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Remediation Technologies

Chemical Treatments

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Overview

- The Chemistries
- Implementation
- Case Study
- Variables on Pricing

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Chemical Approaches

- Chemical Oxidation
- Reductive Dechlorination
- Metal Stabilization
- Bioremediation

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Chemical Oxidation

Oxidation involves breaking apart the chemical bonds and removing electrons

The “Oxidant” is the “Electron Acceptor”, and is chemically reduced by the reaction

Chemicals with double bonds are most readily oxidized

Strong oxidants attack a wider range of bonds

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The Oxidation Chemistries

- Hydrogen Peroxide with Acid Water (pH dependent)
- Sodium Persulfate
- Ozone
- Permanganate (not pH dependent)
- Fenton's Reagent (pH dependent)

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Potassium Permanganate

- Comes in a powder form
- Soluble up to 6%
- Reality in the field is approximately 1% to 3%
- Is not pH dependent
- By-product is manganese dioxide

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Sodium Permanganate

- Shipped in liquid form of 40%
- Common use in the field is from 2% to 15%
- By-product is manganese dioxide and is not pH dependent

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Permanganate

- Chlorinated solvents (mainly ethenes)
- Phenols
- Sulfides
- Explosives

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Persulfate

- Produced in powder form
- Utilized from 1% to 40% solution in the field
- Is not pH dependent
- Can be catalyzed with heat, transitional metals, other oxidants, and chelated iron

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Fenton's / H_2O_2

- Hydrogen Peroxide is produced in a liquid form
- Common use in the field is from 2% to 25%
- Is pH dependent and is catalyzed with transitional metals, and chelated iron

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Ozone

- Ozone is available in a gas
- Degrades to dissolved oxygen
- Reacts with water and hydrogen peroxide to produce hydroxyl-radicals
- Produced on site by an ozone generator

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Persulfate / Fenton's / Ozone

- Chlorinated Solvents
- BTEX
- Napthalenes
- Explosives
- Coal tars

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Oxidation Potentials

Compound	Oxidation Potential
Fluorine	3.03
Hydroxyl radical	2.80
Sulfate Radical	2.60
Ozone	2.07
Sodium Persulfate	2.01
Peroxide	1.78
Permanganate	1.68
Hypochlorite	1.55
Chlorine	1.36

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Reductive Dechlorination

Chemical

- Zero Valent Iron
  (dechlorinates chlorinated compounds)

Biological

- Lactic Acid
- Soy Bean Oil
- Combinations

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Reductive Dechlorination

Chemical

- Zero Valent Iron
- Catalyzed zero valent

  - Aluminum sulfate and acetic acid are used as the catalyzer

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Treatment Example

Treatments (ppm)	Initial	1 d	14 d	28 d	90 d Mixed
Control (Moist)	1,813	1,976	1,766	1,638	1,522
Iron	1,789	972	769	537	504
Iron + Acetic Acid	1,740	403	219	162	90
Iron + $Al_2(SO_4)_3$	1,656	82	40	103	40
Iron + AA + $Al_2(SO_4)_3$	1,402	65	41	34	13

