)	Bulk substrate – higher transportation costs
Handling	Easy and Ready-to-use substrate with no additional operations or safety considerations	Practically impossible to store for long periods (shelf life of 1 day, if not cooled)
Soluble substrate with low organic content (5 % weight)	Suitable for developed infiltration and re-circulation systems, good control of dosing and distribution	Suitability for direct-push injection not tested, repeated injection needed for full clean-up
Dosing frequency	3 – 6 months	Repeated application necessary (minimum 3 times)

CONCLUSIONS

Cheese whey was applied on five sites, differing both in geological conditions (from low permeability river sediments to crystalline fractured bedrock) and initial CAH concentrations (1–100 mg/l in total). Two sites that were remedied completely and successfully have now been fully closed. Three sites are still undergoing treatment and complete reductive dechlorination has been demonstrated in all cases. The field application of cheese whey for support of anaerobic biodegradation has been demonstrated to be an effective method for chloroethenes contamination treatment. These projects proved that whey could serve as an electron donor for complete reductive dechlorination under field conditions at a variety of sites.

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USA

- 2) EPA. 2000. *Engineered Approaches to In Situ Bioremediation of Chlorinated Solvents Fundamentals and Field Applications*. US EPA, EPA 542-R-00-00
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- 4) Kean, J.A. (2003). *Enhanced Reductive Dechlorination and The Relationship Between Cis-1,2-DCE Accumulation and Methanogenesis*. Florida Department of Environmental Protection.
- 5) Sorenson, Jr., K.S. (2000). "Biodegradation of TCE Improved with Lactate Injection in Deep, Fractured Rock." In: *Ground Water Currents*. Issue No. 38, December 2000. EPA 542-N- 00-008.
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Fresh Cheese Whey Application for Enhanced Anaerobic Bioremediation of Low Levels of Chlorinated Ethenes

Vibhav Mankad (mankadv@cdm.com), Carolyn Moore, and
Pawan Sharma (CDM, Walnut Creek, California, USA)
Kent Sorenson, Jr. (CDM, Denver, Colorado, USA)

Cheese whey is a soluble electron donor with growing number of applications for enhanced anaerobic bioremediation (EAB) of chlorinated ethenes such as trichloroethene (TCE). EAB applications with cheese whey in the fresh liquid (~ 6% by weight organic carbon) and dry powder (~ 60% by weight organic carbon) forms have been reported.

This paper will present the results and discuss the treatment effectiveness of fresh cheese whey injection for EAB of low levels of chlorinated ethenes in shallow groundwater immediately downgradient of source area at a Superfund site. The objectives of this cheese whey application, as part of the ongoing EAB pilot program, are to support the proposed amendment to this Superfund site's Record of Decision from groundwater pump and treat to in situ bioremediation and attainment of background concentrations.

The EAB pilot program consisted of one-time source area injection of hydrogen release compound (HRC®) in 2001, which reduced source area concentrations of TCE from more than 50,000 micrograms per liter [$\mu\text{g/L}$] to less than background concentrations (100 $\mu\text{g/L}$), but had minimal effect on improving downgradient groundwater quality. In 2005, direct injection of HRC® into the areas downgradient of the source was completed. However, this has had minimal effect on the degradation of the low levels of TCE and breakdown product cis-1,2-dichloroethene (cDCE), 250 $\mu\text{g/L}$ total. This ineffectiveness of HRC® has been attributed to poor distribution and consumption via non-dechlorinating reactions. As such, for future applications, a soluble electron donor was considered necessary to improve distribution while maintaining low electron donor concentrations to minimize consumption under non-dechlorinating reactions. The physical properties including low viscosity, fast hydrogen release, and ease in distribution facilitated selection of fresh cheese whey over dry cheese whey, sodium lactate, and other soluble electron donors.

Fresh liquid cheese whey with 6% by weight organic carbon will be diluted onsite to 1 to 2% by weight organic carbon. Approximately 1,000 gallons of dilute cheese whey mixture will be injected quarterly into each of the nine injection wells over a one year period. The electron donor addition is targeted to maintain approximately 100 milligrams per liter (mg/L) of organic carbon content within 5-foot radius of an injection well and also facilitate hydrogen for competing electron acceptor such as sulfate (250 mg/L).

Treatment effectiveness monitoring will be conducted quarterly using the injection wells as well as other monitoring wells located within 10 to 15 feet downgradient of the injection wells. In addition to the chlorinated ethene levels, treatment effectiveness will be assessed using levels of dissolved gases (methane, ethane, ethene), and geochemical (dissolved oxygen, oxidation-reduction potential) and microbial (*Dehalococcoides*) parameters.

System Design for Enhanced Biological Treatment of Chlorinated Solvent DNAPL

Perry L. McCarty (Department of Civil and Environmental Engineering, Stanford University, Stanford, California, USA)

Tetrachloroethene (PCE) and trichloroethene (TCE) are the most frequently found and costly to control organic contaminants in groundwater. Chlorinated solvent spills migrate downward to form dense non-aqueous phase liquids (DNAPLs), which constitute sources of contamination to groundwater that may last for decades, if not centuries. Recent research has indicated that near-saturation concentrations of chlorinated solvents can be biodegraded by specialized anaerobic microorganisms that use the chlorinated solvents as electron acceptors in energy metabolism. Efforts based upon this observation are now being directed towards use of biodegradation to reduce the life span of chlorinated solvent DNAPLs.

