LOTS OF HAMMERS

An Overview of Soil Remediation

Santa Susana Site

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GSI Environmental Inc.
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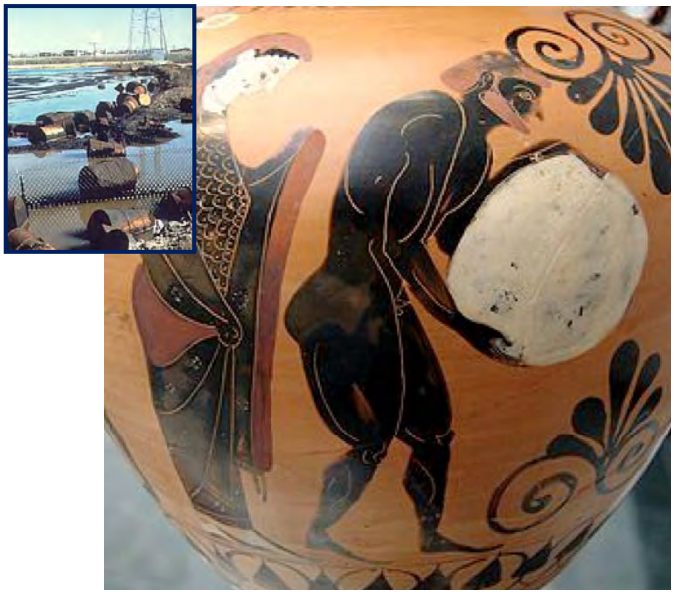
713 522 6300

1
1

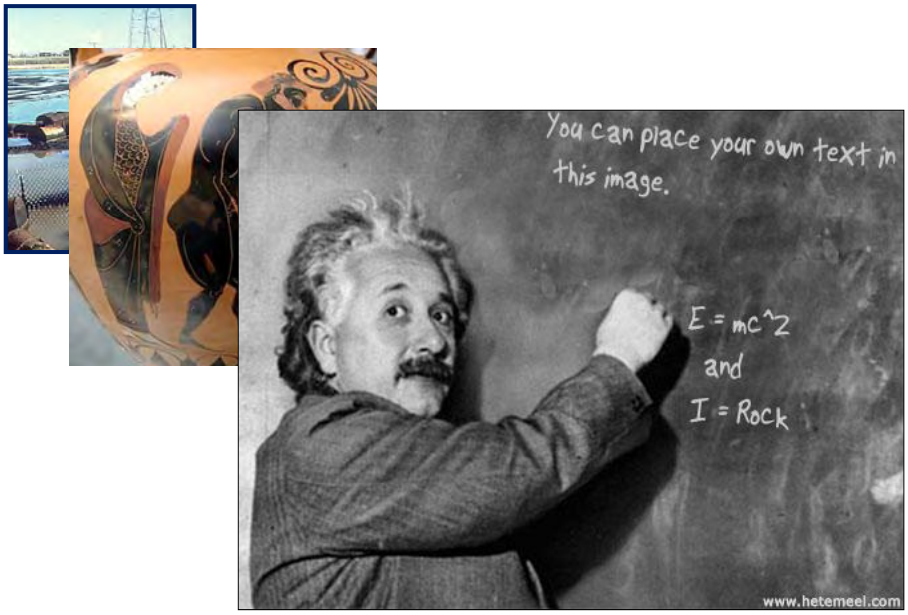
THERE'S A PROBLEM.

2



IT'S BEEN DIFFICULT TO FIX.

3



BUT WE'VE BEEN CLEVER

4

WE CAN MAKE IT BETTER

5

Road Map

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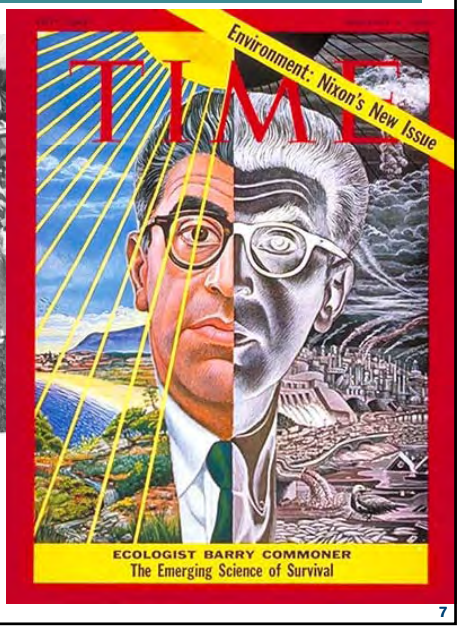
Who is This Person? *"Activist?"*



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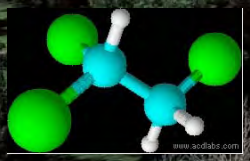
Who is This Person? *Student*



Who is This Person? *Environmental Engineer*

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Recent Projects

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My Assignment Here

- General Overview of Soil Remediation
- Easy on the Nerd Quotient
- "Cold Eyes Review" – No site conditions
- Assume this is first and last trip
- My opinions only

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What's the Game, What Are the Rules

1. Releases Happened
2. You've Got Find It
3. Pick the Hammer You Are Going To Use
4. Use the Hammer

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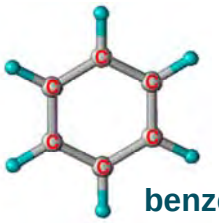
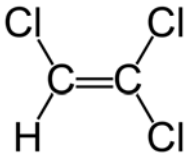
Common Soil Contaminant Chemicals

Fuels



benzene

Chlorinated Solvents



Tri – chloro - ethene

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Others

PAHs: Polycyclic Aromatic Hydrocarbons

PCBs: Polychlorinated Biphenyls

Dioxins:

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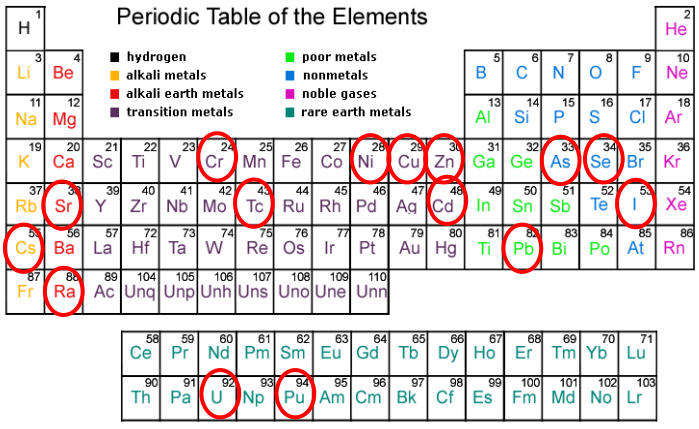
Metals Cr(III), Cr(VI), Pb, Hg

Radionuclides ^{99}Tc, ^{90}Sr, ^{129}I



Common Soil Contaminant Chemicals

- **F**uels
- Chlorinated **S**olvents
- **O**thers
- **M**etals
- **R**adionuclides

F S O M R !

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Chemicals Have Personalities

- Toxic personality?
- Restless personality?
- Stable personality?

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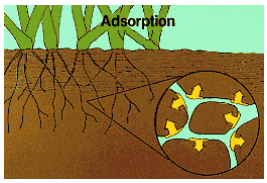
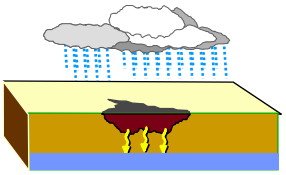
Things That Happen in Soil

Volatilization
(Smell it?)

Adsorption
(Stickiness)



Leaching
(Sugar in tea)



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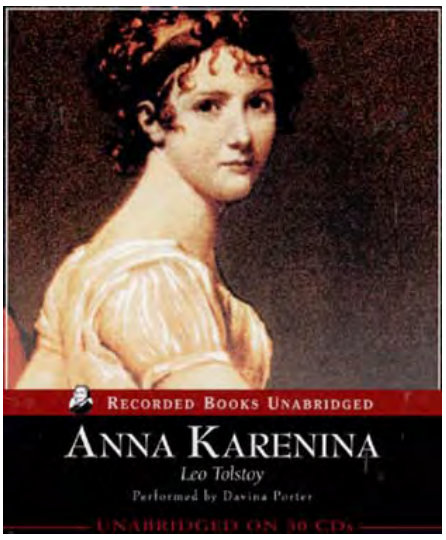
But Environmental Factors are Important



Factors that affect personality:

- Mixtures of contaminants
- Clay vs Sand
- Oxygen vs no oxygen

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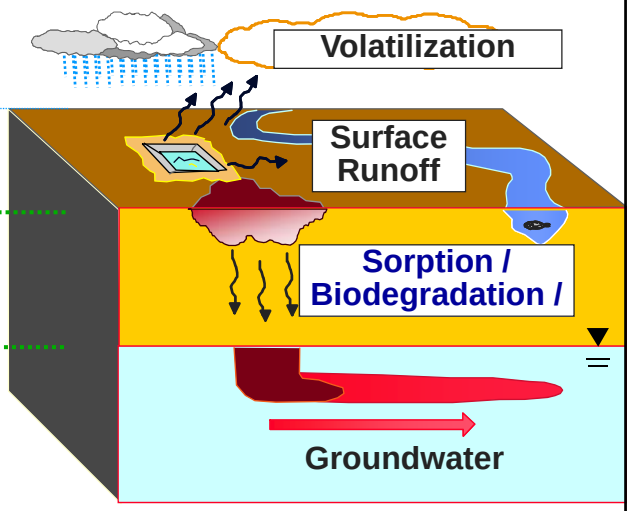
Part 1: Releases Happened….

