Proposal to Perform In-Situ Chemical Oxidation for the Treatment of Source and Residual Contamination via Ferric Oxide Activated Persulfate and Catalyzed Hydroxyl

To

Tetra Tech

For

Hoff VC HSCA Site
334 Layfield Road
New Hanover Township, PA

March 2022

Innovative Environmental Technologies, Inc.
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February 16th, 2022

Johnathan Dziekan
Senior Project Manager
Tetra Tech, Inc.

Dear Mr. Dziekan,

Innovative Environmental Technologies Inc. (IET) has completed a remedial design and quotation for the remediation of the delineated contamination at the site, Hoff Vinyl Chloride (VC) HSCA Site, at 334 Layfield Road in New Hanover Township, Pennsylvania.

The contaminants of concern at the subject site are Volatile Organic Compounds (VOC's) and 1,4-Dioxane. As a result of IET's evaluation of the provided analytical data, monitoring well logs and data collected, IET is pleased to provide a quote utilizing an activated persulfate and catalyzed hydroxyl technology. The following proposal offers the price to implement chemical oxidation with both Sodium Persulfate activated by Ferric Oxide, and Hydrogen Peroxide activated by ferrous sulfate. The remedial design is presented as one treatment area with fourteen permanent injection well locations (IW-1-IW-6 A/B and MW-F A/B). The lump sum cost for the proposed design is The solution shall be applied under IET's United States Apparatus Patent Number 7,044,152.

The following proposal will set-forth a lump sum price for the implementation and follow up of the remedial process. All costs included in the lump sum price are listed below.

- All chemicals and materials necessary to complete the proposed plan
- All equipment and personnel required to execute the proposed plan
- Handling and Management of materials on site
- Mobilization/Demobilization of the required crews
- All per diem for the required crews
- Health and Safety Plan for the site
- Site Restoration
- Final field injection report
- Final plot of injection points
- Six data analysis reports, based on data provided by **Tetra Tech**

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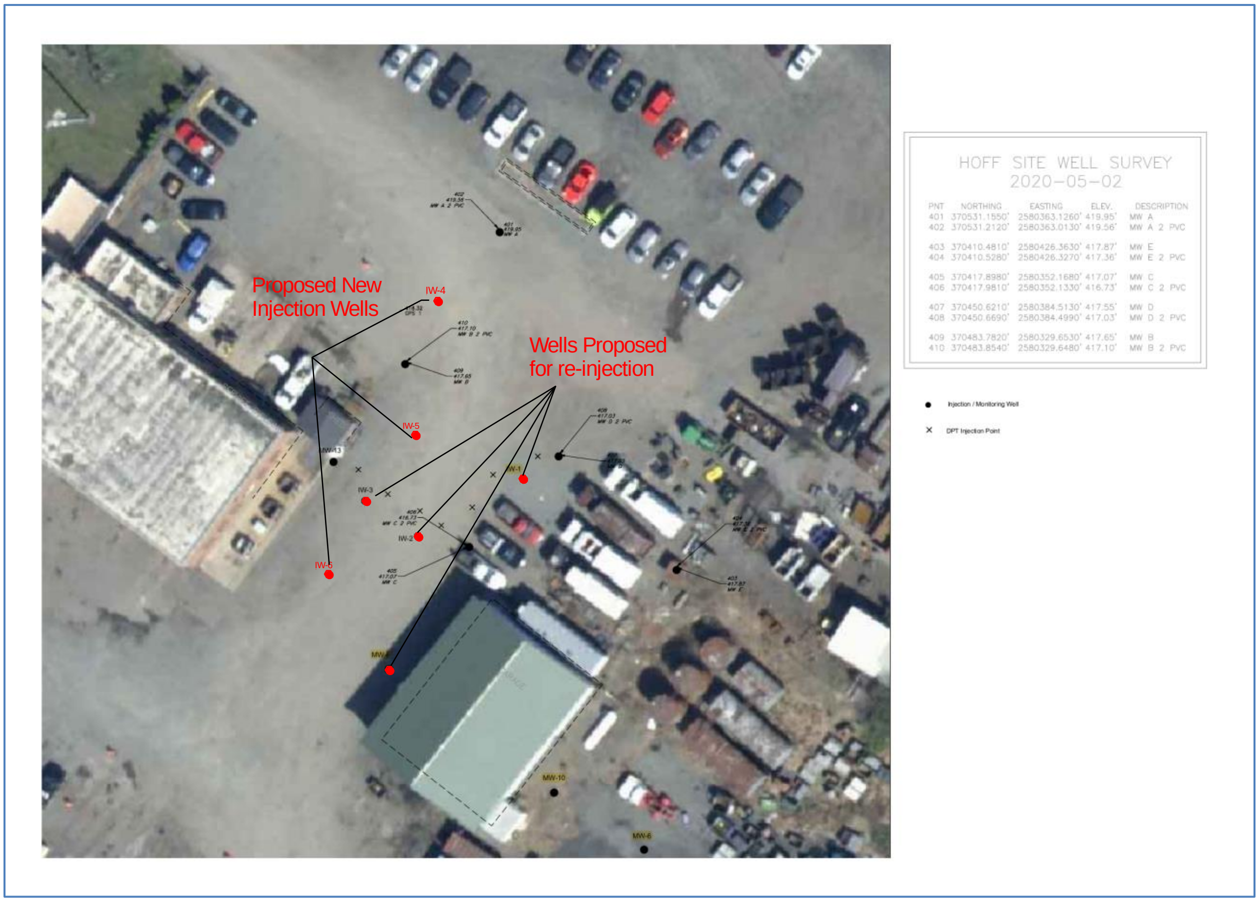
OBJECTIVE

It shall be the objective of IET to conduct a chemical oxidation event at the site located in New Hanover, PA. A unique ISCO process will be implemented in order to directly oxidize the contaminants of concern and stimulate a long lasting in-situ bioremediation process. Multiple injection wells are proposed to treat residual contamination present. The proposed and existing wells are pictured below.