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Reductive Dechlorination

Biological

- Soy Bean Oil
- Lactic Acid
- Combinations

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Reductive Dechlorination

Example Products

- EOS™
- Engineered Soy Bean Oil
- HRC®

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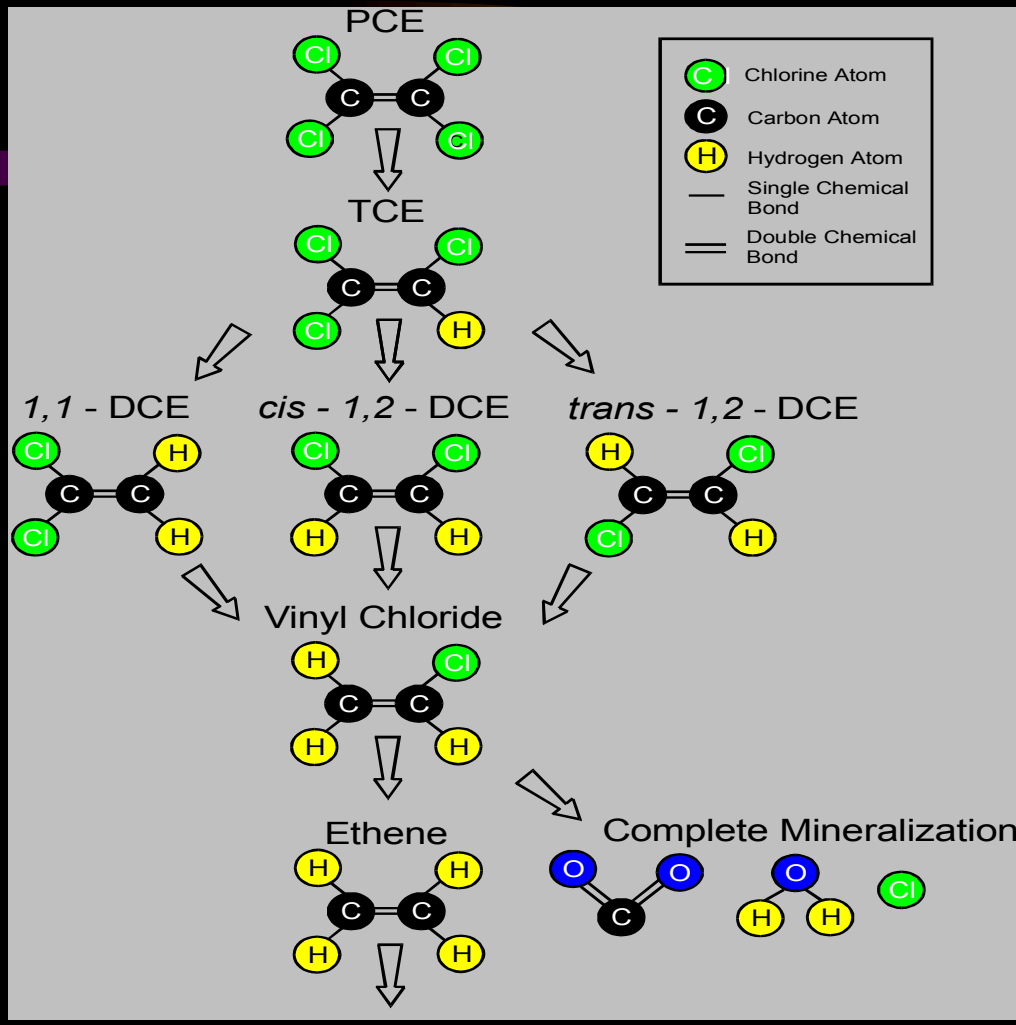
Reductive Dechlorination

Soybean Oil ($C_{18}H_{32}O_2$) ferments to H_2 and simple organics

$$C_{18}H_{32}O_2 + 34\ H_2O \rightarrow$$
$$\rightarrow 18\ CO_2 + 50\ H_2$$

H_2 and simple organics

- Consume oxygen
- Drive dechlorination



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Heavy Metals

- Phosphates (TSP, Enviroblend)
- Fly Ash
- Sulfates
- Ferrous

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Bioremediation

- Calcium Peroxide (PermeOx® Plus)
  Slow release oxygenating compound

- Magnesium Peroxide (ORC®)
  Slow release oxygenating compound

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PermeOx® Plus Versus ORC®

	PermeOx® Plus	ORC®
ctive Oxygen	17%	10%
H	10.5-11.8	10.5 – 11.5
olubility	Slightly	Insoluble
mount needed per ound of hydrocarbon	133 lbs (60 kg)	244 lbs (111 kg)
ost per pound (compound)	$8.00 (US)	$11.00 (US)
ost per pound of O_2 delivered	$44 (US)	$110 (US)

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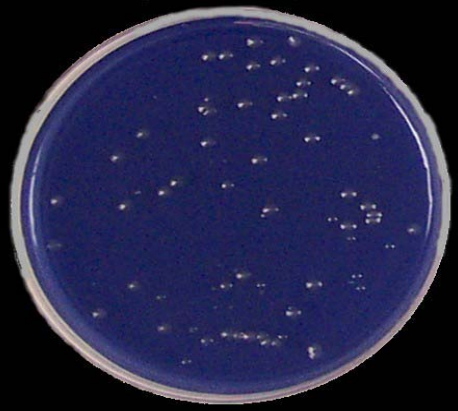
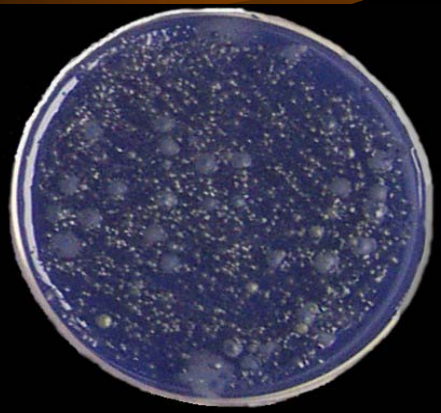
Bacterial Plates