1. *Into air, water?*
2. *Held in soil.*
3. *Reach groundwater?*



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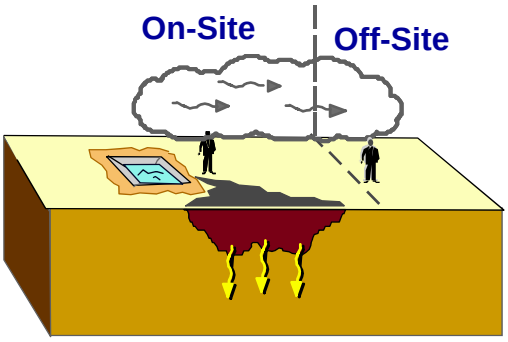
Soil Exposures Concerns and Response

Risk/Concern:

- Vapor / dust inhalation
- Dermal contact
- Impact groundwater



= Point of Exposure

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Example Responses ("Hammers")

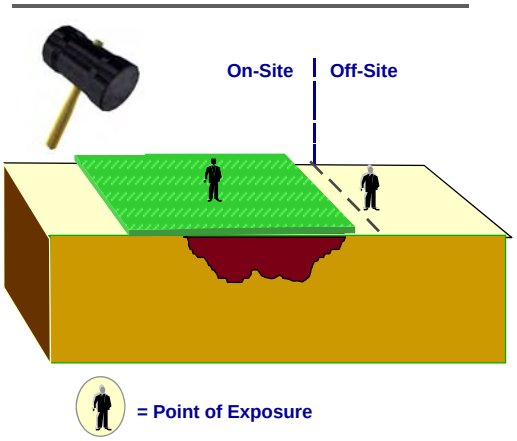
Dig it up, put in landfill

or

Apply In-Place Treatment Technology

or

Immobilize / contain



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What's the Game, What Are the Rules

1. Releases Happened
2. **You've Got Find It**
3. Pick the Hammer You Are Going To Use
4. Use the Hammer

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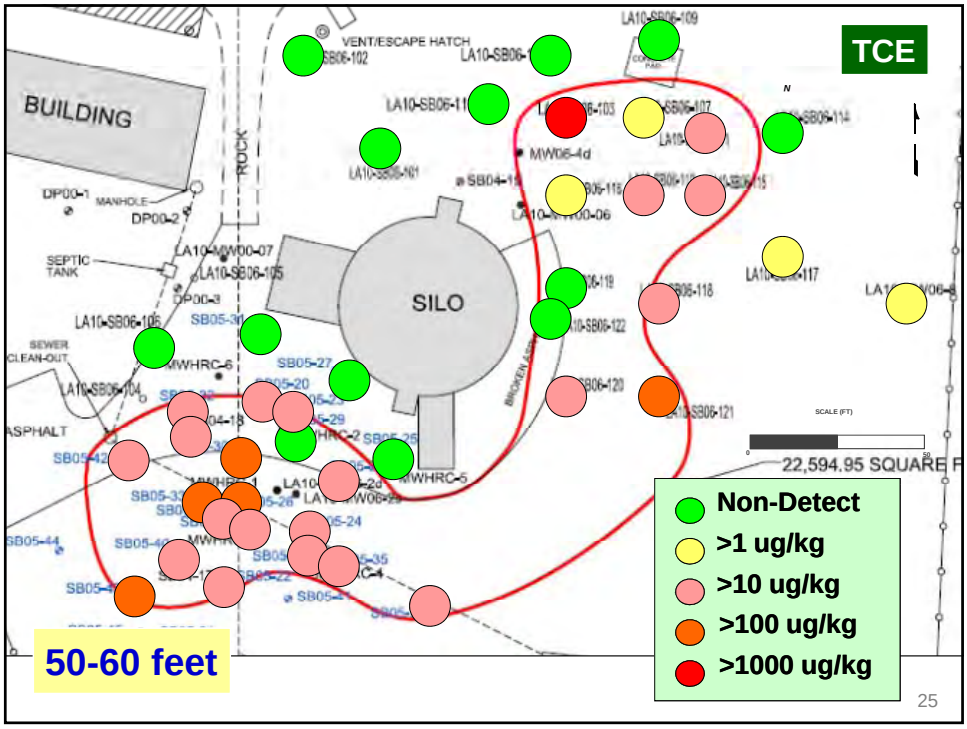

What is a **µg/kg?**

"g" stands for a gram.

µ **"***hey dude, divide by a million"*

K *"hey dude, multiply by a thousand"*

2 grams

Just assume it is a "Part Per Billion" or ppb

Key thing: you compare to the cleanup goal

Non Detect
>1 ppb
>10 ppb
>100 ppb
>1000 ppb

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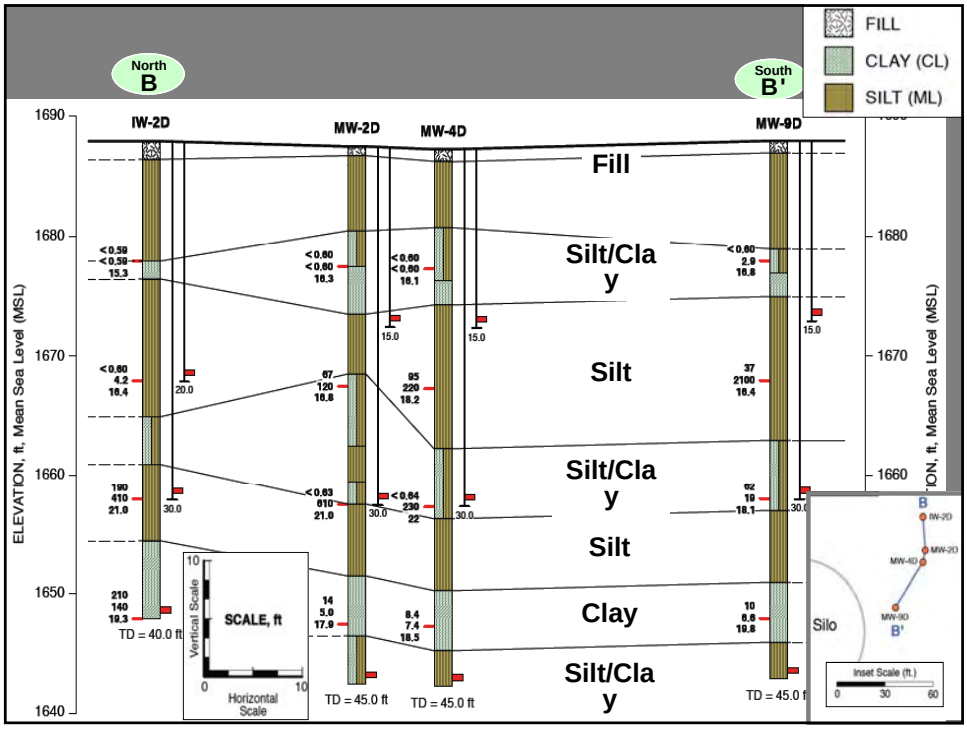
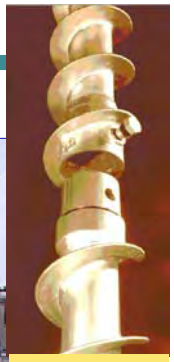
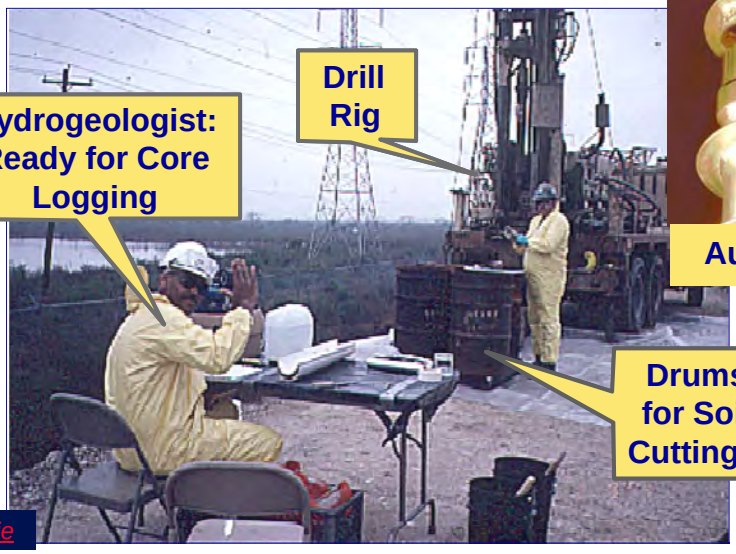


Site Assessment Procedures

Subsurface Soil Sampling



Auger



Hydrogeologist: Ready for Core Logging

Drill Rig

Drums for Soil Cuttings

Movie

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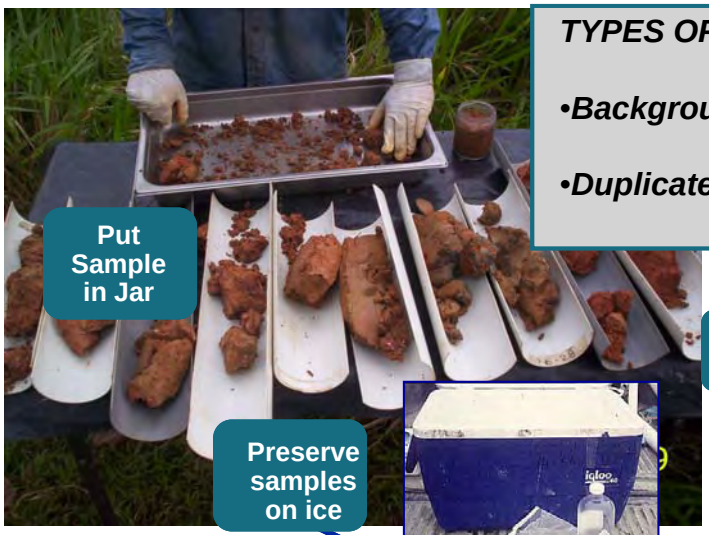
Soil Sample Collection



Put Sample in Jar

Preserve samples on ice

Ship to a Lab

FedEx Freight

TYPES OF SAMPLES

- ***Background***
- ***Duplicate ("Dup")***

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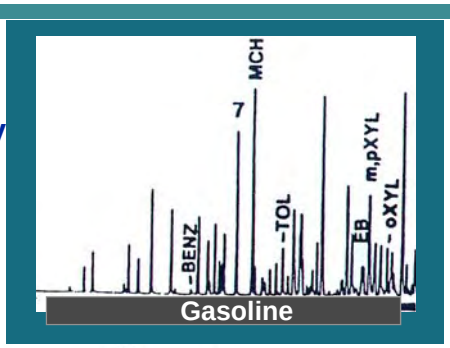
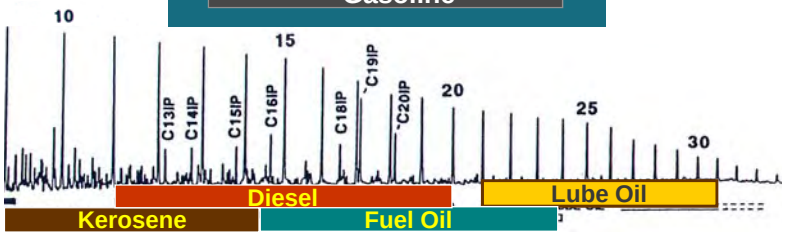
Petroleum Products: *What's In There?*

Gas Chromatography Analysis:

Crude Oil





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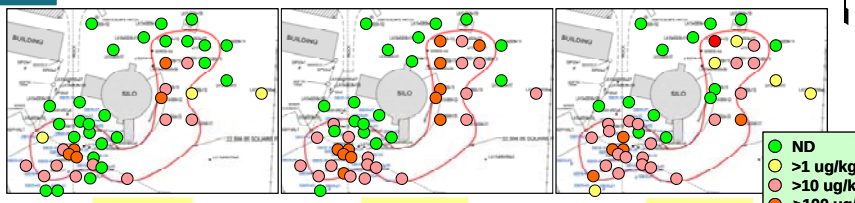
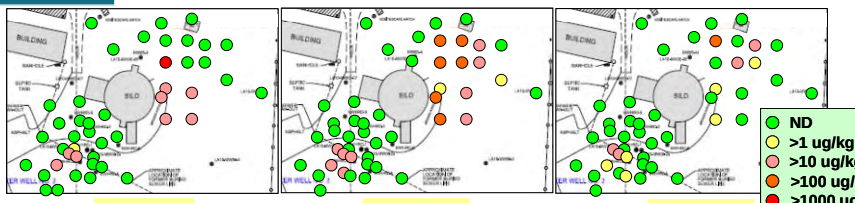
Site Description: 2006 Soil Conc.