Among the advantages of chlorinated solvent DNAPL biodegradation are: (1) it can result in enhanced rates of solvent dissolution, (2) the high chlorinated solvent concentrations near the DNAPL and their degradation products are toxic to microorganisms, such as methanogens, that otherwise compete with dechlorinating microorganisms for electron donor, and (3) the costs for delivery of the electron donor per unit of solvent degraded are much less when applied to high solvent concentrations. A question then arises: What are the best donors for chlorinated solvent dehalogenation and what are the best strategies for their delivery to the DNAPL source area?

Possible electron donors are gaseous materials such as hydrogen and soluble organics such as formate, propionate, lactate, and molasses. There are also a variety of "slow hydrogen release" materials such as vegetable oils, precipitated compounds such as calcium oleate, natural organic solids such as compost, and various commercially available products. Two potential problems with anaerobic chlorinated solvent DNAPL dehalogenation are (1) the production of hydrochloric acid, which can create severe pH problems, and (2) the formation of acetic acid from donor fermentation, an organic acid that can produce adverse water quality problems.

Possible ways to address these potential problems are (1) donor selection and (2) remediation design. For example, both problems are reduced if formate rather than most other organics is used as the donor. First, the cation with which formate is associated (generally sodium) is released during utilization to result in self neutralization of the hydrochloric acid produced. Second, acetic acid is not generated by its use. While previous studies have indicated that the key microorganisms (*Dehalococcoides*) responsible for dehalogenating the intermediate products formed, such as cis-dichloroethene (cDCE) and vinyl chloride (VC), to ethene, cannot use formate as a donor, we have demonstrated that in mixed culture, the formate is converted into hydrogen, which can then be used by these organisms.

Remediation systems can also be designed to reduce the potential problems from hydrochloric acid and acetic acid production. The pH in groundwater is a function of the ratio of the log of bicarbonate concentration to dissolved carbon dioxide concentration,

the higher the ratio the higher the pH. Hydrochloric acid and acetic acid unfortunately both destroy bicarbonate and form carbon dioxide, leading to low pH. Various methods can be used to increase bicarbonate concentration and reduce dissolved carbon dioxide to help reduce this problem. For example with complex donors that produce both hydrogen and acetic acid, properly designed recirculation systems can take advantage of acetic acid production for conversion of PCE and TCE to cDCE, while using the hydrogen produced only for cDCE and VC reduction. These include the use of a combination of nested upgradient injection and down gradient extraction wells, or a combination of groundwater recirculating wells.

Whey Powder As a Cost-Effective Electron Donor: Field Demonstration

Ryan A. Wymore¹, Kevin Harris², Kevin Hall², Michael Koelsch², Dana L. Dettmers², Tamzen W. Macbeth², Lee O. Nelson³, and Kent S. Sorenson Jr.¹

¹CDM, Denver, Colorado USA, ²North Wind Inc. Idaho Falls, Idaho USA, ³Idaho National Laboratory, Idaho Falls, Idaho USA

Whey powder is being evaluated as an electron donor for in-situ bioremediation (ISB) of chlorinated solvents in a trichloroethene (TCE) residual source zone at Test Area North (TAN) located within the Idaho National Laboratory. This evaluation has progressed from a multi-year laboratory study to a field-scale pilot test. The focus of the pilot test is to confirm laboratory results, which suggested that whey powder may be a more cost effective electron donor than sodium lactate, which has been used during ISB operations at TAN since January 1999. Whey powder was recommended for a field-scale pilot test based on the laboratory studies because it enhances the dissolution of TCE DNAPL in column studies more than sodium lactate, has comparable dechlorination efficiency to sodium lactate, and is less expensive than sodium lactate per unit contaminant degraded (Wood et al, 2004). The first phase of the field scale pilot test, which was completed during the summer of 2004, involved high-resolution baseline monitoring following routine injections of sodium lactate. The second phase, which will be performed from August 2004 through June 2005, involves the same high-resolution groundwater monitoring following three cycles of whey powder injections.

During the pilot test, the performance of whey powder is being evaluated relative to sodium lactate in several areas, including the ability to distribute the donor throughout the subsurface, dechlorination efficiency, electron donor utilization, and enhanced dissolution of TCE from the residual source. The performance metrics being considered during the pilot test include a broad range of cost implications including unit price, mass and volumes required to achieve efficient dechlorination and enhanced dissolution, and impacts to remedial timeframe. For example, the laboratory study results suggested that whey powder is as easily distributed through a basalt-packed column as sodium lactate, implying that similar injection volumes should result in similar distribution in the subsurface. Preliminary field results during sodium lactate and whey powder injections indicate that higher concentrations of whey powder can be distributed over approximately the same area as lactate. Secondly, laboratory results also suggested that the overall utilization rate of whey powder is higher than sodium lactate by over a factor of two, and preliminary field results confirm these data. Thirdly, the laboratory studies suggested that whey powder enhances dissolution of TCE DNAPL into the aqueous phase to a greater extent than sodium lactate, which if confirmed in the field, could result in a reduction in operational timeframe of ISB at TAN. Initial pilot test data are consistent with these laboratory findings. Finally, the impact of the whey powder injections to the microbial community is also being evaluated using molecular techniques. Based on preliminary evaluation of these factors, it has been determined that whey powder will be more cost effective than sodium lactate at TAN.

Wood, T., Wymore R., Blackwelder, B., and Sorenson, K.S. 2004. *Effects of Electron Donor Solutions on Dissolution of Chlorinated DNAPLs*. Presented at: Remediation of Chlorinated and Recalcitrant Compounds: The 4th International Conference (Monterey, 24-27 May, 2004).

Appendix B

Inventory of Injection Well Form 3300-253 (5/01)

This information is collected under the authority of the Safe Drinking Water Act.