Control

ORC® Magnesium-Based Product



PermeOx®Plus Calcium Based Product

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Implementation Processes

Ex situ

- Above ground treatment of contaminants

In situ

- In place treatment of contaminants

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Ex situ Methodologies

Ex situ treatment of soil and groundwater

- Pugmill/Backhoe/Soil Tilling
  - ➢ used to mix soil with oxidants or metal treatment
- Frac tanks
  - ➢ used to mix groundwater with oxidants

Advantages

- Treat contaminants on-site
- Reduce liability (no hazardous waste landfilling)

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Ex-Situ Application

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Current In situ *Methodologies*

- Diffusion method
- Dispersion method

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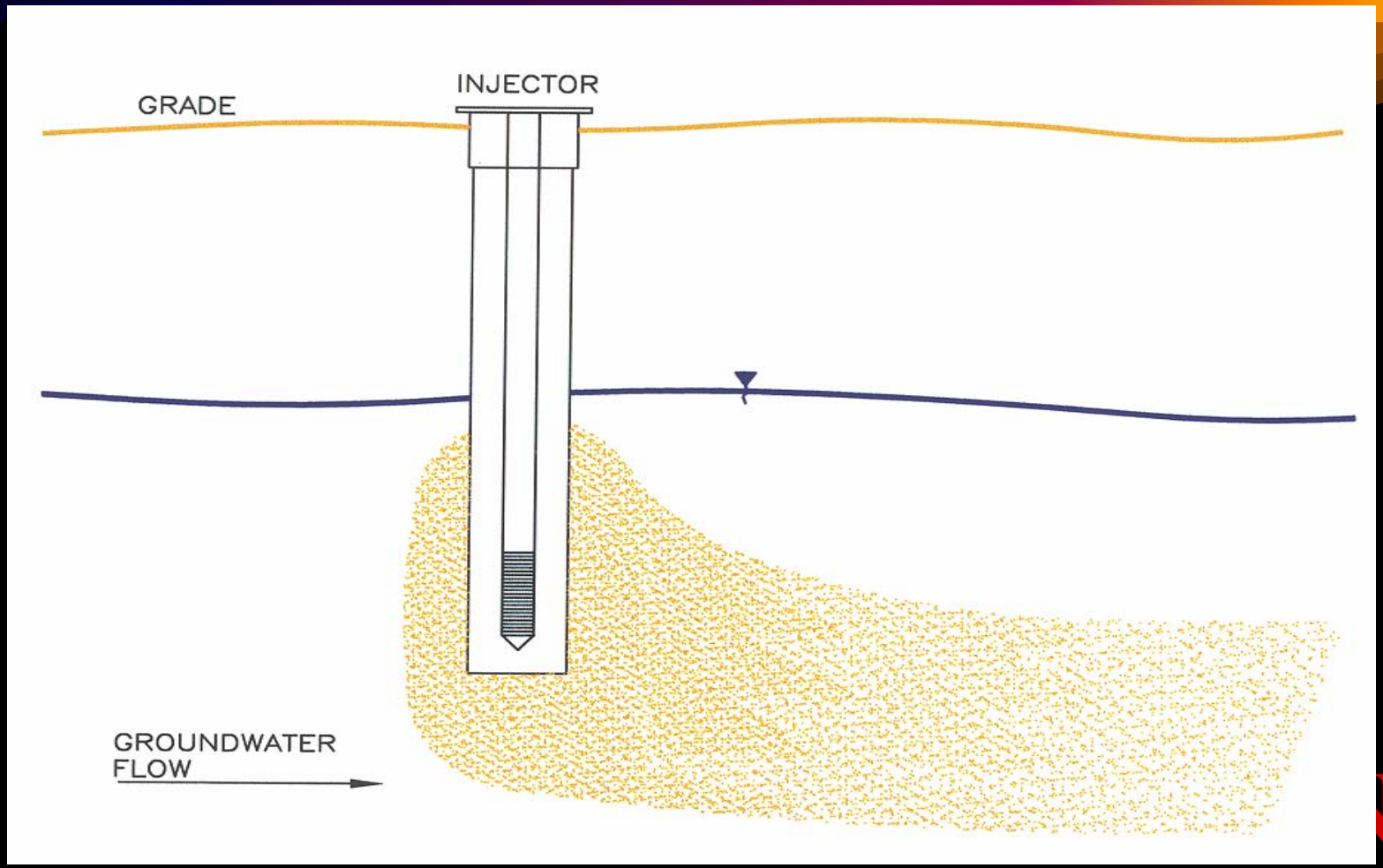
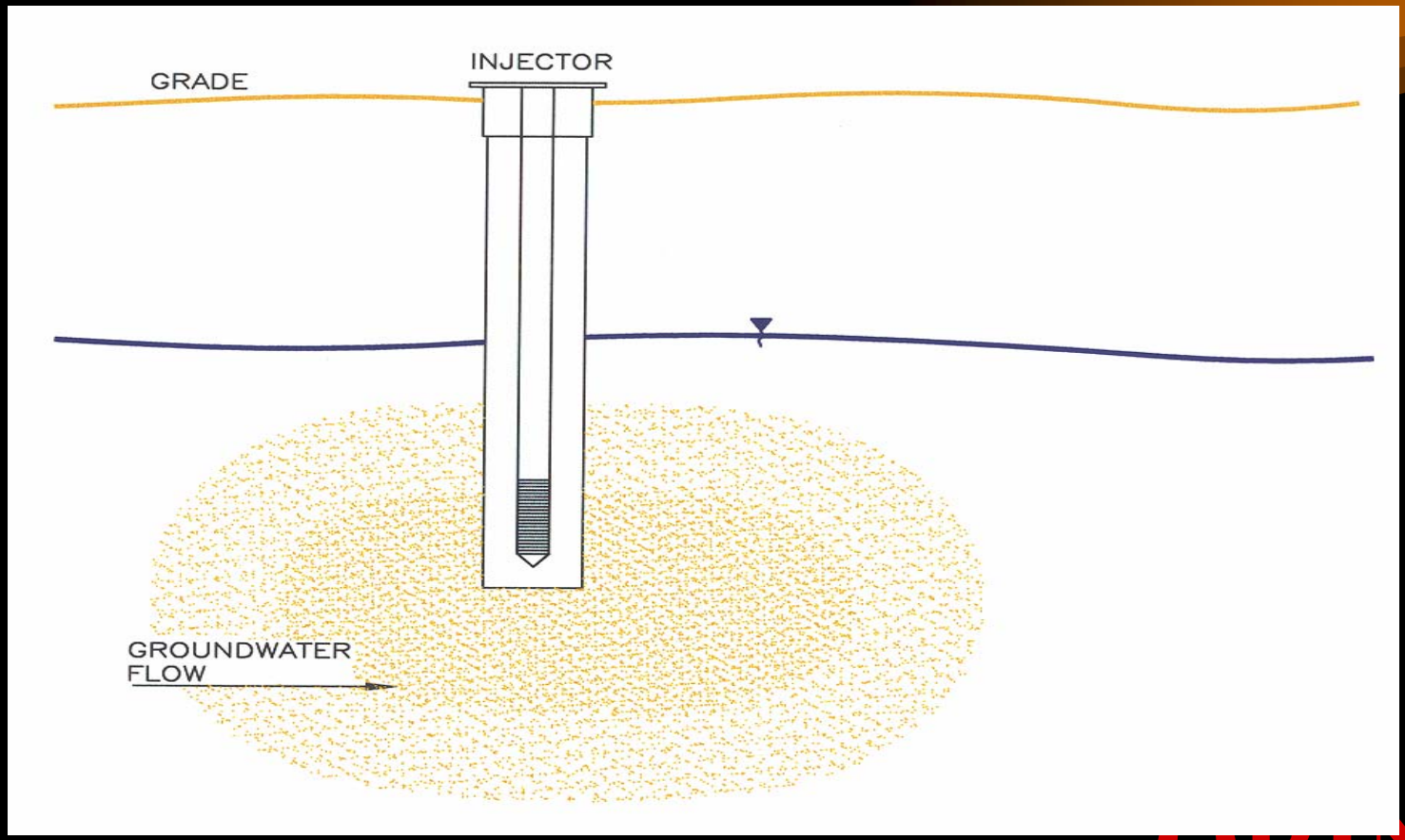
Diffusion