TREATMENT AREA

The defined treatment area will target a 9,076 square foot area and will require 14 permanent injection well points. A 17' radius of influence is estimated across the vertical interval targeted at each injection location. The ROI is estimated based on the site's available geologic data, utilizing historic boring logs to estimate a soil porosity along with assumptions based off of pre vs. post injection groundwater data collected at other sites with similar geology. The soil Freundlich absorbsion correction is assumed moderate in order account for varied VOC's targeted and their varied partitioning characteristics to soil (IET has assumed the value to be 5%). The Freundlich equation is an adsorption isotherm that relates the concentration of a solute on the surface of an adsorbent to the concentration of the solute in a liquid. The Freundlich equation is used to determine the theoretical mass of contamination adsorbed to the soil. The mass of contaminant in the soil was determined using the soil adsorption correction (item 1). The K constant is a figure relating the capacity of the adsorbent for an adsorbate and the 1/n constant is a function of the strength of adsorption (*American Water Works Association*, Water Quality and Treatment, 1999). The Freundlich equation is listed below:

$$q_e=KC_e^{1/n}$$

The theoretical values of K and 1/n are found in the following references: (Dobbs and Cohen, 1980/Faust and Aly, 1983).

Treatment area calculations are located below in Appendix 2.

IET estimates that this injection event will take 7 day(s) to implement. The price present herein is guaranteed *regardless* of the actual field time required to implement. The lump sum pricing assumes a onsite source of water and secure storage of the amendment.

TECHNOLOGY DISCUSSION

Advanced Oxidation

Oxidation is defined as a chemical process in which electrons are transferred from an atom, ion or compound. The *in-situ* chemical oxidation process is designed to destroy organic contaminants either dissolved in groundwater, sorbed to the aquifer material, or present as free product. Oxidants most frequently used in chemical oxidation include hydrogen peroxide (H_2O_2), potassium permanganate ($KMnO_4$), persulfate ($Na_2O_8S_2$) and ozone (O_3). Peroxone, which is a combination of ozone and hydrogen peroxide, is also used. Fenton's Reagent, which is hydrogen peroxide mixed with a metal catalyst, commonly an iron catalyst, can also be used. *In-situ* chemical oxidation (ISCO) can be accomplished by introducing chemical oxidants into the soil or aquifer at a contaminated site using a variety of injection and mixing apparatuses. Normally, vertical or horizontal injection wells are used to deliver chemical oxidants. *Ex-situ* oxidation is accomplished by pumping groundwater from extraction wells and treating the groundwater above ground. In the recirculation approach, oxidants can be mixed with the extracted groundwater, which is subsequently pumped back into the aquifer through injection wells.

What are the advantages and disadvantages of chemical oxidation?

Chemical oxidation offers several advantages over other *in-situ* or *ex-situ* remediation technologies for petroleum compounds:

- The greatest advantages are the rapid treatment time and the ability to treat contaminants present at high concentrations.
- It is effective on a diverse group of contaminants and can often achieve maximum clean-up results.

What contaminants can be treated with chemical oxidation?

Common contaminants treated by chemical oxidation are amines, phenols, chlorophenols, cyanides, halogenated aliphatic compounds, mercaptans, BTEX compounds, MTBE and certain pesticides in liquid waste streams. Oxidation effectiveness depends on the organic compound.

Is chemical oxidation safe?

While the use of chemical oxidation can be quite safe if done properly, there are significant potential hazards. Most oxidants are corrosive. This means that they have the ability to burn the skin and wear away certain materials. Chemical oxidation also has some disadvantages. The disadvantages are as follows:

• Oxidation is nonselective. As such, the oxidant will not only react with the target contaminants but also with substances found in the soil that can be readily oxidized. In the case of gaseous ozone, the ozone can react with water and decompose to oxygen. Oxygen production can lead to serious problems such as the development of high pressures below the ground surface and possible explosions.

• Control of pH, temperature, and contact time is important to ensure the desired extent of oxidation.

How long does chemical oxidation take?

The time required to clean up a contaminated site using chemical oxidation is dependent on the reactivity of the contaminant with the oxidant, the size and depth of the contaminated zone, the speed and direction of groundwater flow and type of soils and the conditions present at the contaminated facility. Generally, chemical oxidation is more rapid than other treatment technologies. The time scale is usually measured in months, rather than years.

In-situ oxidation uses contact chemistry of the oxidizing agent to react with volatile organic compounds, munitions, certain pesticides and wood preservatives. The most common oxidizers used in soil and groundwater remediation are hydrogen peroxide (and the hydroxyl radical), potassium permanganate, and ozone, which are non-selective oxidizers. Other oxidants are available, but are used less due to cost, time or potential toxic by-products.