Notice: Code of Federal Regulations (40 CFR 144.26 Inventory Requirements): owners or operators of all injection wells authorized by rule shall submit inventory information to an approved State Underground Injection Control Program. Personal information collected on this form will be used for inventory purposes. Information will be made accessible to requesters under Wisconsin's Open Records laws (s. 19.32 to 19.39, Wis. Stats.) and requirements.

Date Prepared (Year, Month, Day) 2009, November, 16	Facility ID Number 157001460	Transaction Type (Please check one of the following) <input type="checkbox"/> Deletion <input type="checkbox"/> Entry Change <input checked="" type="checkbox"/> First Time Entry <input type="checkbox"/> Replacement
--	---------------------------------	---

Facility Name and Location

Last Name Reedsburg Cleaners	First	MI	Latitude: DEG MIN SEC N	Longitude: DEG MIN SEC W
Street Address / Route Number 349 E. Main Street			Township 12 N	Range 4 E
City / Town Reedsburg			State WI	ZIP Code 53959
County Sauk			Tribal Land <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	

Legal Contact

Type <input checked="" type="checkbox"/> Owner <input type="checkbox"/> Operator	Last Name Butz	First Wayne	MI	Telephone Number (incl. area code)
Organization Reedsburg Cleaners			Ownership	
Street / P.O. Box 349 E. Main Street			<input type="checkbox"/> Private <input type="checkbox"/> County / Local Government <input type="checkbox"/> State <input type="checkbox"/> Federal <input type="checkbox"/> Specify Other _____	
City / Town Reedsburg			State WI	ZIP Code 53959

Well Information

WELL CLASS	WELL TYPE	TOTAL NUMBER OF WELLS	WELL OPERATION STATUS					KEY:
			UC	AC	TA	PA	AN	
	Remediation	6						DEG = Degree MIN = Minute SEC = Seconds SECT = Section ¼ SECT = Quarter Section AC = Active UC = Under Construction PA = Permanently Abandoned and Approved by State AN = Permanently Abandoned and Not Approved by State TA = Temporarily Abandoned and Not Approved by State

Comments (Optional):



AECOM
SITE SAFETY PLAN
PROJECT NAME: Reedsburg Cleaners
PROJECT NO: 13229.001

A. SUMMARY INFORMATION

DATE: November 13, 2009

UPDATE:

PROJECT LOCATION: 342 East Main St, Reedsburg, WI
SITE CONTACT AND PHONE NO: Anna Volk, (608) 524-2212

TYPE OF FACILITY: Dry Cleaner

PLAN PREPARED BY: Mark Mejac

SITE SAFETY OFFICER:

CPR/FIRST AID TRAINED STAFF:

REVIEWED BY:

DATE:

OBJECTIVE(S)/SCOPE OF AECOM INVOLVEMENT:

Task 1: Groundwater Sampling

Task 2: Oversight of Injection Well
Installation

Task 3: Oversight of Electron Donor
Injection

PROPOSED DATE OF EXPLORATION AND COMPLETION DATE: May 2009

UNUSUAL FEATURES/SITE SECURITY (include site map with control boundary description):

UTILITIES: Marked () Scheduled Meet () _____ date _____ time

ANALYTICAL DATA (to be summarized below or attached, if available): none available. Possibility of low-level CVOCs

CONFINED SPACE: Yes () No (X) (If yes, describe and address permitting and entry procedures in an attachment.)

AIR MONITORING:

Monitoring equipment: () PID meter with 10.6 eV lamp or _____
() O₂ meter, () FID, () Detector tubes, () L.E.L. meter, () H²S meter
Other _____

Action level = 15 PID units in breathing zone (b.z.) or Level C upgrade. Stop work = 50 PID units in b.z.

Other action levels:

PERSONAL PROTECTION: Level of Protection: A _____ B _____ C _____ or D X

Special Requirements:

COMMUNICATION EQUIPMENT: (Mobile Phone or other phone location and number, etc.) Mobile Phone

HEAT/COLD STRESS CONTROLS: (attach appropriate cold/heat related hazard summary) Cold



SPECIAL PHYSICAL HAZARD CONTROLS: Barricades for work area, reflective vests,
other _____

SPECIAL SITE EMERGENCY COMMUNICATION PROCEDURES: (Evacuation signals, routes, spill containment)

LOCAL EMERGENCY RESOURCES AND TELEPHONE NUMBERS

Emergency Eye Wash/Shower Location: AECOM Vehicle
Fire Extinguisher: AECOM Vehicle
Police: 911
Fire Department: 911
Poison Control: 911

HOSPITAL: Reedsburg Area Medial Center 608-524-6487
Address: 2000 North Dewey Avenue Reedsburg, WI
Telephone: Directions (supply map): see attached map

EMERGENCY AECOM CONTACTS

1. _____ 1-800-_____ or local
2. Department Manager: Kevin Brehm: 414-577-1314
3. Consulting Physician: Work Care, Dr. Peter Greaney, 1-800-455-6155 ext 114

PRE-ENTRY SAFETY BRIEFING

I have received and read this health and safety plan including the attached sections B through I. I understand the plan and had the opportunity to ask questions. I understand the information and instructions in the plan. I have also participated in the education and training programs in compliance with Federal OSHA 1910.120(e): 40 hours of initial instruction and 8 hours of annual refresher training. I understand that medicine can complicate the effects from exposure to toxic chemicals. If I am taking any prescription or over the counter medicine, or have a current medical condition which may increase my risks, I will advise my supervisor.