TCE



0-20 ft-bgs | 20-50 ft-bgs | 50-60 ft-bgs

cis-DCE



0-20 ft-bgs | 20-50 ft-bgs | 50-60 ft-bgs

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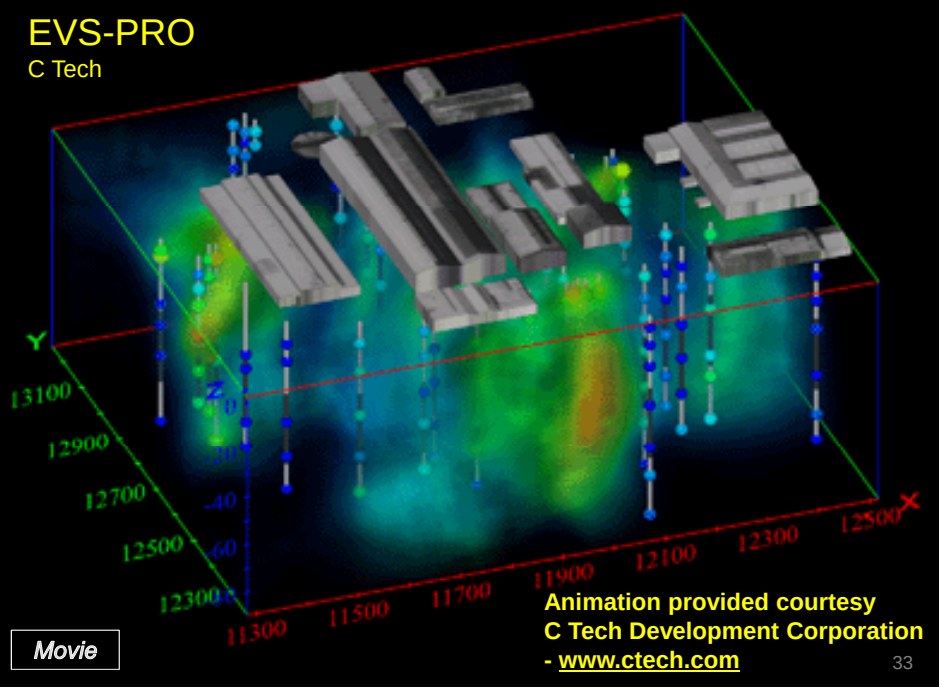
EVS-PRO

C Tech



Movie

Animation provided courtesy
C Tech Development Corporation
- www.ctech.com

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Group Exercise:

“Its dark down there..”

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What's the Game, What Are the Rules

1. Releases Happened
2. You've Got Find It
3. **Pick the Hammer You Are Going To Use**
4. Use the Hammer

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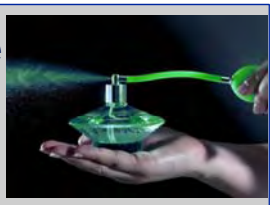
Key Hammers

Dig and haul

Change and move to surface



Convert with bugs or chemicals

Immobilize

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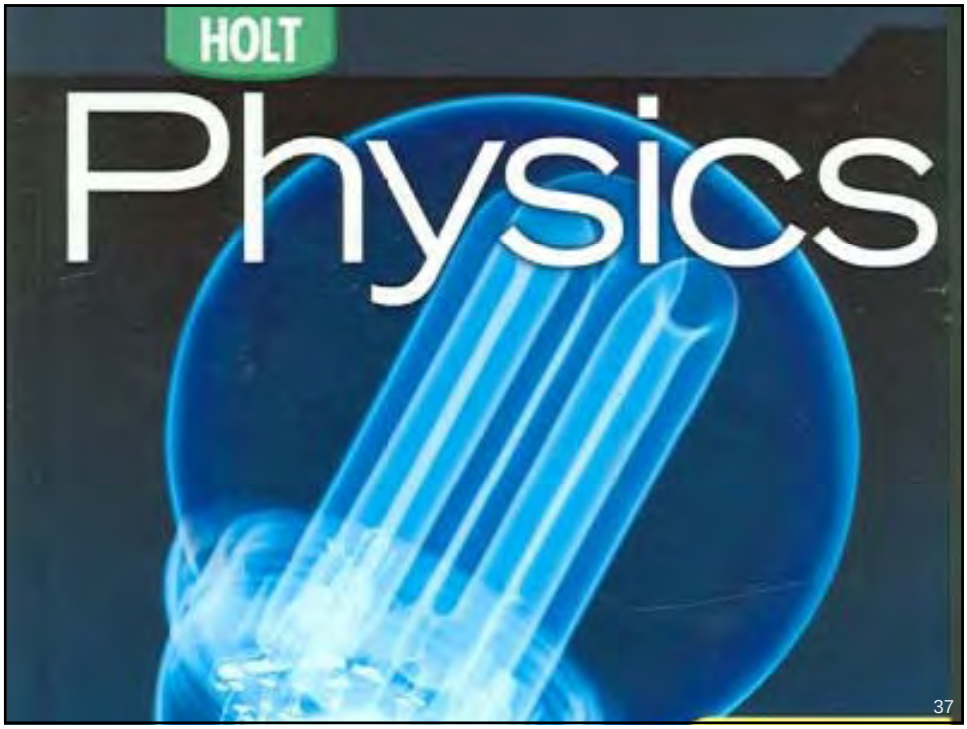

Excavation & Disposal / Treatment: Overview

Haul To Off-Site Landfill

On-Site or Off-Site Thermal Treatment

On-Site Treatment

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KOMATSU
JLG

Excavation & Disposal / Treatment: *Design Considerations*

- **Depth: < 25 feet**
- **Above water table**
- **Diggable?**
- **How far away is away**
- **Community issues, Sustainability**

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EPA

A Citizen's Guide to Soil Excavation

The Citizen's Guide Series

EPA uses many methods to clean up pollution at Superfund and other sites. If you live, work, or go to school near a Superfund site, you may want to learn more about cleanup methods. Perhaps they are being used or are proposed for use at your site. How do they work? Are they safe? This Citizen's Guide is one in a series to help answer your questions.

What is excavation?

Excavation is digging up polluted soil so it can be cleaned or disposed of properly in a landfill. The soil is excavated using construction equipment, like backhoes or bulldozers.

How does it work?

Before soil can be excavated, EPA must figure out how much of it there is. EPA also determines the types of harmful chemicals in the soil. This requires research on past activities at the site as well as testing of the soil.

Once the polluted areas are found, digging can begin. Backhoes, bulldozers and front-end loaders remove the soil and put it on tarps or in containers. The soil is covered to prevent wind and rain from blowing or washing it away. The covers also keep workers and other people near the site from coming into contact with polluted soil. The digging is complete when test results show that the remaining soil does not pose a risk to people or the environment.

The polluted soil may be cleaned up onsite or taken elsewhere for this purpose (See *A Citizen's Guide to Thermal Desorption* [EPA 542-F-01-003], and *A Citizen's Guide to Soil Washing* [EPA 542-F-01-008]). The soil may also may be disposed of in a regulated landfill. If the soil is cleaned, it may be returned to the holes it came from. This is called *backfilling*. The area may also be backfilled with clean soil from another location.

Google: EPA Citizen's Guide remediation technology

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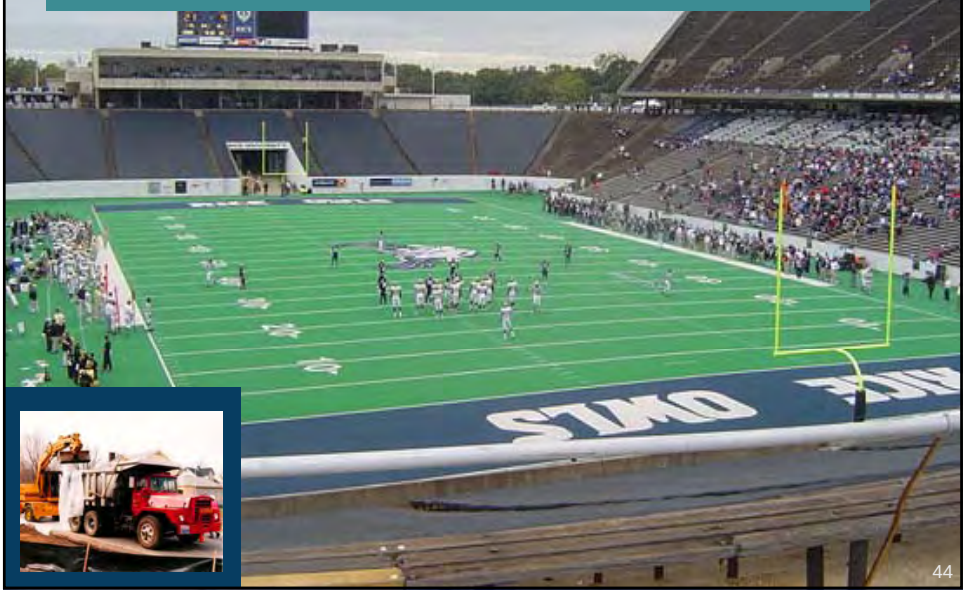
Excavation & Disposal: *How Many Trucks?*

Assume football field of dirt, dig down 20 feet



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Excavation & Disposal:
Design Considerations

- Dump truck holds 25 tons of soil
- Soil expansion factor: add 30%
- 360 feet by 160 feet by 20 feet
- Volume: 1.5 million cubic feet of soil
- 120 pounds per cubic foot soil
- 2000 pounds per ton
- 90,000 tons of soil to be moved

TOTAL: 3600 trucks

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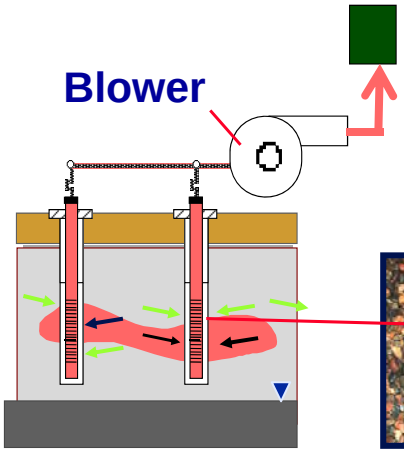
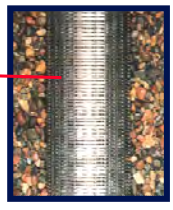
Soil Vapor Extraction: *Overview*

Air vacuum extracts volatile contaminants from the soil.