Technology Selection

Persulfate is activated by Fe III which requires a lower activation energy than alternative mechanisms while not consuming the persulfate oxidant. The chosen activation mechanism is believed to elevate the oxidation state of the iron transiently to a supercharged iron ion which in itself may act as an oxidant. As this supercharged iron cation is consumed, the resulting ferric species can act as a terminal electron acceptor for biological attenuation. Coincidentally, the generated sulfate ion from the decomposition of the persulfate provides a terminal electron acceptor for sulfate reducers which may further remediate the targeted compounds in the groundwater and soils. In addition, for the injection locations where the primary compound of concern is 1,4 dioxane catalyzed hydroxyl radicals are proposed to be injected with 2-5% hydrogen peroxide and ferrous sulfate as the injectant in order to re-create oxidizing conditions in the groundwater near these locations. The desired ISCO reactions that occur in the subsurface include persulfate radicals and ferrate, as summarized below (Equation 1):

$$S_2O_8^{-2} + Fe^{+3} \text{ ---------> } Fe^{(+4\text{ to}+6)} + SO_4^{2-} + SO_4^{2-\bullet} \qquad \text{(Eq. 1)}$$

Secondary Attenuation Processes

After dissolved oxygen has been depleted in the treatment area, sulfate (a by-product of the persulfate oxidation) may be used as an electron acceptor for anaerobic biodegradation by indigenous microbes. This process is termed sulfidogenesis and results in the production of sulfide. Stoichiometrically, each 1.0 mg/L of sulfate consumed by microbe's results in the destruction of approximately 0.21 mg/L of BTEX compounds. Sulfate can play an important role in bioremediation of petroleum products, acting as an electron acceptor in co-metabolic processes as well. For example, the basic reactions for the mineralization of benzene and toluene under sulfate reducing conditions are presented in equations 2 and 3:

$$C_6H_6 + 3.75\ SO_4^{2-} + 3\ H_2O \dashrightarrow 0.37\ H^+ + 6\ HCO_3^- + 1.87\ HS^- + 1.88\ H_2S^- \quad \text{(Eq. 2)}$$

$$C_7H_8 + 4.5\ SO_4^{2-} + 3\ H_2O \dashrightarrow 0.25\ H^+ + 7\ HCO_3^- + 2.25\ HS^- + 2.25\ H_2S^- \quad \text{(Eq. 3)}$$

Ferric iron is also used as an electron acceptor during anaerobic biodegradation of many contaminants, sometimes in conjunction with sulfate. During this process, ferric iron is reduced to ferrous iron, which is soluble in water. Hence, ferrous iron may be used as an indicator of anaerobic activity. As an example, Stoichiometrically, the degradation of 1 mg/L of BTEX results in the average consumption of approximately 22 mg/L of ferric iron (or "production" of ferrous iron) as shown below (equations 4-6).

$$C_6H_6 + 18\ H_2O + 30\ Fe^{3+} \text{------->} 6\ HCO_3 - + 30\ Fe^{2+} + 36\ H^+ \text{ (Eq. 4)}$$

$$C_7H_8 + 21\ H_2O + 36\ Fe^{3+} \text{------->} 7\ HCO_3 - + 36\ Fe^{2+} + 43\ H^+ \text{ (Eq. 5)}$$

$$C_8H_{10} + 24\ H_2O + 42\ Fe^{3+} \text{------->} 8\ HCO_3 - + 42\ Fe^{2+} + 50\ H^+ \text{ (Eq. 6)}$$

While ferrous iron is formed as a result of the use of the ferric species as a terminal electron acceptor, residual sulfate is utilized as a terminal electron acceptor by facultative organisms thereby generating sulfide under these same conditions. Together, the ferrous iron and the sulfide promote the formation of pyrite as a remedial byproduct (equation 7). This reaction combats the toxic effects of sulfide and hydrogen sulfide accumulation on the facultative bacteria, while also providing a means of removing targeted organic and inorganic COIs via precipitation reactions. Moreover, pyrite possesses a high number of reactive sites that are directly proportional to both its reductive capacity and the rate of decay for the target organics.

$$Fe^{2+} + 2S^{2-} \text{------->} FeS_2 + 2e \text{ (Eq. 7)}$$

SCOPE OF WORK

Subsurface Pathway Development

Initially, compressed air shall be delivered to the subsurface via IET proprietary injection trailer system. This process step allows for confirmation of open delivery routes while enhancing horizontal injection pathways. The confirmation of open and viable subsurface delivery pathways insures that upon introduction of the oxidizer(s) injections will occur freely thus minimizing health and safety risks associated with oxidant full injection lines and injection tooling when no subsurface delivery route has been established. Confirmation of open and free pathways is accomplished via observed pressure drops and fee moving compressed gases to the subsurface.

Oxidant Injection

A colloidal suspension of the ferric-based catalysed persulfate is immediately injected into the subsurface pathways and voids that were developed during the compressed air injection step, under constant pressure ranging from 10-110 psi. A small amount of water follows this step in order to rinse the injection equipment. IET expects the need of the liquid pressures to fall in the range of **30-75** psi in order to introduce the material into the lithology documented onsite.