Signature of:

<u>Team Member</u>	<u>Responsibility</u>	<u>Date</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____

Refer to Sections B through I and appropriate attachments for Additional Information for the following site type:

- General low-level Contamination
- Manufactured Gas Plant Sites
- Paper Sludge Landfill
- Petroleum Contamination
- Site Specific Plan
- Heat Related Hazards
- Cold Related Hazards

COMMENTS:

AECOM¹
SITE SAFETY PLAN
LOW CONTAMINATION OF FUEL,
CHLORINATEDS & PNA_s IN SOILS

DOCUMENTATION SUMMARY:

The health and safety protocols established in this plan are based on the site conditions and chemical hazards known and/or anticipated to be present from available site data. The possibility of soil contamination within the site requires a conservative approach to on-site safety procedures. The following Site Safety Plan is intended solely for use during the proposed activities described in the site exploration work plan. Specifications herein are subject to review and revision based on actual conditions encountered in the field. This document meets or exceeds the performance criteria required by 29 CFR 1910.120.



¹ This plan was prepared for the exclusive use of AECOM staff and those persons or organizations whose use has been authorized in writing by AECOM. This Site Health and Safety Plan does not supersede or in any way relieve subcontractors of their obligations under any applicable OSHA regulations. Neither this plan nor any information contained therein is to be used or relied upon by any other party. AECOM assumes no responsibility or liability for damages or injuries which arise from or relate to any such unauthorized use. This plan is not to be reproduced in whole or in part without the expressed written authorization of AECOM. Updates will occur as conditions change. The plan will expire at completion of AECOM's involvement. Documentation of training and medical surveillance can be obtained upon written request to AECOM, Corporate Health and Safety Manager, Deerfield, Illinois.

**SITE SAFETY PLAN
LOW CONTAMINATION OF FUEL,
CHLORINATEDS, PNAs IN SOIL**

**A. GENERAL INFORMATION
See Site Specific Summary Sheet**

B. SITE/WASTE CHARACTERISTICS

WASTE TYPE(S) CHARACTERISTICS: Liquid___ Solid X Sludge___ Gas___
Corrosive___ Ignitable___ Radioactive___ Volatile___
Toxic___ Reactive___ Unknown X Other___

OVERALL HAZARD: Low

ROUTES OF ENTRY:

Inhalation X Ingestion X Skin Absorption X

PATHWAYS FOR DISPERSION OF HAZARDOUS MATERIALS: Soil, water, and air.
Perched groundwater and/or migration through fill into natural soils and airborne emissions.

WIND DIRECTION: Variable due to changing weather systems. Wind direction will be observed so that staff can be positioned to conduct operations, as much as possible upwind.

SITE RESOURCES:

Fire Extinguisher: Available on rig or AECOM vehicle. All personnel will be made aware of the location of the fire extinguisher and should be prepared to use it at any moment.

Telephone: Mobile phone will be available on all sites unless otherwise indicated in Section A.

C. HAZARD RECOGNITION AND EVALUATION

POSSIBLE CONTAMINANTS:

Consideration in developing site safety plans is given to the potential hazard of the known chemicals, evaluating the toxicity, ignitability, reactivity, corrosiveness, physical state, and the quantity of the raw or waste materials that were expected to be generated or disposed of on site. The materials which may be found on this site can be classified as having a low order of environmental concern. The potential for fuel, lubricating oil, or gasoline contaminated soil is thought to be remote, but these orphaned wastes are sometimes found on vacant property and city lots. The hazards are covered below as a precaution. Typically, fuel oils and lubricating oils are insufficiently volatile to cause respiratory damage, but the gasoline mixes can cause symptoms if in high enough concentrations. The solvent mixes are all primary irritants and defat the skin. Routes of entry include: inhalation, ingestion, skin absorption.

EXPLOSIVE GASES:

To be measured by a combustible gas indicator if conditions warrant, i.e., confined space, otherwise concentrations of air contaminants will be kept below health hazard concentrations, thereby controlling for the explosion potential.

<u>Explosives Type(s)</u>	<u>Action Level</u>	<u>Required Actions</u>
Possibly volatiles from fuels	10% of LEL	Stop work, retreat and vent. Re-evaluate for flammability Resume work when LEL is below 10%.
Oxygen	Less than 19.5%	Stop work. Ambient O ₂ levels should be 20.8%.

Caution: L.E.L. meter must be calibrated to known toxic gas. Do not use methane calibrated meter for BTEX constituents.

C. HAZARD RECOGNITION AND EVALUATION (Cont.)

SPECIFIC ORGANIC COMPOUNDS:

Chemical Name I.P.	TLV¹/STEL³	IDLH²	Symptoms of Overexposure	Odor/Threshold
Gasoline IP=n.a.	500 ppm STEL	10,000 ppm	Dizziness, irritated eyes, nose, headache, nausea	gas/100 ppm
Petroleum Distillates IP=n.a.	500 ppm T.W.A.	10,000 ppm	Same as gasoline	gas/100 ppm
n-Hexane IP=10.17	50 ppm T.W.A.	5,000 ppm	Same as gasoline	gas/65-248 ppm
Benzene IP=9.25	<ul style="list-style-type: none"> • 10 TWA⁶ • 1 ppm PEL⁴ • 5 ppm STEL • Skin⁵ • 0.1 ppm NIOSH⁹ • 0.3 ppm NIC¹⁰ 	Human Carcinogen	Primary irritation to skin, eyes and upper respiratory tract. Brief high exposure may cause narcosis. Odor not an adequate warning.	Sweet, solventy/61 ppm
Toluene IP=8.82	<ul style="list-style-type: none"> • 100 ppm T.W.A. • 150 ppm STEL • Skin⁵ 	2,000 ppm	Same as gasoline	Mothballs/1.6 ppm
n-Heptane IP=9.9	<ul style="list-style-type: none"> • 400 ppm T.W.A. • 500 ppm STEL 	5,000 ppm	Same as gasoline	gas/330 ppm
Ethylbenzene IP=8.76	<ul style="list-style-type: none"> • 100 ppm T.W.A. • 150 ppm STEL 	2,000 ppm	Same as gasoline	gas/0.6 ppm
Xylene IP=8.44	<ul style="list-style-type: none"> • 100 ppm T.W.A. • 150 ppm STEL 	1,000 ppm	Same as gasoline	gas/20 ppm