Vapors are
- released
- soaked up
- burned



Well Screen

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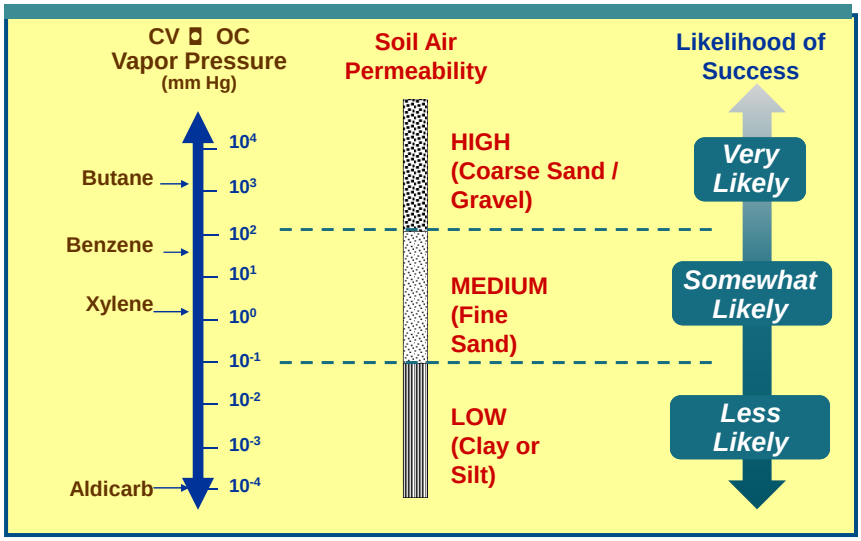
Soil Vapor Extraction:
Design Considerations



Source: CDM, 1988

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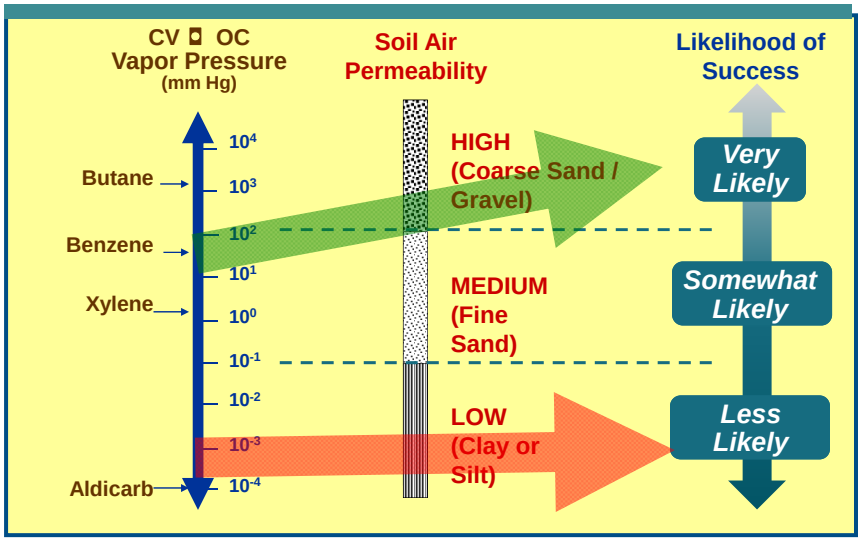
Soil Vapor Extraction:
Design Considerations



Source: CDM, 1988

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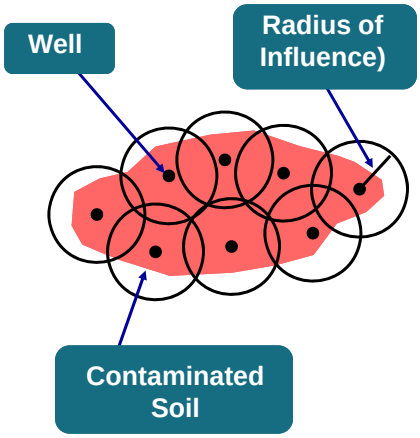
Soil Vapor Extraction: *Equipment Options*



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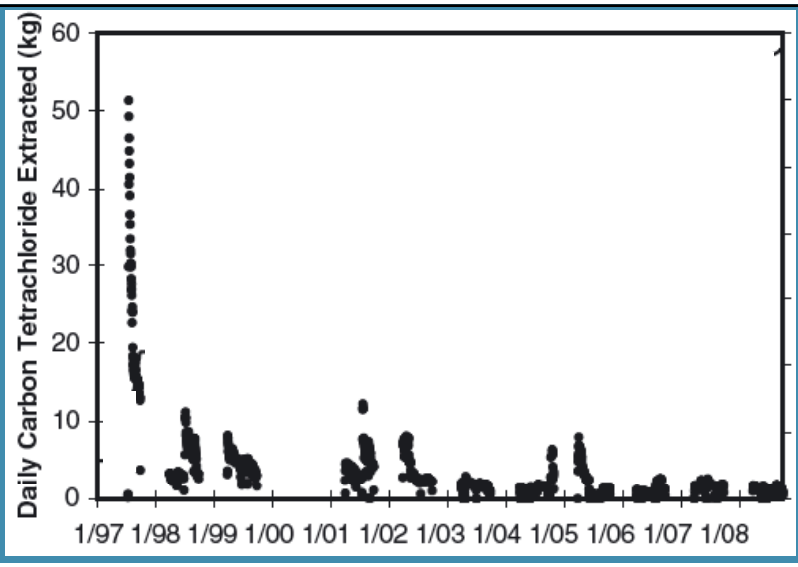

Analysis of Soil Vapor Extraction Data to Evaluate Mass-Transfer Constraints and Estimate Source-Zone Mass Flux

by Mark L. Brusseau, Virginia Rohay, and Michael J. Truex

Ground Water Monitoring & Remediation

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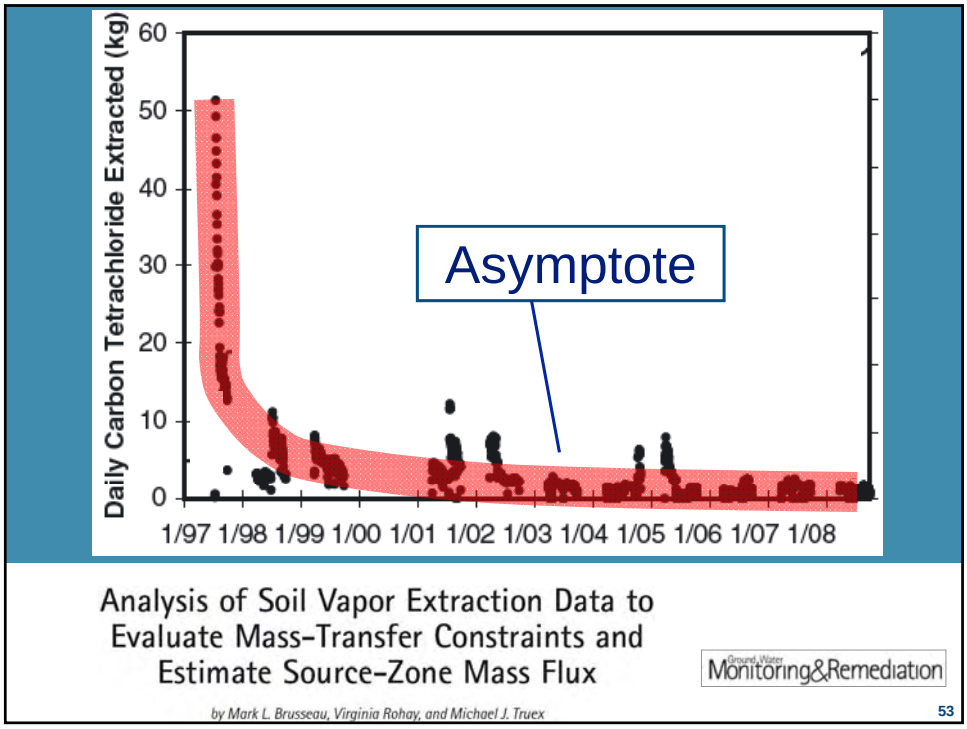
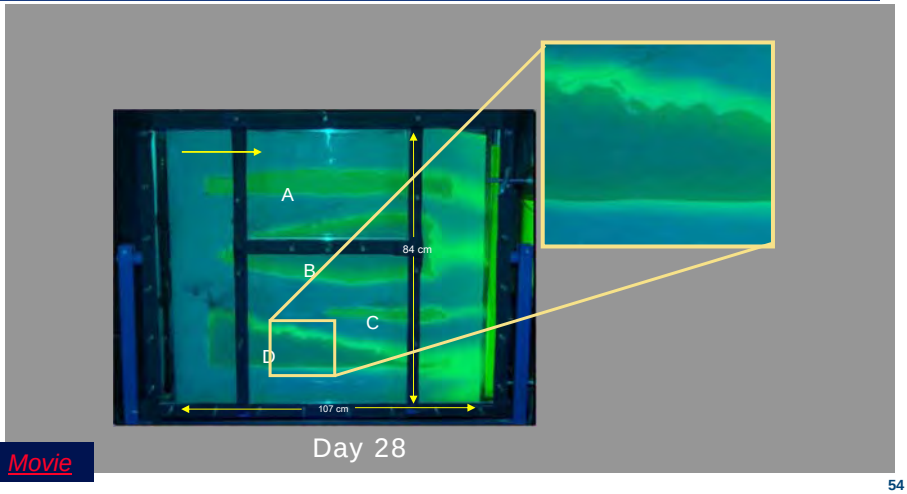


Diffusion into Clays

Contaminant storage and release processes in low permeability zone is is governed by concentrations gradients that occur at scales of *centimeters to millimeters.*