Post Liquid Injection – Compressed Air Injection

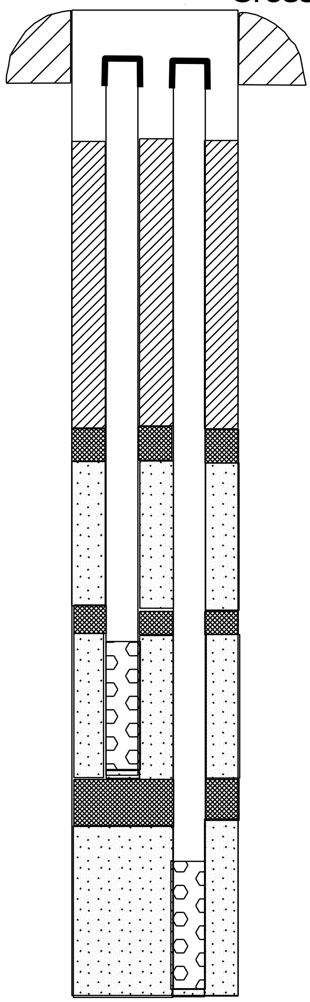
Lastly, the injection lines are cleared of liquids and all injectants are forced into the created formation and upward into the vadose zone. This step insures that all material is injected outward into the formation and minimizes any surface excursions of injectants following the release of the injection pressure. Once the injection cycle is complete, the injection point is temporarily capped to allow for the pressurized subsurface to accept the injectants.

Permanent Injection Well Injection

Similar procedure is followed when injecting into permanent injection wells, fourteen existing wells are proposed to be injected at the Hoff site, a pvc fitting will be attached to the riser and injection will be attempted across the entire well's screen. Three additional Injection wells are proposed to be installed (IW-4-IW-6) these are proposed to be screened at two isolated depths from 30-35' and 20-25'. A Construction diagram of the injection wells is included below. The new wells will be installed using 4.25" HSA and 3.75" air rotary to depth once HSA refusal is encountered. Pricing for installation of two additional monitoring wells is also included in this proposal.

Nested Injection Well Construction Details
Flush Grade Manhole
Cross Sectional View

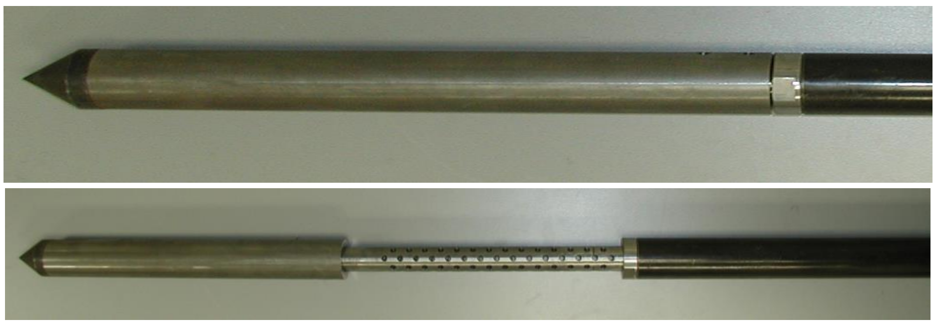
Threaded Well Cap



Concrete Pad	
Pad Dimentions	2 feet x 2 feet
Hieght Above Ground	flush mounted
Well Casing(s)	
Material	sch 80 PVC
Diameter	1 inch
Joint Type	Coupling(s)
Length	20, 30 feet
Backfill Around Casing(s)	
Material	cement-sand grout
Thickness	19 feet
Seal(s)	
Type of Seal	Bentonite
Thickness	1 foot min.
Filter Pack(s)	
Type of Filter	Pea Gravel
Distance Above Screen	6 inch min
Well Screens	
Screen Material	sch 80 PVC
Diameter	1 inch
Length	5 feet
Perforated	3/32 inches
Depth to Bottom of Injection Wells	25, 35 feet
Depth to Bottom of Borehole	35 feet
Diameter of Borehole	3-6 inches

Equipment Description

The injections shall occur via IET's mobile injection trailer and permanent injection wells as described. The injection lines are composed of the following: stainless steel fittings, Viton seals, chemical resistant one inch and ¾ inch diameter hose. The patented injection system includes: two 200 gallon conical tanks capable of maintaining 30% solids as a suspension via lightning mixers; on-board generator, all stainless steel tig welded piping, 2" pneumatic diaphragm pump with an operating pressure of 110 psi.; on-board 25 CFM/175 psig compressor with 120 gallons of air storage; self-contained eye wash and safety shower. IET proprietary injection rods with retractable injection zones and backflow protection Injection zones of 18 inches are to be used in combination with 24" injection AWJ-Rods where appropriate.



<u>Well Installation Equipment – AMS 9500 Series Track Rig</u>

IET plans to use a 9500 Series AMS DPT rig to io install the permanent injection wells. This unit can be viewed below.

IET INJECTION SYSTEM
UNITED STATES PATENT 7,044,152

Injection Trailers Include: Multiple Liquid Feed Systems, Stainless Steel Piping, Isolated Compressed Gas Containment, Safety Shower, Eyewash Station, Onboard Generator, Chemical Resistant Construction, Mobile Office Space

SUMMARY

Innovative Environmental Technologies, Inc. presents this proposal with one treatment area. It is estimated to cost . It is assumed that it will take 7.**0** days to complete the remedial program. The lump sum price is independent of the amount of time that the injection event takes.