C. HAZARD RECOGNITION AND EVALUATION (Cont.)

Chemical Name I.P.	TLV¹/STEL³	IDLH²	Symptoms of Overexposure	Odor/Threshold
1,1,1 Trichloroethane IP=11.00	350/450 ppm	1,000 ppm	Headache, dizziness, irritation to eyes.	Etherish/390 ppm
Vinyl Chloride IP=9.99	1 ppm PEL A1 Carcinogen		Weakness, abdominal pain, GI disturbance	Sweet/10 ppm
1,2 Dichloroethylene IP=9.65	200 ppm	4,000 ppm	Irritation to eyes, respiratory system, CNS depress.	Sweet/17 ppm
1,2 Dichloroethane (Ethylenedichloride) IP=11.05	1 ppm PEL/ 2 ppm Skin B2 Carcinogen	1,000 ppm	CNS depress, nausea, vomiting, dermatitis, irritation to eyes.	Sweet/26 ppm
Vinylidene chloride (1,1,Dichloroethylene)	1 ppm PEL		Skin and eye irritation.	Sweet/190 ppm
1,1,2 Trichloroethane	10 ppm Skin		Irritation to mucous membranes, CNS depress.	Sweet chloroform-like/N.A.
Trichloroethylene	50 ppm/200	1,000 ppm	Head, vertigo, tremors	Etherish/100 ppm
1,2,2 Tetrachloroethane	1 ppm PEL Skin		Nausea, vomiting, tremor in fingers	Unstated/1.5 ppm
1,1 Dichloroethane IP=11.06	100 ppm		CNS depression, skin irritation	
Tetrachloroethylene IP=9.32	25 ppm/100 ppm		Irritation to eyes, nose, throat, dizziness, nausea	Dry cleaner/47 ppm
Polynuclear aromatic hydrocarbons (dust)	0.2 mg/m ³	NA Human Carcinogen A1	Bronchitis, skin rash	

C. HAZARD RECOGNITION AND EVALUATION (Cont.)

Chemical Name I.P.	TLV ¹ /STEL ³	IDLH ²	Symptoms of Overexposure	Odor/Threshold
Lead (tetraethyl) IP=11.1	<ul style="list-style-type: none"> • 0.10 mg/m³ T.W.A. • 0.075 mg/m³ PEL • Skin⁵ 	40 mg/m ³	Insomnia, anxiety, spastic, convulsion, coma. Dust in contact with moist skin or eyes may cause itching, burning and transient redness.	Garlic
Methanol ⁸ IP=10.85	200 ppm Skin ⁵	25,000 ppm	Eye irritation, headache, nausea, blindness, if ingested.	Pungent/160 ppm

1. TLV/TWA = Threshold limit valve for an 8-hr. time weighted average (TWA) exposure.
2. IDLH = Immediately dangerous to life and health.
3. STEL = Short term exposure limit - 15 minute maximum exposure.
4. PEL = OSHA Permissible Exposure Level.
5. Skin = Can be absorbed through the intact skin.
6. NIOSH = National Institute for Occupational Safety and Health recommended control level.
7. NIC = Notice of Intended Change for 1996 TLV-TWA listing.

GENERAL ORGANIC VAPORS

Health Action Levels

Background -15
15-50 PID units in
breathing zone (petroleum vapors)
>50 PID units in breathing zone.

Required PPE Level

Level D
Level C

Suspend work and call in
(or if breakthrough occurs)

The AECOM action level for donning respiratory protection is conservative due to the possibility of an unknown contaminant.

C. HAZARD RECOGNITION AND EVALUATION (Cont.)

CONFINED SPACE: Before considering any confined space entry (trench, low-lying area, tank, etc.) where hazardous gases, fumes, mists, or an atmosphere deficient in oxygen may be encountered or other safety hazards may be realized; procedures as outlined in the Health and Safety Manual **must be explicitly followed and the AECOM Safe Work Permit and Confined Space checklist must be completed and attached to Section A of the SSP as well as the following information provided in a separate attachment:**

Types:

Work to be done:

Contaminants expected:

Required PPE level:

AECOM Confined Space Work Permit Attached

PHYSICAL HAZARDS

General Hazards

Note land features, vehicle movement, heavy equipment, noise, fire and explosion potential, pools of liquid, uneven terrain, slippery gravel, electrical hazards, welding, cutting, etc., that may create safety hazards. See AECOM Standard Safe Work Practices for contaminated sites.

Weather Related Hazards

Exposure to cold temperatures and heat stress can be hazardous to worker safety. Adverse weather conditions may be present during the scheduled time of field operations. Exposure may also be exacerbated by wearing PPE ensembles. Refer to SSP attachments for heat and cold stress which cover recognition of stress conditions, prevention, monitoring and treatment.

SPILL CONTAINMENT PROGRAM

If there is a potential for spill, a spill containment program will be included as an attachment to Section A of this SSP.

D. ON-SITE CONTROL

CONTROL BOUNDARIES:

Safe perimeter: Outside the site boundary.

Exclusion Zone: 30 feet around drill rig or 50 feet from excavation unless otherwise identified.