Movie

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Microblowe Baroball

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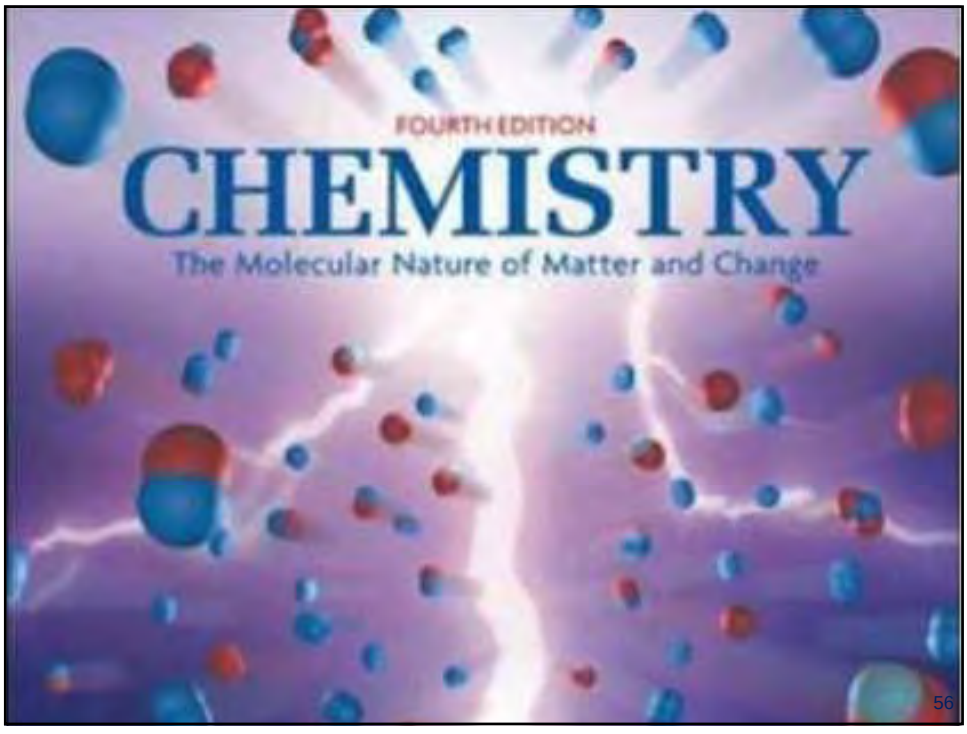

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Chemical Oxidation: *Overview*

Add Chemical:

- **Ozone**

Peroxide

Permanganate

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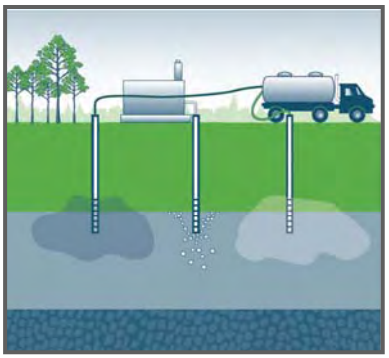
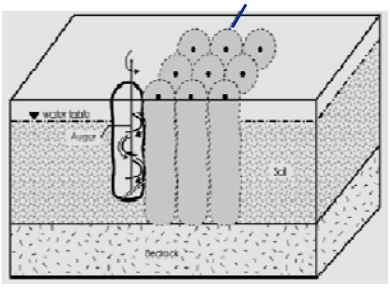
Chemical Oxidation: *Overview*

Using variety methods:

- **Direct-push probes**
- **Drilled wells**
- **Specialized injectors**
- **Soil mixing**



Treated columns



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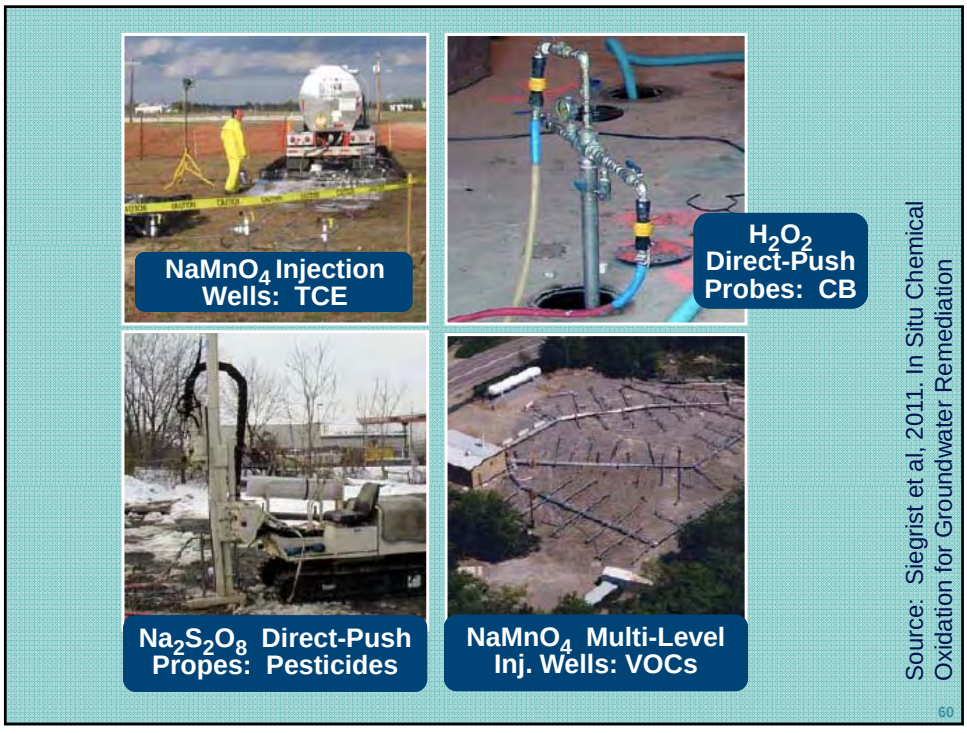
09.06 04:07
09.07 02:42
09.07 10:38
59


$NaMnO_4$ Injection Wells: TCE
H_2O_2 Direct-Push Probes: CB
$Na_2S_2O_8$ Direct-Push Propes: Pesticides
$NaMnO_4$ Multi-Level Inj. Wells: VOCs
Source: Siegrist et al, 2011. In Situ Chemical Oxidation for Groundwater Remediation
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Direct Push Injection

Movie

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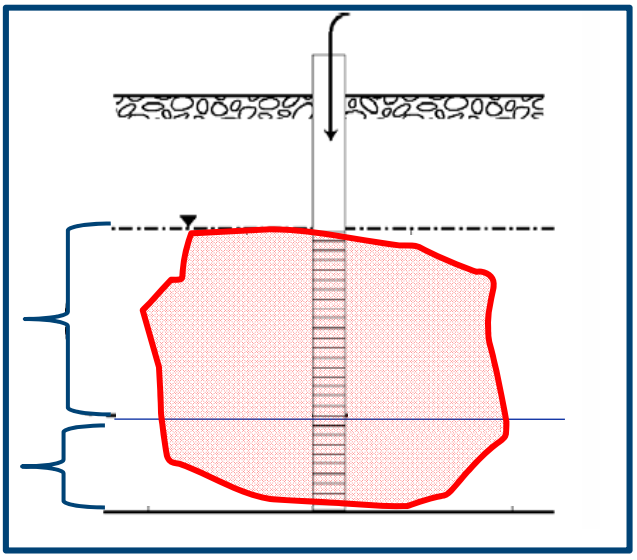
X-SECTION



Adapted from:
ITRC 2005

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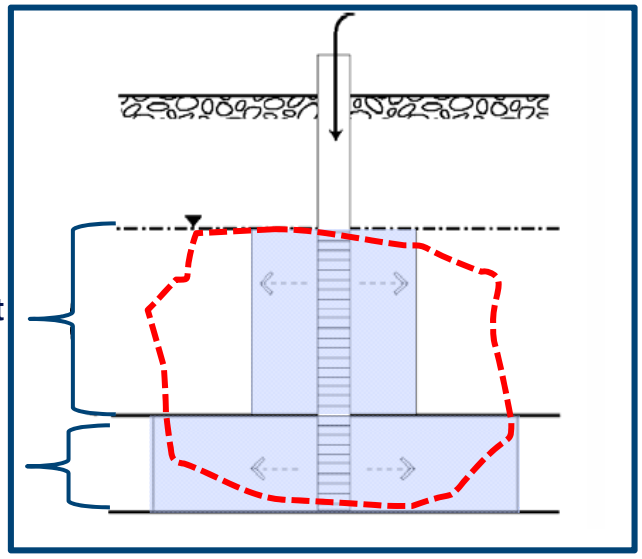
X-SECTION



Adapted from:
ITRC 2005

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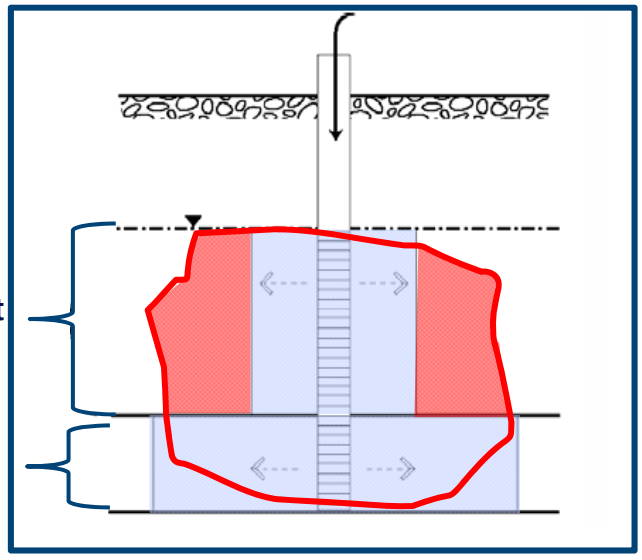
X-SECTION



Adapted from:
ITRC 2005

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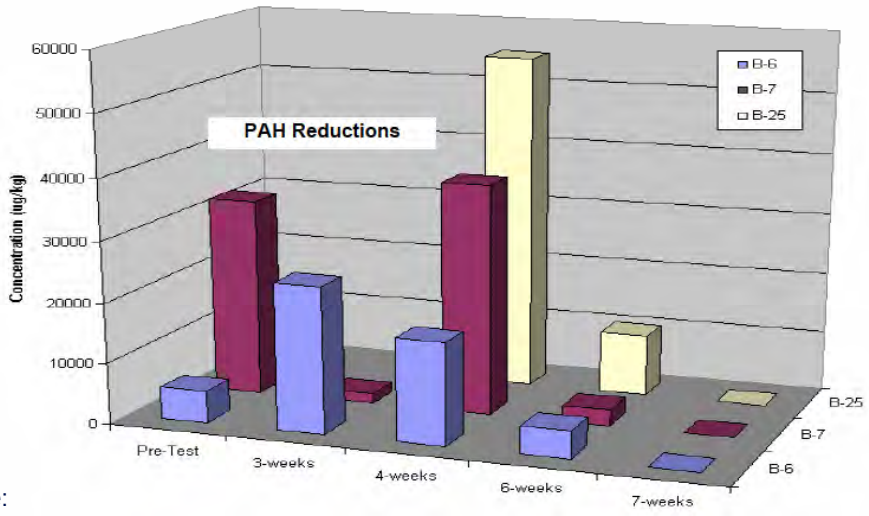
Fuel Terminal
About 0.5 acres
Treatment zone 2 to 8 feet

10 sparge points
Added Ozone gas
Operated for 8 weeks
90% reduction



Source:
ITRC 2005

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Photo Courtesy of Redox Tech

66


Applying Persulfate
Photo Courtesy of Redox Tech
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Photo Courtesy of Redox Tech