Treatment Areas	Area (FtXFt)	Mass of Soil/BR (tons)	Lbs FeO/Persulfate	Gallons 50% H2O2	Lbs FeSO4	Injection Pts	Days
IW-A	907	403.32	0	12	23	1	0.2
IW-B	907	403.32	0	18	23	1	0.2
IW-2A	907	403.32	0	26	23	1	0.2
IW-3A	907	403.32	0	26	23	1	0.2
IW-3B	908	403.32	0	26	23	1	0.2
IW-2b	908	403.32	770	0	0	1	0.25
New Wells	3,630	3,226.67	4,070	0	0	8	2.75
Total	9,076	5,646.56	4,840	107	115	14	4

Line Items	Unit
Well Installation	LS
Materials Handling and Forklift Rental	1
Hazmat Shipping	LS
Per Diem (2 man Crew)	7
Private Utility Markout	0.5
Administrative and Reporting Cost	LS
Total Project Cost	

All Prices Quoted are Valid for 60 Days from the Date on Proposal

APPENDICES

APPENDIX 1: SITE MAP

Injection / Monitoring Well

DPT Injection Point

HOFF SITE WELL SURVEY 2020-05-02

PNT	NORTHING	EASTING	ELEV.	DESCRIPTION
401	370531.1550'	2580363.1260'	419.95'	MW A
402	370531.2120'	2580363.0130'	419.56'	MW A 2 PVC
403	370410.4810'	2580426.3630'	417.87'	MW E
404	370410.5280'	2580426.3270'	417.36'	MW E 2 PVC
405	370417.8980'	2580352.1680'	417.07'	MW C
406	370417.9810'	2580352.1330'	416.73'	MW C 2 PVC
407	370450.6210'	2580384.5130'	417.55'	MW D
408	370450.6690'	2580384.4990'	417.03'	MW D 2 PVC
409	370483.7820'	2580329.6530'	417.65'	MW B
410	370483.8540'	2580329.6480'	417.10'	MW B 2 PVC

APPENDIX 2: DOSAGE CALCULATIONS

PERMANENT WELL CALCULATIONS

Tetratech-Hoff VC, PA				
Pilot Area		**Saturated Zone**		
IW-A				
Parameters	**Units**	**Assumptions**		
Target Area	Ft.X Ft.	907.46		
Injection Radii	Ft	17		
Soil Absorbsion Correction for GAC Constant	%	5		
Area of influence of Remediation Injection(s)	Sq. Ft.	907.91951		
Estimated Number of Injections to Treat Area	# Injections	1		
vertical impacted zone	Ft.	10		
Target Zone		15-25'		
Total Volume Targeted	Cu. Yd.	336.0962963		
Porosity	%	20.00%		
Mass of soil to be targeted	lbs	806631.1111		
Mass of soil to be targeted	grams	366210524.4		
Volume of Groundw ater targeted	gals	13611.9		
Contaminant Conc.	ppm	0.06	**Calculations Targeted Compounds**	
Mass of Contaminant - w ater	lb.	0.006819562	Ave Mol Mass of Targeted Compounds g/mol	95
Mass of Contaminant -w ater	Grams	**3.096081103**	**Moles**	**7.345584531**
Mass of Contaminant -soil	lb.	1.530252091	Mole Mass of H2O2	34
Mass of Contaminant -soil	Grams	**694.7344494**	**Moles of H2O2**	**820.9770947**
Mass of Contaminent Targeted	Grams	**697.8305305**	Mole Mass of Persulfate	**238**
Mass of Contaminent Targeted	lbs	**1.537071653**	**Moles of Na2S2O8**	**212.9702545**
Calculated soil conc.	ppm	**1.905544718**		
Grams of H2O2 Required	Grams	27913.22122		
Lbs of H2O2 Required	lbs	**61.48286612**		
Targeted percentage of FeSO4 in solution	%	**0.02%**	**H2O2**	**111.76**
Pounds of FeSO4 required	pounds	23	**Na2S2O8**	**28.99**
Injection Summary				
Number of Injection Locations		**1.00**		
Injection Depth		**15-25'**		
Pounds of FeSO4		**23.00**		
Galons of 50% H2O2		**11.71**		
Injection Point Summary - Number of Intervals		**1.00**		
Injection Zones	**20-25'**			
Pounds of FeSO4 per interval		**23**		
Gallons of 2% H2O2 per interval		**293**		
Cost Basis Per injection Event				
Cost Basis Event #1		**$/Unit**		
Pounds of FeSO4 required	**23.00**			
Gallons of 50% H2O2 Required	**12.00**			
Number of Injection Points per Event	**1.00**			
Days of Injection Trailer and Rig	**0.2**			
Material Cost (Including on-site management etc)				
Total				