Contamination Reduction Zone: Adjacent to and upwind of exclusion zone. If boundaries are necessary, they will be identified by marking of zones with boundary tape, cones or other barriers.

SITE ENTRY PROCEDURES:

A site safety briefing with the Site Safety Officer will be held; any specific procedures will be explained at this time and any questions answered. Everyone must understand the plan and sign. Decon all equipment prior to arrival. Wearing Level D protection, the Site Safety Officer will walkover the site with monitoring equipment to survey and document background. As necessary, document that underground clearances have been made. Advise field crew of telephone locations. Proceed.

WORK LIMITATIONS (Time of day, heat, cold, etc.):

Daylight hours. Suspend work if it begins to rain or lightening.

The Site Safety Officer has the authority, should weather threaten, to place site activities on standby, cease operation and evacuate the site as necessary.

AIR MONITORING:

Monitoring procedures: Monitoring of breathing zones will be conducted periodically after the initial characterization; particularly when work begins in a different area of the site, new conditions or contaminants are noticed and/or when a markedly different type of operation is initiated. See General Organic Vapor-Health Action Levels and required personal protection required. Readings should be taken more frequently when elevated PID levels are measured from samples or within the breathing zone or when odors are observed. **If readings in the breathing zone exceed 50 ppm, evacuate the site vicinity, allow the area to ventilate, re-check with PID. Do not return to area unless the readings are less than 50 ppm.**

All preventive maintenance and calibration will be performed in accordance with the manufacturer's operation manual which is kept with the instrument. The instrument will be pre- and post calibrated and the span changed after each calibration check.

D. ON-SITE CONTROL (Cont.)

EXPLORATION-DERIVED MATERIAL DISPOSAL:

All sampling equipment in contact with subsurface materials shall be decontaminated before removal from site. Soil samples, if shown to possess contaminants upon laboratory analyses will be returned to the site. All contaminated auger cuttings and trench spoils should be placed on plastic sheeting or into open headed 55-gallon drums for subsequent appropriate handling and disposal.

Equipment: Plastic sheeting, 55-gallon open head drums and bags as necessary

E. PERSONAL PROTECTION

AECOM staff have received training on OSHA 29 CFR 1910.132-138 Personal Protective Equipment Standards. A hazardous assessment meeting the requirements of 29 CFR 1910.132 to identify hazards present or likely to be present which would necessitate the use of personal protective equipment was conducted by Edie Scala-Hampson, Corporate Health & Safety officer (revised February 1996).

LEVEL OF PROTECTION: A__ B__ C__ D_X

MODIFICATIONS: Level D modified will include the additional use of Tyvek. Upgrade to respirator will occur if PID levels exceed 15 units on PID.

HEAD

HARDHAT

EYE/FACE

SAFETY GLASSES/GOGGLES

FACE SHIELD

HAND - (If contact with soils)

NEOPRENE

NITRILE

OTHER

VITON

UNDERGLOVE (Nitrile or PVC)

EDMONT MONKEY GRIP (Drillers)

SILVER SHIELD OR 4H

BODY

TWO-PIECE RAINUIT, MATERIAL:

ONE-PIECE SPLASH SUIT, MATERIAL:

TYVEK SUIT

RESPIRATOR (Not required for Level D protection) Be prepared to upgrade to Level C, if necessary.

EAR - Either:

EARPLUG or EARMUFF, type: If noise level exceeds 85 dB, use hearing protection with NRR of 25 or above

FOOT

BOOTS, type: Steel-toed, boots & rubber overboot (if contamination is evident or in muddy conditions)

COMMUNICATION EQUIPMENT (Unless otherwise indicated in Section A).

Mobile Phone

Other

Visual contact at all times

Two-way radio

E. PERSONAL PROTECTION (con't)

LEVEL OF PROTECTION: A__ B__ C X D__

PID reading of 15-50 units.

HEAD

X HARDHAT

EYE/FACE

X SAFETY GLASSES/GOGGLES

__ FACE SHIELD

HAND

__ NEOPRENE

X NITRILE

__ PVC

__ VITON

X UNDERGLOVE (Nitrile or PVC)

X EDMONT WINTER MONKEY GRIP (Drillers)

__ OTHER

BODY

__ TWO-PIECE RAINSUIT, MATERIAL:

__ ONE-PIECE SPLASH SUIT, MATERIAL:

X TYVEK SUIT

__ TYVEK/SARANAX SUIT

__ TYVEK/POLYETHYLENE SUIT

__ Chemical Protective Fabric (CPF)

or as indicated on the General Summary Sheet

RESPIRATOR

If air purifying respirators are authorized, the filtering media will be appropriate for use with the involved substance at the expected concentrations. A competent individual has determined that all criteria for using this type of respiratory protection have been met.

__ SCBA (open circuit, pressure demand):

X FULL FACE RESPIRATOR, cartridge: organic vapor/HEPA filter

OR

X HALF MASK RESPIRATOR, cartridge: organic vapor/HEPA filter

__ OTHER:

EAR - Either:

X EARPLUG or EARMUFF, type: If noise level exceeds 85 dB, use hearing protection with NRR of 25 or above

FOOT

X BOOTS, type: Steel-toed, boots & rubber overboot in contaminated or muddy conditions.

No changes to the specified levels of protection shall be made without the approval of the Site Safety Officer and the Project Engineer.

E. PERSONAL PROTECTION (con't)

HEAT STRESS/COLD CONTROL

Cooling Vest and/or Gatorade

Thermal Attire for Cold

COMMUNICATION PROCEDURE

PERSONNEL IN THE "HOT ZONE" WILL REMAIN IN CONSTANT COMMUNICATION (EITHER VISUALLY OR VERBALLY) with the site safety officer at all times.