Photo Courtesy of Redox Tech
69


RegenOx Injections
Galveston Sulfur Terminal
October-November 2011

Reagents


Part B
(Activator- Liquid)
Part A
(Oxidizer - Powder)


REGENESIS
REGENESIS
Part A
(Oxidizer - Powder)

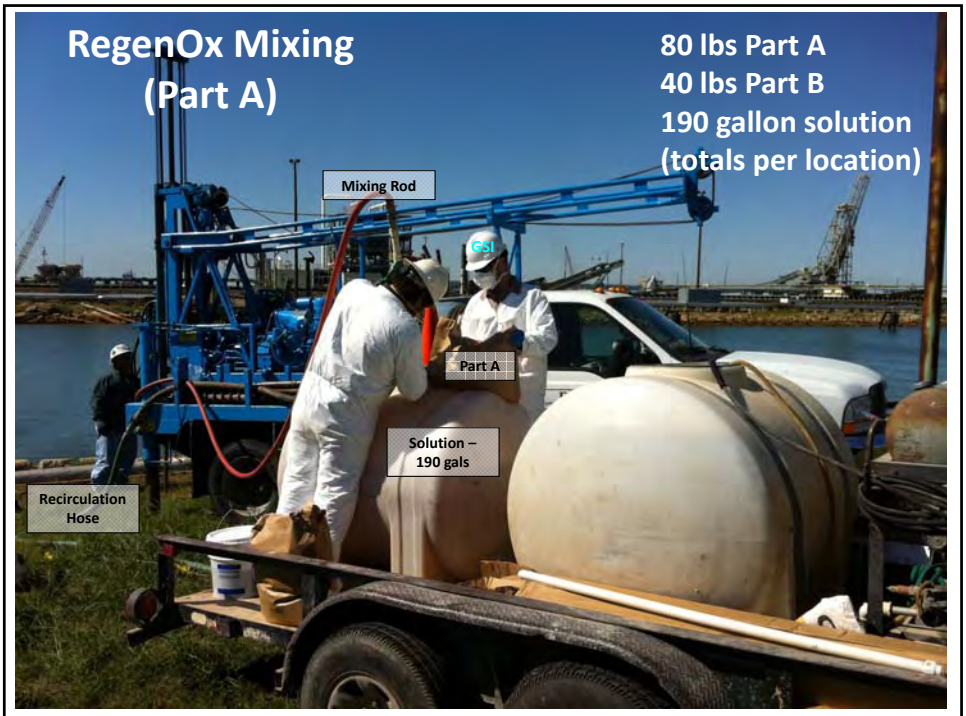

RegenOX
Part B
(Activator- Liquid)


Part A + B

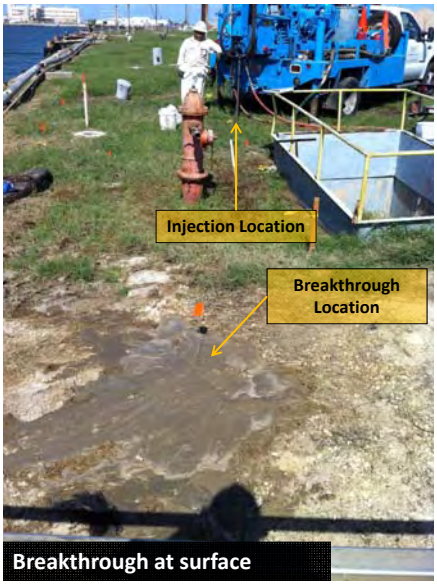

Injection Equipment
Injection Pump
Mixing Tanks
Direct Push Rig

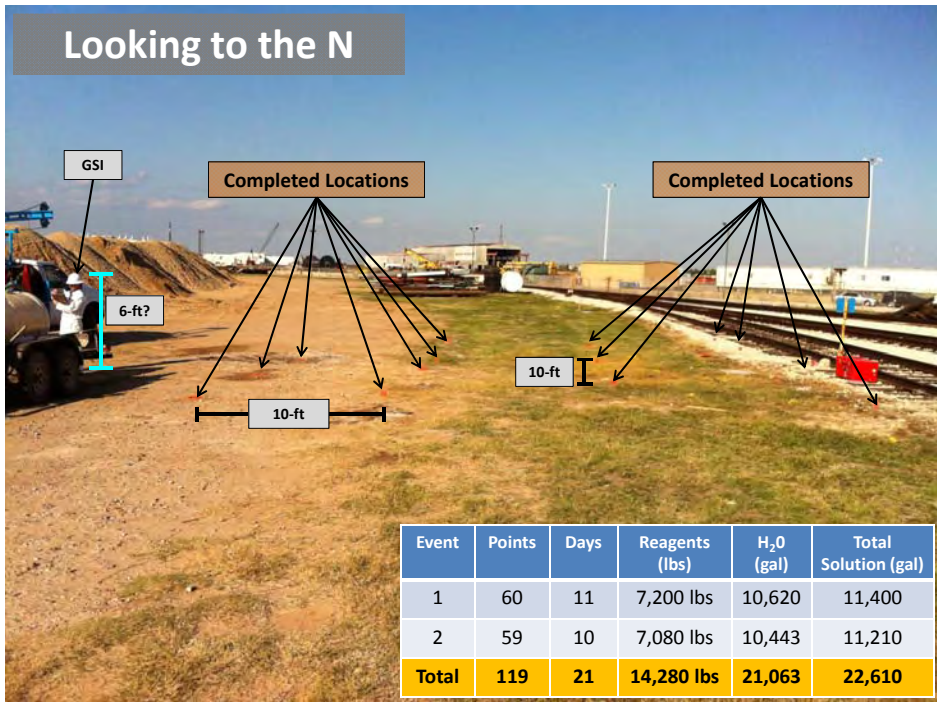
RegenOx Mixing (Part A)

80 lbs Part A
40 lbs Part B
190 gallon solution
(totals per location)



Issues

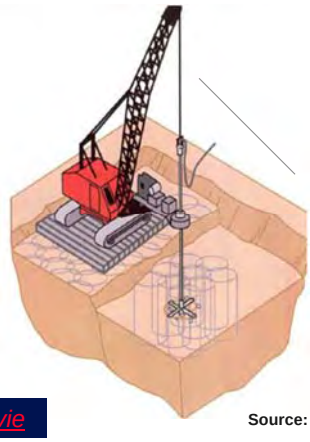




Event	Points	Days	Reagents (lbs)	H_2O (gal)	Total Solution (gal)
1	60	11	7,200 lbs	10,620	11,400
2	59	10	7,080 lbs	10,443	11,210
Total	**119**	**21**	**14,280 lbs**	**21,063**	**22,610**

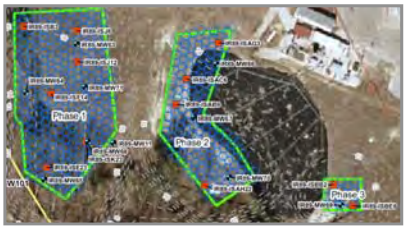
Deep Soil Mixing/ ZVI Clay

- Technology Developers: DuPont, now all Colorado State
- Destroys chlorinated solvents
- Mixes iron filings and special clay together

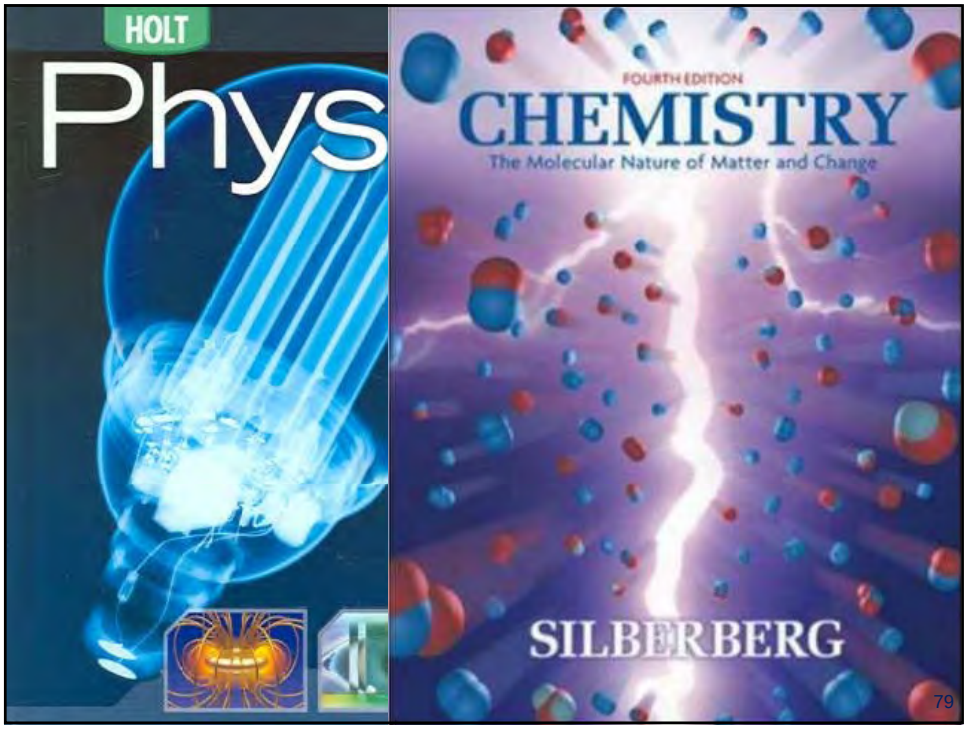


Movie

Source: CSU



78



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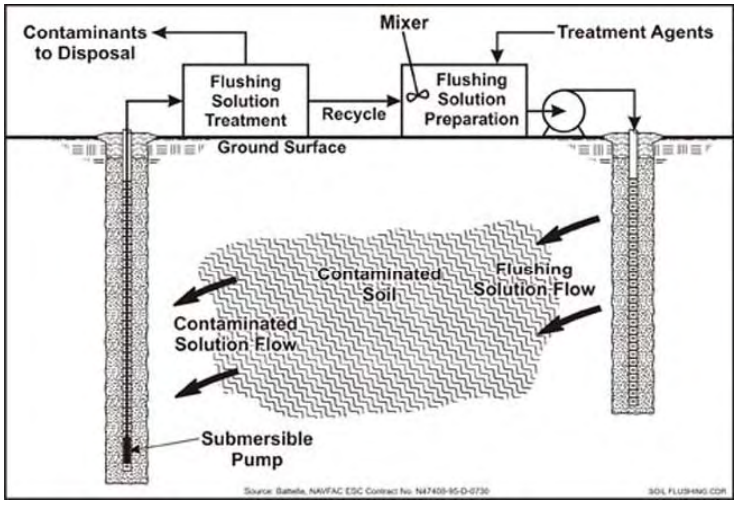
Soil Flushing