Dispersion



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Types subsurface mixing techniques

- Grouted in injection points
- Backhoe mixing
- Direct Push

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Injection Point

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Injection Rod With Disposable Point

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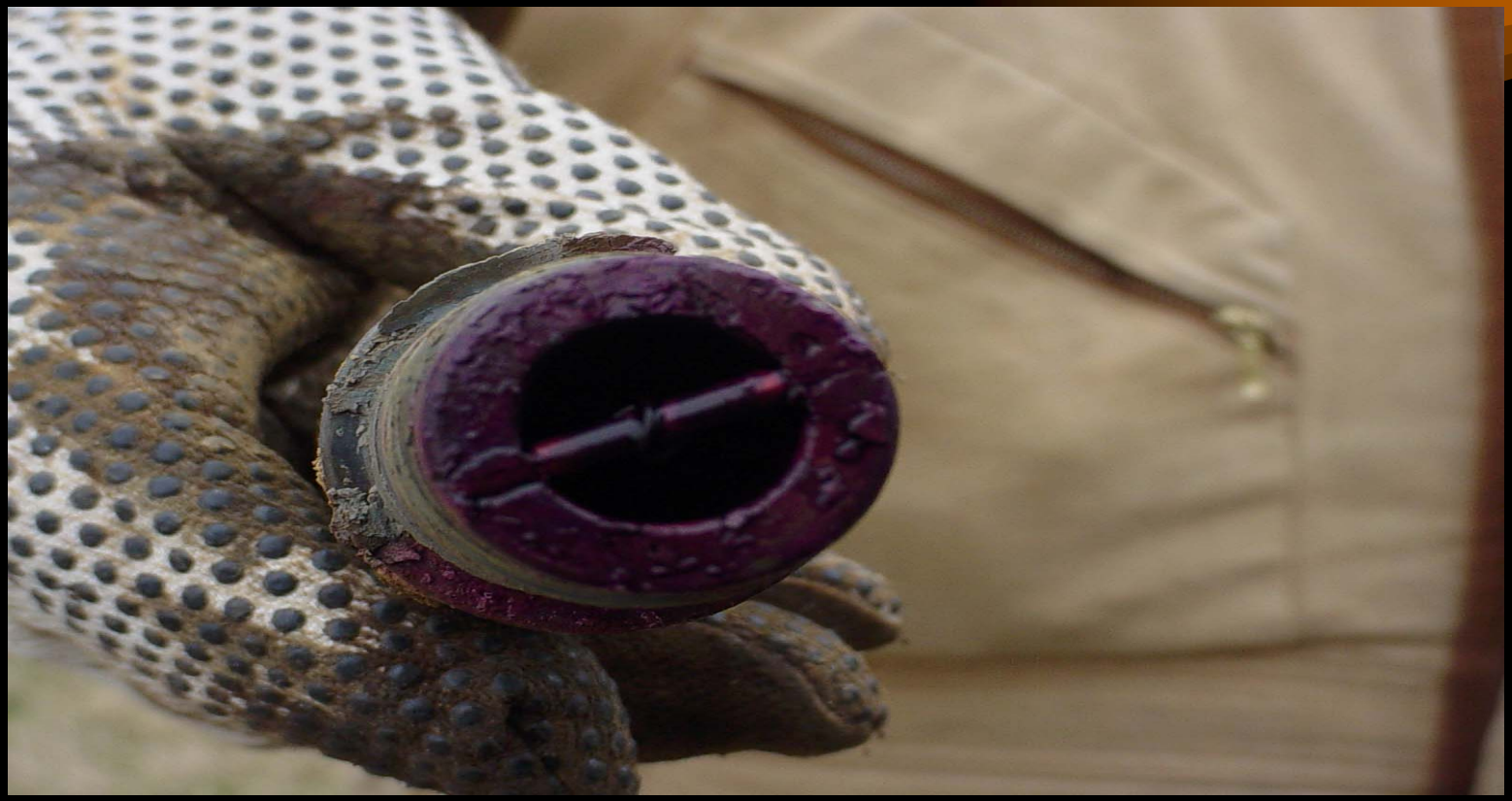
Direct Push Injection