Tetratech-Hoff VC, PA				
Pilot Area		**Saturated Zone**		
IW-B				
Parameters	**Units**	**Assumptions**		
Target Area	Ft.X Ft.	907.46		
Injection Radii	Ft	17		
Soil Absorbsion Correction for GAC Constant	%	5		
Area of influence of Remediation Injection(s)	Sq. Ft.	907.91951		
Estimated Number of Injections to Treat Area	# Injections	1		
vertical impacted zone	Ft.	10		
Target Zone		25-35'		
Total Volume Targeted	Cu. Yd.	336.0962963		
Porosity	%	20.00%		
Mass of soil to be targeted	lbs	806631.1111		
Mass of soil to be targeted	grams	366210524.4		
Volume of Groundw ater targeted	gals	13611.9		
Contaminant Conc.	ppm	0.2	**Calculations Targeted Compounds**	
Mass of Contaminant - w ater	lb.	0.022731873	Ave Mol Mass of Targeted Compounds g/mol	95
Mass of Contaminant -w ater	Grams	**10.32027034**	**Moles**	**11.22741175**
Mass of Contaminant -soil	lb.	2.3266164	Mole Mass of H_2O_2	34
Mass of Contaminant -soil	Grams	**1056.283845**	**Moles of H_2O_2**	**1254.828372**
Mass of Contaminent Targeted	Grams	**1066.604116**	Mole Mass of Persulfate	**238**
Mass of Contaminent Targeted	lbs	**2.349348273**	**Moles of $Na_2S_2O_8$**	**325.5159242**
Calculated soil conc.	ppm	**2.912543591**		
Grams of H_2O_2 Required	Grams	42664.16463		
Lbs of H_2O_2 Required	lbs	**93.97393091**		
Targeted percentage of $FeSO_4$ in solution	%	**0.02%**	**H_2O_2**	**111.76**
Pounds of $FeSO_4$ required	pounds	23	**$Na_2S_2O_8$**	**28.99**
Injection Summary				
Number of Injection Locations		**1.00**		
Injection Depth		**25-35'**		
Pounds of $FeSO_4$		**23.00**		
Galons of 50% H_2O_2		**17.90**		
Injection Point Summary - Number of Intervals		**1.00**		
Injection Zones	**30-35'**			
Pounds of $FeSO_4$ per interval		**23**		
Gallons of 4% H_2O_2 per interval		**224**		
Cost Basis Per injection Event				
Cost Basis Event #1				
Pounds of $FeSO_4$ required	**23.00**			
Gallons of 50% H_2O_2 Required	**18.00**			
Number of Injection Points per Event	**1.00**			
Days of Injection Trailer and Rig	**0.2**			
Material Cost (Including on-site management etc)				
Total				

Tetratech-Hoff VC, PA				
Pilot Area		**Saturated Zone**		
IW-2A				
Parameters	**Units**	**Assumptions**		
Target Area	Ft.X Ft.	907.46		
Injection Radii	Ft	17		
Soil Absorbsion Correction for GAC Constant	%	5		
Area of influence of Remediation Injection(s)	Sq. Ft.	907.91951		
Estimated Number of Injections to Treat Area	# Injections	1		
vertical impacted zone	Ft.	10		
Target Zone		15-25'		
Total Volume Targeted	Cu. Yd.	336.0962963		
Porosity	%	20.00%		
Mass of soil to be targeted	lbs	806631.1111		
Mass of soil to be targeted	grams	366210524.4		
Volume of Groundw ater targeted	gals	13611.9		
Contaminant Conc.	ppm	0.55	**Calculations Targeted Compounds**	
Mass of Contaminant - w ater	lb.	0.062512651	Ave Mol Mass of Targeted Compounds g/mol	95
Mass of Contaminant -w ater	Grams	**28.38074344**	**Moles**	**16.10921574**
Mass of Contaminant -soil	lb.	3.308358485	Mole Mass of H2O2	34
Mass of Contaminant -soil	Grams	**1501.994752**	**Moles of H2O2**	**1800.44176**
Mass of Contaminent Targeted	Grams	**1530.375496**	Mole Mass of Persulfate	**238**
Mass of Contaminent Targeted	lbs	**3.370871136**	**Moles of Na2S2O8**	**467.0538829**
Calculated soil conc.	ppm	**4.178950067**		
Grams of H2O2 Required	Grams	61215.01983		
Lbs of H2O2 Required	lbs	**134.8348454**		
Targeted percentage of FeSO4 in solution	%	**0.02%**	**H2O2**	**111.76**
Pounds of FeSO4 required	pounds	23	**Na2S2O8**	**28.99**
Injection Summary				
Number of Injection Locations		**1.00**		
Injection Depth		**15-25'**		
Pounds of FeSO4		**23.00**		
Galons of 50% H2O2		**25.68**		
Injection Point Summary - Number of Intervals		**1.00**		
Injection Zones	**20-25'**			
Pounds of FeSO4 per interval		**23**		
Gallons of 5% H2O2 per interval		**257**		
Cost Basis Per injection Event				
Cost Basis Event #1				
Pounds of FeSO4 required	**23.00**			
Gallons of 50% H2O2 Required	**26.00**			
Number of Injection Points per Event	**1.00**			
Days of Injection Trailer and Rig	**0.2**			
Material Cost (Including on-site management etc)				
Total				

Tetratech-Hoff VC, PA				
Pilot Area		**Saturated Zone**		
IW-3A				
Parameters	**Units**	**Assumptions**		
Target Area	Ft.X Ft.	907.46		
Injection Radii	Ft	17		
Soil Absorbsion Correction for GAC Constant	%	5		
Area of influence of Remediation Injection(s)	Sq. Ft.	907.91951		
Estimated Number of Injections to Treat Area	# Injections	1		
vertical impacted zone	Ft.	10		
Target Zone		15-25'		
Total Volume Targeted	Cu. Yd.	336.0962963		
Porosity	%	20.00%		
Mass of soil to be targeted	lbs	806631.1111		
Mass of soil to be targeted	grams	366210524.4		
Volume of Groundwater targeted	gals	13611.9		
Contaminant Conc.	ppm	0.55	**Calculations Targeted Compounds**	
Mass of Contaminant - water	lb.	0.062512651	Ave Mol Mass of Targeted Compounds g/mol	95
Mass of Contaminant -water	Grams	**28.38074344**	**Moles**	**16.10921574**
Mass of Contaminant -soil	lb.	3.308358485	Mole Mass of H2O2	34
Mass of Contaminant -soil	Grams	**1501.994752**	**Moles of H2O2**	**1800.44176**
Mass of Contaminent Targeted	Grams	**1530.375496**	Mole Mass of Persulfate	**238**
Mass of Contaminent Targeted	lbs	**3.370871136**	**Moles of Na2S2O8**	**467.0538829**
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Grams of H2O2 Required	Grams	61215.01983		
Lbs of H2O2 Required	lbs	**134.8348454**		
Targeted percentage of FeSO4 in solution	%	**0.02%**	**H2O2**	**111.76**
Pounds of FeSO4 required	pounds	23	**Na2S2O8**	**28.99**
Injection Summary				
Number of Injection Locations		**1.00**		
Injection Depth		**15-25'**		
Pounds of FeSO4		**23.00**		
Galons of 50% H2O2		**25.68**		
Injection Point Summary - Number of Intervals		**1.00**		
Injection Zones	**20-25'**			
Pounds of FeSO4 per interval		**23**		
Gallons of 5% H2O2 per interval		**257**		
Cost Basis Per injection Event				
Cost Basis Event #1				
Pounds of FeSO4 required	**23.00**			
Gallons of 50% H2O2 Required	**26.00**			
Number of Injection Points per Event	**1.00**			
Days of Injection Trailer and Rig	**0.2**			
Material Cost (Including on-site management etc)				
Total				