Add Detergent, Run Through Soil Zone



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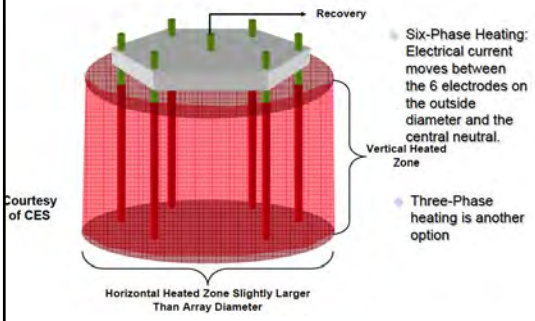
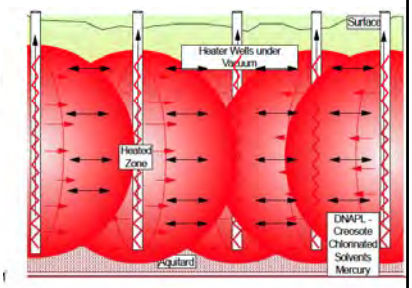
Thermal Remediation: *Overview*

HEAT: MOBILIZES, DESTROYS CHEMICALS

RUN ELECTRICITY THROUGH SOIL



HOT RODS IN GROUND



Source: TerraTherm

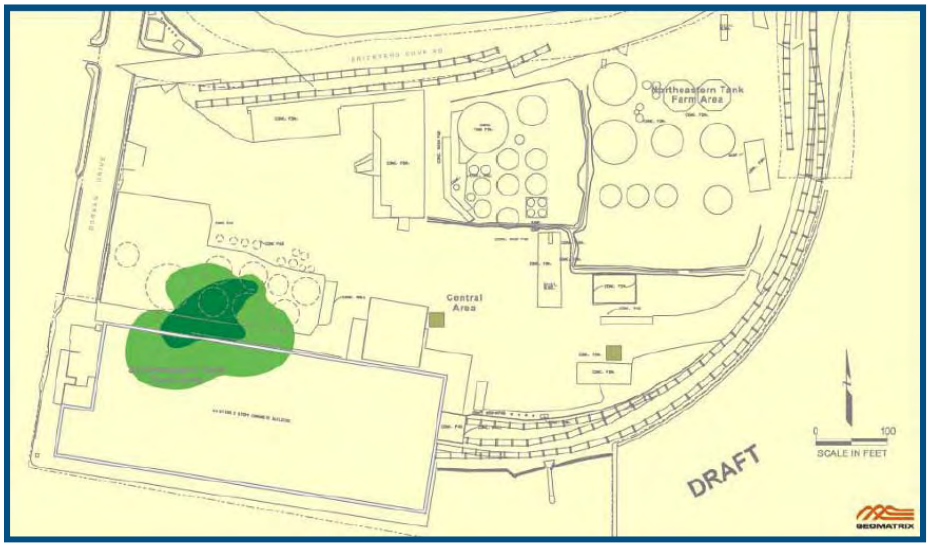
81

Thermal: *Applicability*

- Better performance than other in-place technologies
- Can be costly
- Need SVE
- Access, sustainability issues

Source: TerraTherm, Conley et. al

Areas to be Cleaned Up in Southwestern Tank Farm



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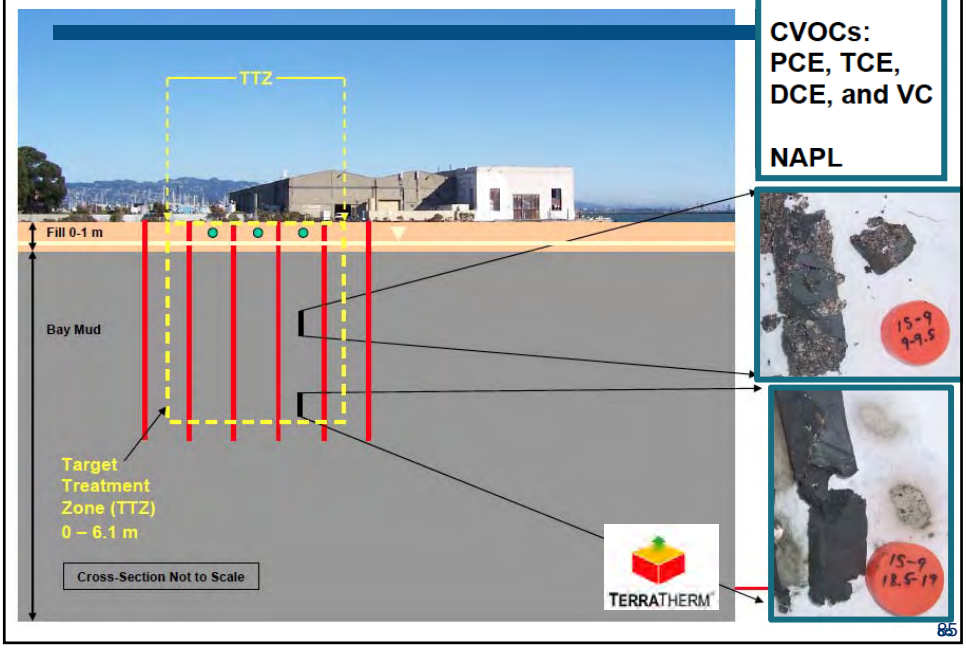
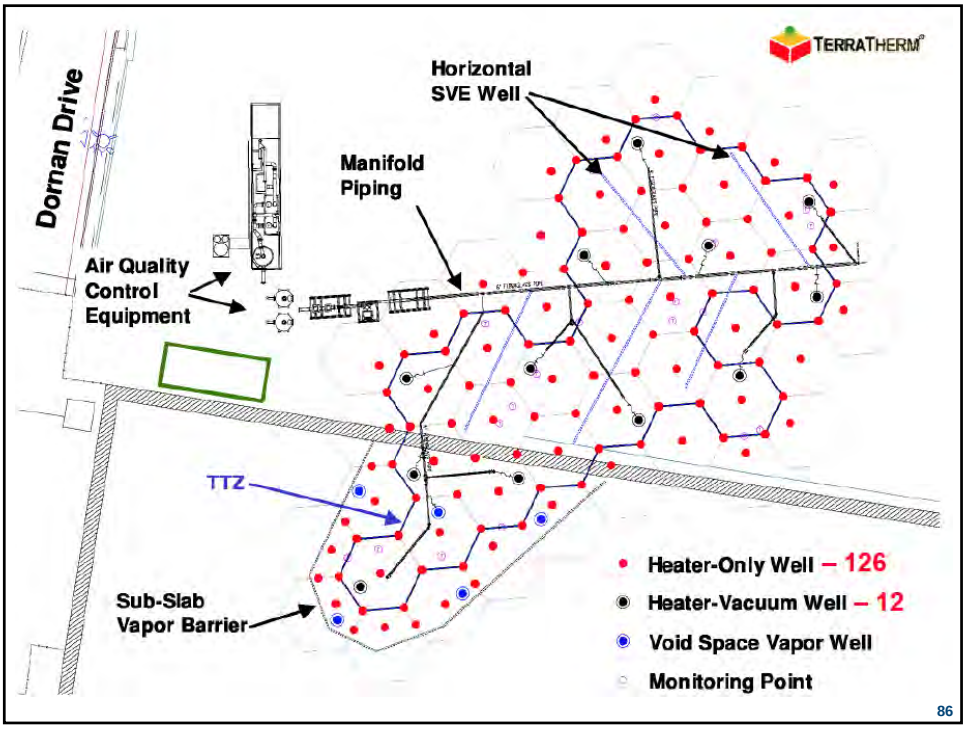
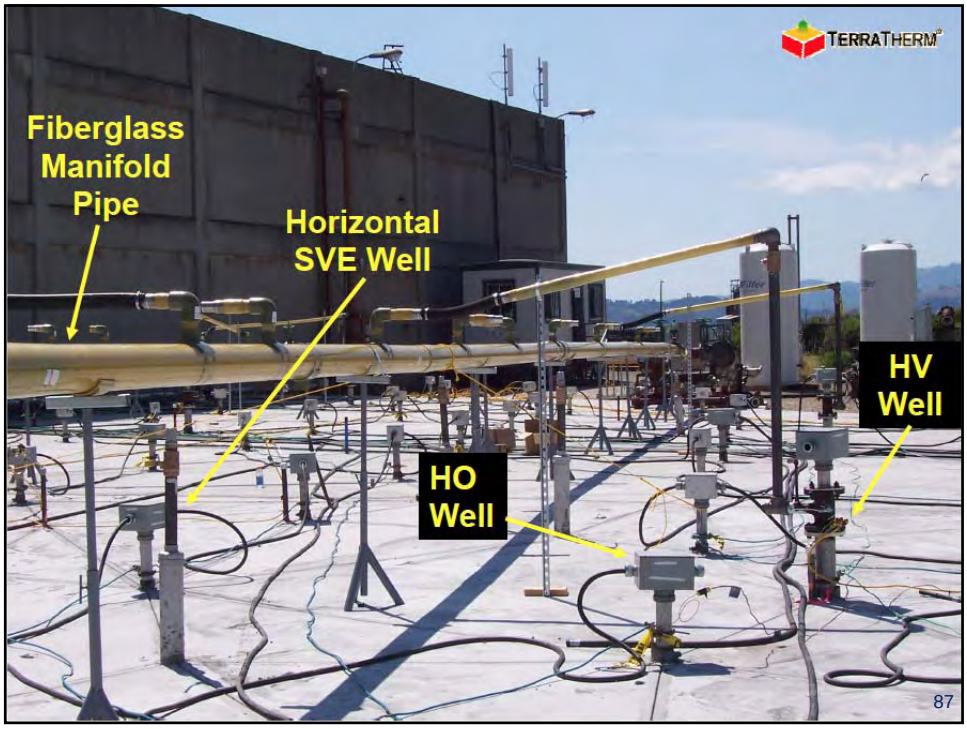
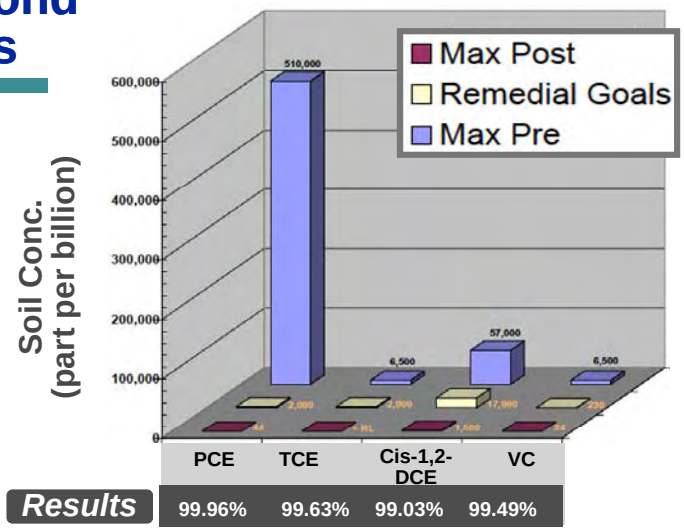
Richmond Site Cross-Section







Richmond Results



Results	PCE	TCE	Cis-1,2-DCE	VC
	99.96%	99.63%	99.03%	99.49%

TERRATHERM

Richmond results are based on 17 pre-treatment samples and 64 post-treatment samples. Post-treatment samples were collected from centroids (i.e., coolest locations) at random and biased depths (15 or 23% were collected between 5.5 and 6.1 m bgs).