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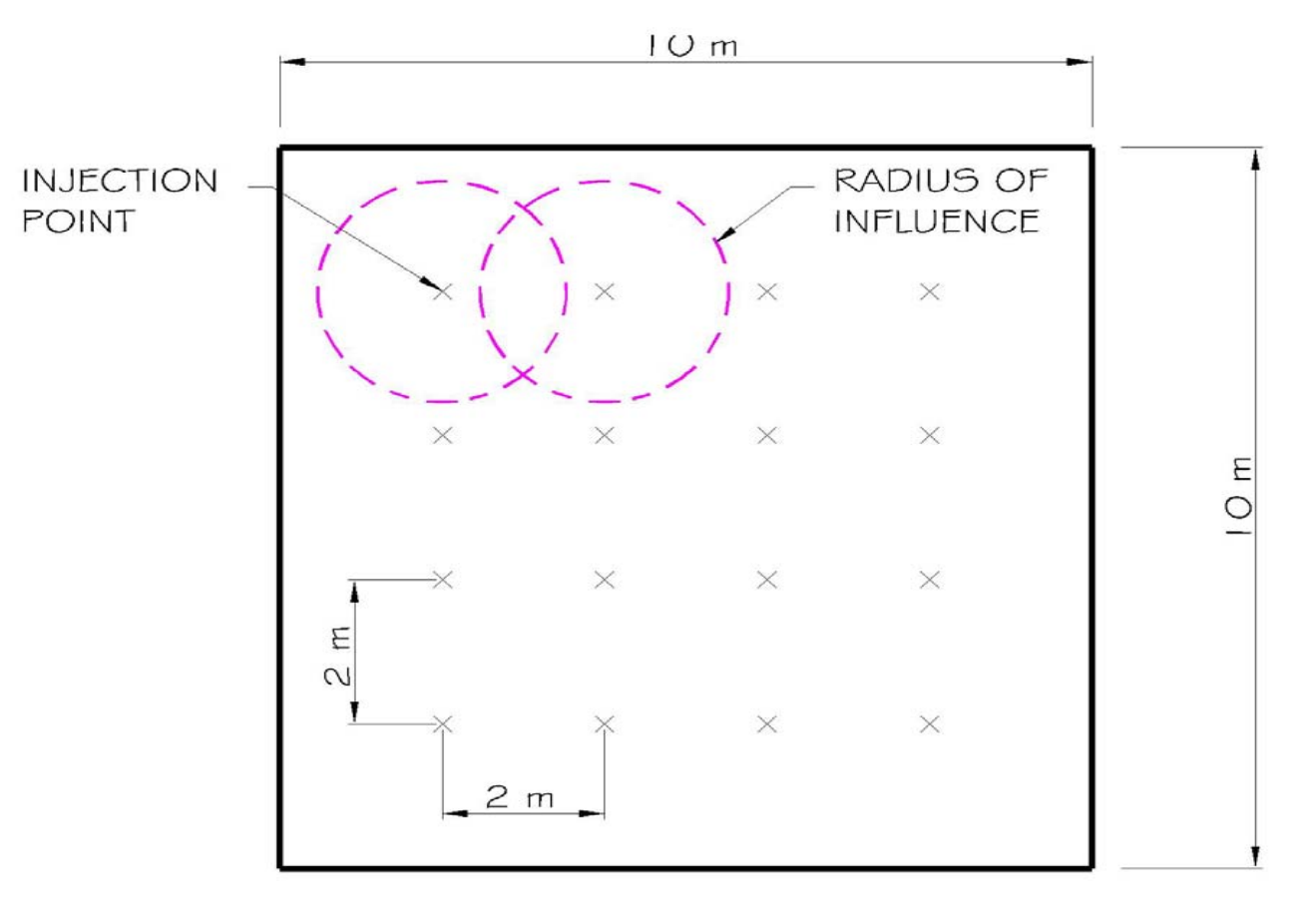
Typical Injection Point Layout



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Injection pump

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Injection Trailer

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Back Of Injection Trailer

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Typical Site Equipment Setup