The following hand signals may be used:

Thumbs Up: O.K.; I'm all right; I understand

Thumbs down: No; negative

Hands on Top of Head: I need assistance

Grip Partner's Wrist or Both Hands Around Waist: Leave area **IMMEDIATELY!**

Hand Grasping Throat: Out of air; Can't breathe; Respirator problem

F. DECONTAMINATION PROCEDURES

PERSONNEL DECONTAMINATION:

Level D: Wash outer gloves, boots, and sampling equipment with Alconox soap and water, rinse with potable water supplied by AECOM water truck at respective borehole locations. Retain wash water in drum, if determined to be hazardous.

Remove outer gloves.

Remove inner gloves, and dispose of with the drilling material.

Wash hands and face at breaks, before eating, and prior to leaving site.

Level C: If Level C personal protection is required at the site, the contamination reduction zone will be established upwind of site activities. The decontamination will be accomplished as described.

1. Place equipment on a plastic drop cloth
2. Scrub outer boots, outer gloves, and tyvek with TSP or Alconox and water in tub. Rinse in water.
3. Remove outer boots.
4. Remove tyvek.
5. Remove outer gloves.
6. Remove respirator without touching face with gloves. Place respirator on plastic.
7. Remove inner gloves.
8. Wash face and hands.

EQUIPMENT DECONTAMINATION:

Decon boring equipment between each sampling location. Decon solution to consist of soap and water. Contain wash water in drums for appropriate handling and disposal following analyses of samples. Steam-clean rig and augers prior to leaving site. Level C protection will be worn during steam cleaning operations if contamination is encountered during site activities.

EMERGENCY DECONTAMINATION PROCEDURES:

Flush any wounds immediately and go directly to hospital for medical attention. Since the expected contaminants are not extremely hazardous, immediate decontamination will not be essential to life saving first aid procedures. If decontamination does not interfere with essential treatment, it should be performed as indicated above.

G. EMERGENCY PROCEDURES

The following standard emergency procedures will be used by on-site personnel. The Site Safety Officer shall be notified of any on-site emergencies and be responsible for ensuring that the appropriate procedures are followed.

Personnel Injury in the Exclusion Zone: Upon notification of an injury in the Exclusion Zone, the designated emergency signal shall be sounded. All site personnel shall assemble at the decontamination line. The rescue team will enter the Exclusion Zone (if required) to remove the injured person to the hotline. The Site Safety Officer should evaluate the nature of the injury, and the affected person should be decontaminated to the extent possible prior to movement to the Support Zone. The DESIGNATED FIRST AID PERSON shall initiate the appropriate first aid, and contact should be made for an ambulance and with the designated medical facility (if required). No persons shall reenter the Exclusion Zone until the cause of the injury or symptoms is determined.

Personnel Injury in the Support Zone: Upon notification of an injury in the Support Zone, the Site Safety Officer will assess the nature of the injury. If the cause of the injury and loss of the injured person does not affect the performance of site personnel, operations may continue, with the on-site designated first aid person initiating the appropriate first aid and necessary follow-up as stated above. If the injury increases the risk to others, the designated emergency signal shall be sounded and all site personnel shall move to the decontamination line for further instructions. Activities on site will stop until the added risk is removed or minimized.

Fire/Explosion: Upon notification of a fire or explosion on site, the designated emergency signal shall be sounded and all site personnel assembled at the decontamination line. The fire department shall be alerted and all personnel moved to a safe distance from the involved area.

Personnel Protective Equipment Failure: If any site worker experiences a failure or alteration of protective equipment that affects the protection factor, that person and his/her buddy shall immediately leave the Exclusion Zone. Reentry shall not be permitted until the equipment has been repaired or replaced.

Other Equipment Failure: If any other equipment on site fails to operate properly, the Project Engineer and Site Safety Officer shall be notified and then determine the effect of this failure on continuing operations on site. If the failure affects the safety of personnel or prevents completion of the assigned tasks, all personnel shall leave the Exclusion Zone until the situation is evaluated and appropriate actions taken.

G. EMERGENCY PROCEDURES (Cont.)

First Aid Measures: In the event personnel exposure symptoms occur, the following procedures will be used:

Eye Contact: Flush eye immediately with copious amounts of water. Repeat until irritation is eliminated. If prolonged irritation occurs for more than 15 minutes, seek medical attention.

Skin Contact: Wash exposed area with soap and water. If dermatitis or severe reddening occurs, seek medical attention.

Inhalation: Remove person into fresh air. If symptom occurs for more than 15 minutes, seek medical attention.

Ingestion: Do not induce vomiting. Seek immediate medical attention.

Puncture Wound-Injury : In accordance with OSHA requirements, AECOM, through the provisions of the Bloodborne Pathogen Plan, provides for a post exposure Hepatitis B vaccination **within 24 hours of possible exposure**. It is necessary that an exposure evaluation and follow-up be provided for an employee who has been exposed to an incident involving the release of blood or contact with potentially infectious materials. If the first aid responder does not consent to the Hepatitis B vaccination, this personal decision **must be in writing** with the employee's signature. See AECOM Health and Safety Manual, Section 1.5 for further details. A Supervisor Report of Injury form must be completed in addition to the Bloodborne Pathogen Exposure Control Form in Exhibit I of the AECOM Health and Safety Manual. The forms must be provided to the office safety committee member and Corporate Health and Safety Officer, Deerfield, Illinois.