Tetratech-Hoff VC, PA						
Pilot Area		**Saturated Zone**				
IW-3B						
Parameters	**Units**	**Assumptions**				
Target Area	Ft.X Ft.	907.46				
Injection Radii	Ft	17				
Soil Absorbsion Correction for GAC Constant	%	5				
Area of influence of Remediation Injection(s)	Sq. Ft.	907.91951				
Estimated Number of Injections to Treat Area	# Injections	1				
vertical impacted zone	Ft.	10				
Target Zone		25-35'				
Total Volume Targeted	Cu. Yd.	336.0962963				
Porosity	%	20.00%				
Mass of soil to be targeted	lbs	806631.1111				
Mass of soil to be targeted	grams	366210524.4				
Volume of Groundwater targeted	gals	13611.9				
Contaminant Conc.	ppm	0.55	**Calculations Targeted Compounds**			
Mass of Contaminant - water	lb.	0.062512651	Ave Mol Mass of Targeted Compounds g/mol	95		
Mass of Contaminant -water	Grams	**28.38074344**	**Moles**	**16.10921574**		
Mass of Contaminant -soil	lb.	3.308358485	Mole Mass of H2O2	34		
Mass of Contaminant -soil	Grams	**1501.994752**	**Moles of H2O2**	**1800.44176**		
Mass of Contaminent Targeted	Grams	**1530.375496**	Mole Mass of Persulfate	**238**		
Mass of Contaminent Targeted	lbs	**3.370871136**	**Moles of Na2S2O8**	**467.0538829**		
Calculated soil conc.	ppm	**4.178950067**				
Grams of H2O2 Required	Grams	61215.01983				
Lbs of H2O2 Required	lbs	**134.8348454**				
Targeted percentage of FeSO4 in solution	%	**0.02%**	**H2O2**	**111.76**		
Pounds of FeSO4 required	pounds	23	**Na2S2O8**	**28.99**		
Injection Summary						
Number of Injection Locations		**1.00**				
Injection Depth		**25-35'**				
Pounds of FeSO4		**23.00**				
Galons of 50% H2O2		**25.68**				
Injection Point Summary - Number of Intervals		**1.00**				
Injection Zones	**30-35'**					
Pounds of FeSO4 per interval		**23**				
Gallons of 5% H2O2 per interval		**257**				
Cost Basis Per injection Event						
Cost Basis Event #1						
Pounds of FeSO4 required	**23.00**					
Gallons of 50% H2O2 Required	**26.00**					
Number of Injection Points per Event	**1.00**					
Days of Injection Trailer and Rig	**0.2**					
Material Cost (Including on-site management etc)						
Total						

Tetratech						
Hoff VC Site Montco PA		**Saturated Zone**				
IW-2b						
Parameters	**Units**	**Assumptions**				
Target Area	Ft.X Ft.	907.46				
Injection Radii	Ft	17				
Soil Absorbsion Correction for GAC Constant	%	5				
Area of influence of Remediation Injection(s)	Sq. Ft.	907.9				
Estimated Number of Injections to Treat Area	# Injections	1				
vertical impacted zone	Ft.	10				
Target Zone		25-35'				
Total Volume Targeted	Cu. Yd.	336				
Porosity	%	20.00%				
Mass of soil to be targeted	lbs	8.07E+05				
Mass of soil to be targeted	grams	3.66E+08				
Volume of Groundwater targeted	gals	1.36E+04				
		TVOCs				
Contaminant Conc.	ppm	30		**Calculations Targeted Compounds**		
Mass of Contaminant - water	lb.	3.4		Ave Mol Mass of Targeted Compounds g/mol	92	
Mass of Contaminant -water	Grams	**1548.0**		**Moles**	**82.9**	
Mass of Contaminant -soil	lb.	13.4		Mole Mass of H2O2	34	
Mass of Contaminant -soil	Grams	**6081.6**		**Moles of H2O2**	**#REF!**	
Mass of Contaminent Targeted	Grams	**7629.6**		Mole Mass of Persulfate	**238**	
Mass of Contaminent Targeted	lbs	**16.8**		**Moles of Na2S2O8**	**1205.4**	
Calculated soil conc.	ppm	**20.8**				
Ratio of S2O3 to targeted Compouns	Ratio	**20**				
Grams of sodium persulfate	grams	**152591.9**		**Molar Ratio Calc**		
Pounds of Sodium Persulfate Required	Pounds	**336.1**		**Targeted Compounds**	**1**	
Allocation per compound (persulfate)	%	**100.0%**				
Total Pounds of Sodium Persulfate Required	Pounds	**336.1**				
Decomposition Rate of Sodium Persulfate	%/day	1.10%				
Targeted Longevity of Persulfate	days	80				
Total Persulfate Calcualted dosage	pounds	632				
Total Pounds of Ferric Oxide Required	Pounds	**63**				
Injection Summary						
Number of Injection Locations		**1**				
Injection Depth		**30-35'**				
Pounds of Persulfate		**700**				
Pounds of Ferric Oxide		**70**				
Pounds of Persulfate/Ferric Oxide		**770**				
Minimum Pounds of MgO						
Actual Pounds of MgO		**0**				
Injection Point Summary - Number of Intervals		**1**				
Injection Zones		**30-35'**				
Pounds of Sodium Persulfate w/ longevity	**per well**	**700**		**Gallons of Water needed (area)**	**400**	
Pounds of Ferric Oxide	**per well**	**70**				
Pounds of Persulfate/Ferric	**per well**	**770**				
Cost Basis Summary	**Units**					
Pounds of Persulfate/Ferric Oxide	**770**					
Number of Injection Points per Event	**1**					
Days of Injection Trailer (3 Man Crew)	**0.25**					