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Case Study

Property Transaction Site

InSitu Chemical Treatment

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General Information

- Oil Refinery (pipeline leak)
- Soil: silty clay
- Depth of contamination: 4 to 13 feet
- Contaminants: BTEX
- PermeOx® Plus injected 15% to 40%
- Number of injection points: 35
- Number of days on injecting: 3

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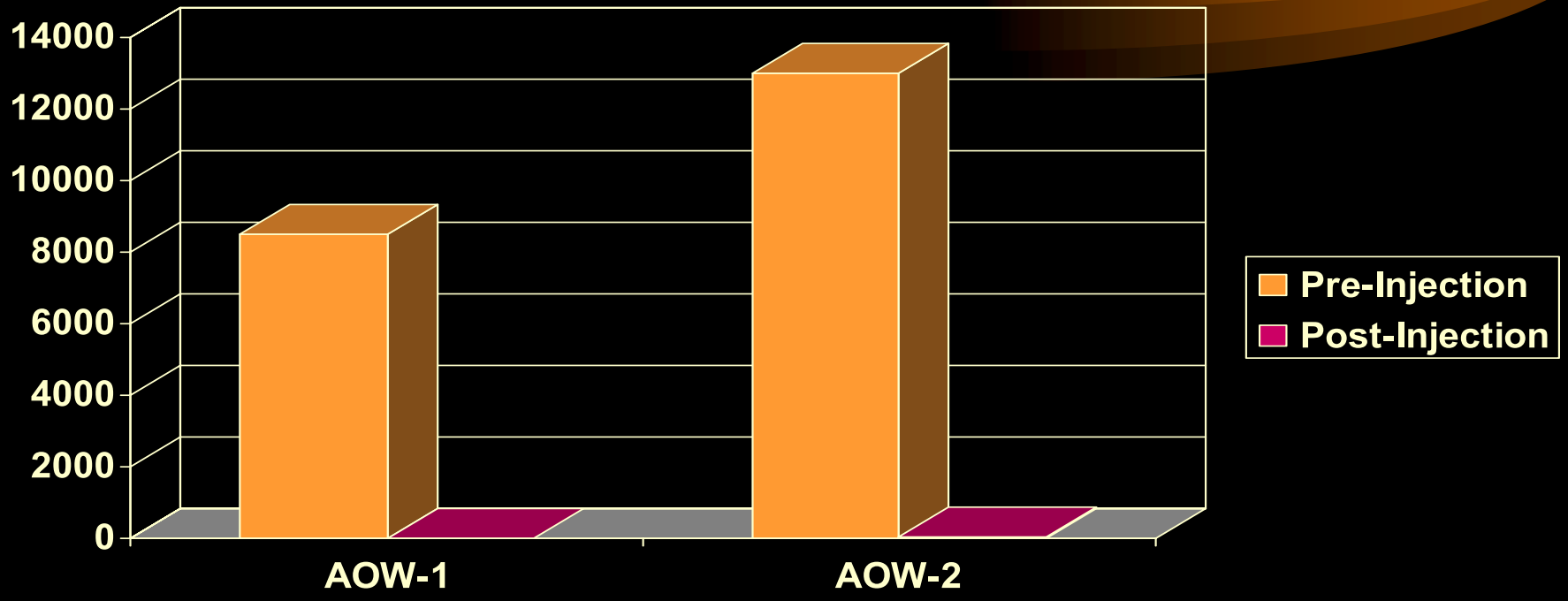
Groundwater Results



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Case Study

Source Removal in a Waste Lagoon

ExSitu Chemical Treatment

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General Information

- Cosmetic and Cleaning Products Manufacture
- Soil: silty clay overlaid by sand
- Depth of contamination: 5 to 20 feet
- Contaminants: PVOCs, SVOCs, PCBs, and Chlorinated Solvents
- Chemistry: Catalyzed Persulfate 15% to 25%
- Approximately 9000 cubic yards
- Number of treatment days: 35