When possible, site workers will refrain from administering first aid for **serious injury or illness** and await for the arrival of professional paramedics at the site to take the appropriate action. Unless they are in immediate danger, injured persons will not be moved until paramedics can attend to them. Some injuries, such as severe cuts and lacerations or burns, may require immediate treatment. Any first aid instructions that can be obtained from doctors or paramedics before an emergency-response squad arrives at the hospital will be followed closely.

The Health and Safety Plan which includes information on Chemical Hazards will be brought to the hospital, if deemed necessary.

G. EMERGENCY PROCEDURES (Cont.)

FIRST AID Equipment available:

Bloodborne pathogen kit	<u>AECOM Truck</u>
First-aid kit	<u>AECOM Truck</u>
Emergency eye wash	See Section A - (Available as required)
Emergency shower	See Section A - (Available as required)
Fire extinguisher	<u>AECOM Truck</u>

First Aid Kit Equipment List

The first aid kit(s) that are kept at the site will consist of a weatherproof container with individually sealed packages for each type of item. The kit will include at least the following items:

- Gauze roller bandages, 1 inch and 2 inch
- Gauze compress bandages, 4 inch
- Gauze pads, 2 inch
- Adhesive tape, 1 inch
- Band-aids, 1 inch
- Butterfly bandages
- Triangular bandages, 40 inch
- Ampules of ammonia inhalants
- Antiseptic applicators or swabs
- Burn dressing and sterilized towels
- Surgical scissors
- Eye dressing
- Emergency eye wash
- Emergency oxygen supply
- Tourniquet
- Alcohol
- Hydrogen peroxide

Other Emergency Equipment

One portable fire extinguisher having a rating of 2A:20B:C and one portable extinguisher having a rating of 2A, will be conspicuously and centrally located between the restricted and non-restricted zones. In addition, similar extinguishers of the same size and class will be located so that the maximum travel distance to the nearest fire extinguisher shall not exceed 500 feet. Portable extinguishers will be properly tagged indicating inspection dates and maintained in accordance with "Maintenance and Use of Portable Fire Extinguishers."

An emergency on-site, such as a fire, might require that some appropriately trained site workers direct traffic on or near the site.

G. EMERGENCY PROCEDURES (Cont.)

STEPS TO TAKE IF THERE IS AN ACCIDENT OR YOU PROVIDE FIRST AID

1. Seek first aid or emergency treatment immediately. If you render first aid and come into contact with body fluids of the victim, you must have a Hepatitis B vaccination within 24 hours or sign a form indicating that you decline the vaccination. Should the injured employee require medical attention or if paramedics are called, an AECOM staffer should accompany the paramedics to the hospital so that known details of the injury and type of accident can be described to them and hospital emergency room staff. The site safety plan should be brought along if there is reason to suspect a chemical over exposure.
2. Report the accident or first aid response, no matter how slight, to the safety officer and your supervisor. The supervisor should be called as soon as the employee that was injured has been fully cared for and/or is under the supervision of hospital staff. Your supervisor and local office medical program administrator can complete the injury report and the Bloodborne Pathogen Exposure Control Form from your verbal description of the accident. (If possible, call from the hospital or if treated on site, call from the site). Your supervisor will inform our insurance management of the accident. The Supervisor's Accident Report Form needs to be filed with the State within 24 hours, if possible.

The Regional Health Safety Officer or local medical program administrator will schedule the Hepatitis B vaccination for the first aid responder, if contact was made with body fluids.

3. If emergency treatment is required, inform the doctor or hospital that the injury is a job-related accident and provide them with the **AECOM Worker's Compensation** insurance card. All billings should be directed to AECOM, not to the insurance company.
4. The injured employee should retain a copy of all the doctor's paperwork. A doctors statement will be required prior to return to work. The doctor's report must indicate follow-up procedures that may be necessary.
5. The Regional Health Safety Officer will also investigate the accident. Any additional details should be given at this time.
 - What task was employee performing?
 - What happened?
 - What were the causes of the accident? (employee, machine, environs, etc.)
 - Describe any unsafe acts.
 - Describe any unsafe conditions, work practices or machinery.
 - List fundamental causes (lack of policy, lack of enforcement, inadequate training in safety...), if they exist.
 - What can be done to prevent a recurrence of a similar accident?
 - Has it been done (date)?

H. EMERGENCY RESOURCES

SEE A. GENERAL SUMMARY for site specific resources.

National Spill Response: 1-800-424-8802

Chemtrex: 1-800-424-9300

Hospital Emergency Routes are to be driven by AECOM personnel prior to site activities.

I. AECOM RECORDKEEPING

Records of medical clearance, respirator certification and training verification are on file with:

AECOM Consultants, Ltd.
Health and Safety Coordinator
11425 W. Lake Park Drive
Milwaukee, Wisconsin 53224

Attachments: Outline of 40 Hour Health & Safety Training
Outline of Medical Surveillance Program
AECOM Standard Safe Work Practices for Contaminated Sites
UST Safe Work Practices
Cold Stress & Heat Stress Hazards
General Drilling Safety

AECOM (NYSE: ACM) is a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental and energy. With 45,000 employees around the world, AECOM is a leader in all of the key markets that it serves. AECOM provides a blend of global reach, local knowledge, innovation, and technical excellence in delivering solutions that enhance and sustain the world's built, natural, and social environments. A *Fortune 500* company, AECOM serves clients in more than 100 countries and had revenue of \$6.1 billion during the 12-month period ended June 30, 2009. More information on AECOM and its services can be found at www.aecom.com.

AECOM
2 Technology Park Drive
Westford, Massachusetts 01886
T: +1.978.589.3000
F: +1.978.589.3100
AskEnvironment@aecom.com