Tetratech					
Hoff VC Site Montco PA		**Saturated Zone**			
New Wells					
Parameters	**Units**	**Assumptions**			
Target Area	Ft.X Ft.	3630			
Injection Radii	Ft	17			
Soil Absorbsion Correction for GAC Constant	%	5			
Area of influence of Remediation Injection(s)	Sq. Ft.	907.9			
Estimated Number of Injections to Treat Area	# Injections	4			
vertical impacted zone	Ft.	20			
Target Zone		15-35			
Total Volume Targeted	Cu. Yd.	2689			
Porosity	%	20.00%			
Mass of soil to be targeted	lbs	6.45E+06			
Mass of soil to be targeted	grams	2.93E+09			
Volume of Groundwater targeted	gals	1.09E+05			
		TVOCs			
Contaminant Conc.	ppm	15		**Calculations Targeted Compounds**	
Mass of Contaminant - water	lb.	13.6		Ave Mol Mass of Targeted Compounds g/mol	92
Mass of Contaminant -water	Grams	**6192.4**		**Moles**	**482.2**
Mass of Contaminant -soil	lb.	84.1		Mole Mass of H2O2	34
Mass of Contaminant -soil	Grams	**38173.6**		**Moles of H2O2**	**#REF!**
Mass of Contaminent Targeted	Grams	**44366.0**		Mole Mass of Persulfate	**238**
Mass of Contaminent Targeted	lbs	**97.7**		**Moles of Na2S2O8**	**7009.1**
Calculated soil conc.	ppm	**15.1**			
Ratio of S2O3 to targeted Compouns	Ratio	**20**			
Grams of sodium persulfate	grams	**887321.0**		**Molar Ratio Calc**	
Pounds of Sodium Persulfate Required	Pounds	**1954.5**		**Targeted Compounds**	**1**
Allocation per compound (persulfate)	%	**100.0%**			
Total Pounds of Sodium Persulfate Required	Pounds	**1954.5**			
Decomposition Rate of Sodium Persulfate	%/day	1.10%			
Targeted Longevity of Persulfate	days	80			
Total Persulfate Calcualted dosage	pounds	3674			
Total Pounds of Ferric Oxide Required	Pounds	**367**			
Injection Summary					
Number of Injection Locations		**4**			
Injection Depth		**20-35'**			
Pounds of Persulfate		**3700**			
Pounds of Ferric Oxide		**370**			
Pounds of Persulfate/Ferric Oxide		**4070**			
Minimum Pounds of MgO					
Actual Pounds of MgO		**0**			
Injection Point Summary - Number of Intervals		**2**			
Injection Zones		**20-25', 30-35'**			
Pounds of Sodium Persulfate w/ longevity	**per well**	**463**		**Gallons of Water needed (area)**	**2400**
Pounds of Ferric Oxide	**per well**	**46**			
Pounds of Persulfate/Ferric	**per well**	**509**			
Cost Basis Summary	**Units**				
Pounds of Persulfate/Ferric Oxide	**4070**				
Number of Injection Points per Event	**4**				
Days of Injection Trailer (3 Man Crew)	**2.75**				

INJECTION WELL INSTALLATION

	Area (FtXFt)	Mass of Soil/BR (tons)	Lbs FeO/Persulfate	Gallons 50% H2O2	Lbs FeSO4	Injection Pts	Days
Treatment Areas							
IW-A	907	403.32	0	12	23	1	0.2
IW-B	907	403.32	0	18	23	1	0.2
IW-2A	907	403.32	0	26	23	1	0.2
IW-3A	907	403.32	0	26	23	1	0.2
IW-3B	908	403.32	0	26	23	1	0.2
IW-2b	908	403.32	770	0	0	1	0.25
New Wells	3,630	3,226.67	4,070	0	0	8	2.75
Total	9,076	5,646.56	4,840	107	115	14	4

Line Items	Unit
Well Installation	LS
Materials Handling and Forklift Rental	1
Hazmat Shipping	LS
Per Diem (2 man Crew)	7
Private Utility Markout	0.5
Administrative and Reporting Cost	LS
Total Project Cost	