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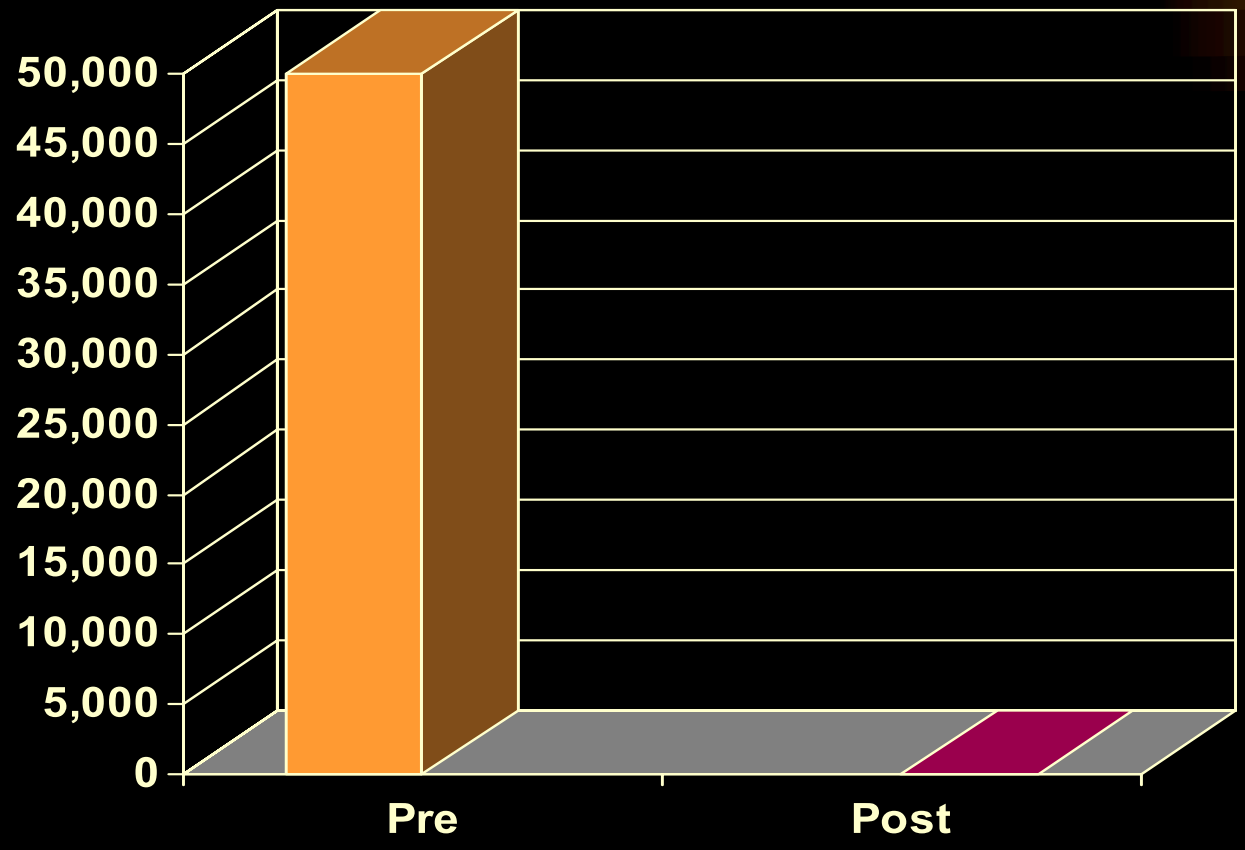
Chemical Mixing

Soil Results



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Concerns Relating to Chemical Treatment

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Displacement

- Injection results in creating a mixed zone
- Sentinel wells have been installed in the clean-up areas at other sites with no impacts
- Typical injection is from the outside moving in

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Effects on Natural Attenuation

- Aerobic degradation is enhanced due to increased oxygen levels (depending on chemistry used)
- It does not completely sterilize the treatment zone

Health and Safety

- Review of site conditions (utility corridor, constituents, surrounding land use)
- Site-specific Health and Safety Plan
- Subsurface mixing of reactive chemicals
- Health and Safety audits

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Variable Project Costs

- Volume of contaminant
- Size of the plume
- Type of lithology
- Days on site

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Advantages of Chemical Treatments

- Can be more cost-effective than traditional remediation methods
- Dramatically reduces the time required to restore and redevelop contaminated sites
- Accepted by the USEPA and are proven chemistries
- Technology can achieve groundwater standards
- Can be used as a stand-alone treatment or in conjunction with other treatment options

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Question and Answers Relating to Chemical Treatment

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