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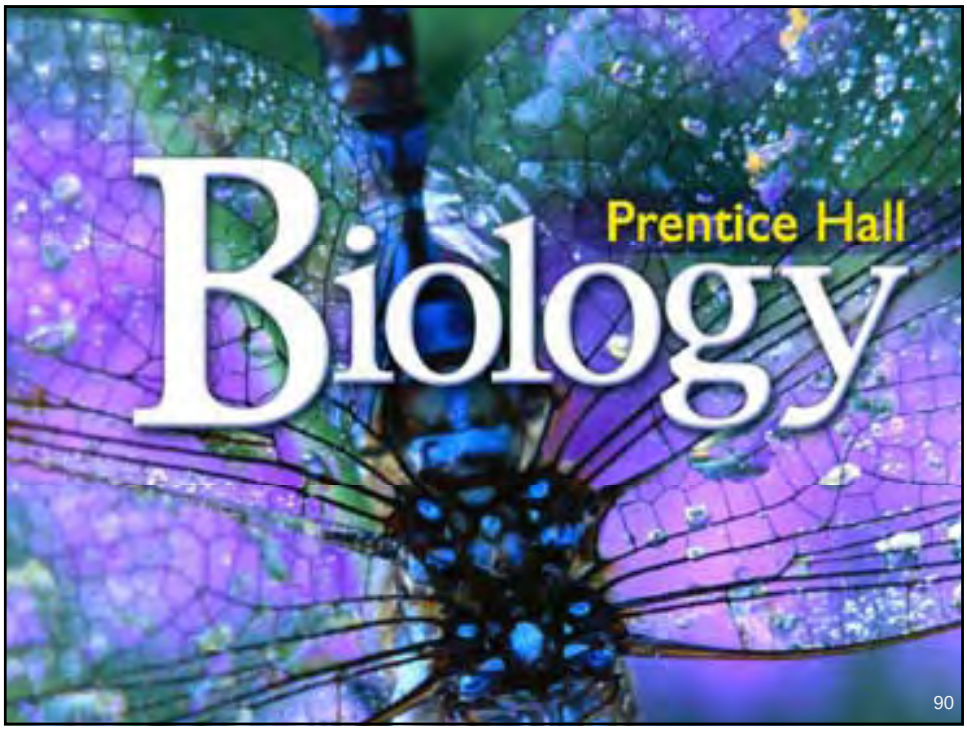
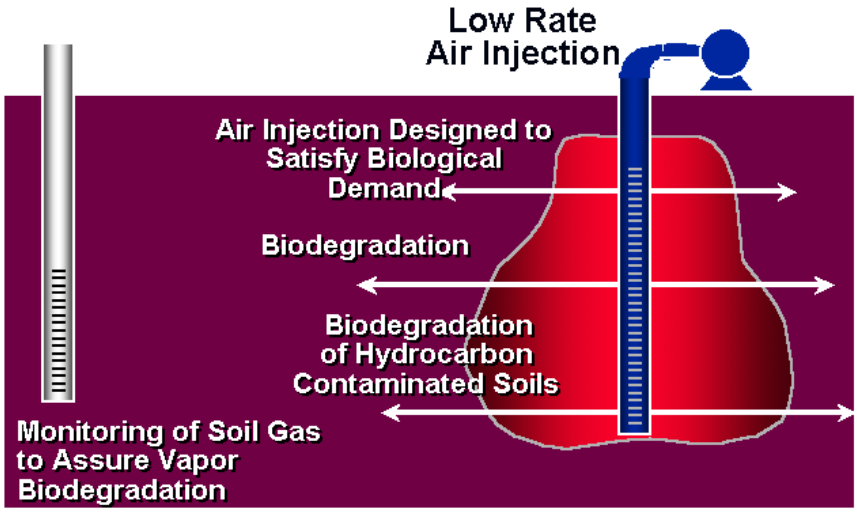
TERRATHERM
Project completed on time and on budget
-- Performance guaranteed
-- Remedial goals achieved
7 months for construction and treatment
Total TT Project Cost: $1.7 M
Cost of power: $250K
Post-development value: ~ $300M
89


Prentice Hall
Biology
90

Bioventing System (for "F" Chemicals)



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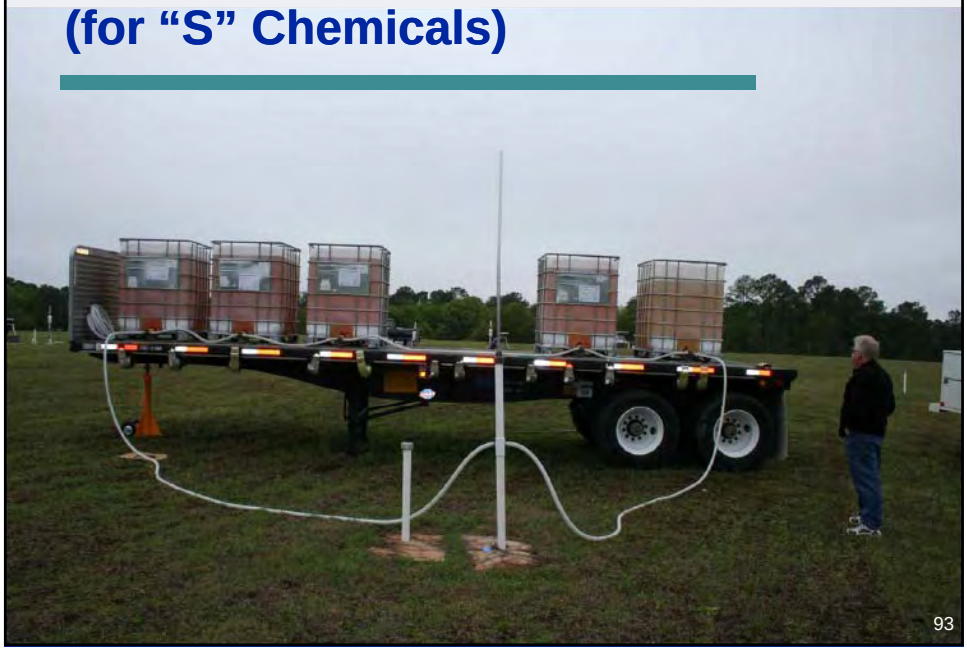
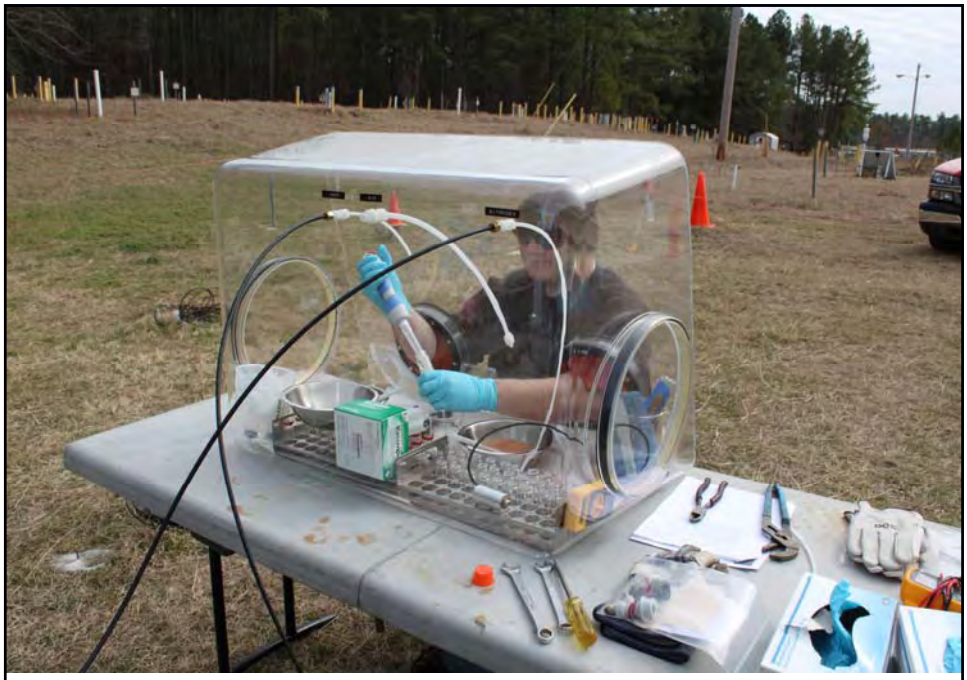
ADD VEGETABLE OIL (for “S” Chemicals)



93

94



95

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Research Team – Hydrogen Addition

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Why Researching Hydrogen?

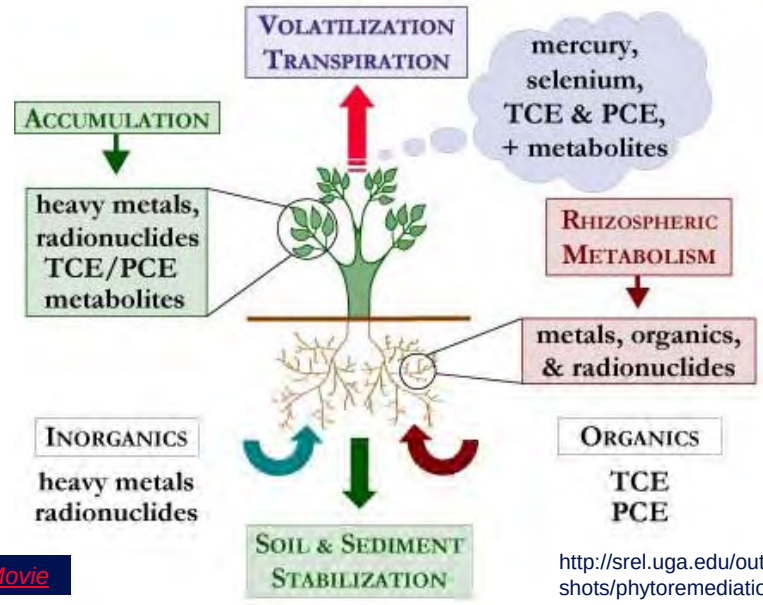
Hydrogen+Bugs ➡ Converts Chlorinated Solvents

98

Gas Injection System

99

PHYTOREMEDIATION



Movie

http://srel.uga.edu/outreach/snapshots/phytoremediation.htm

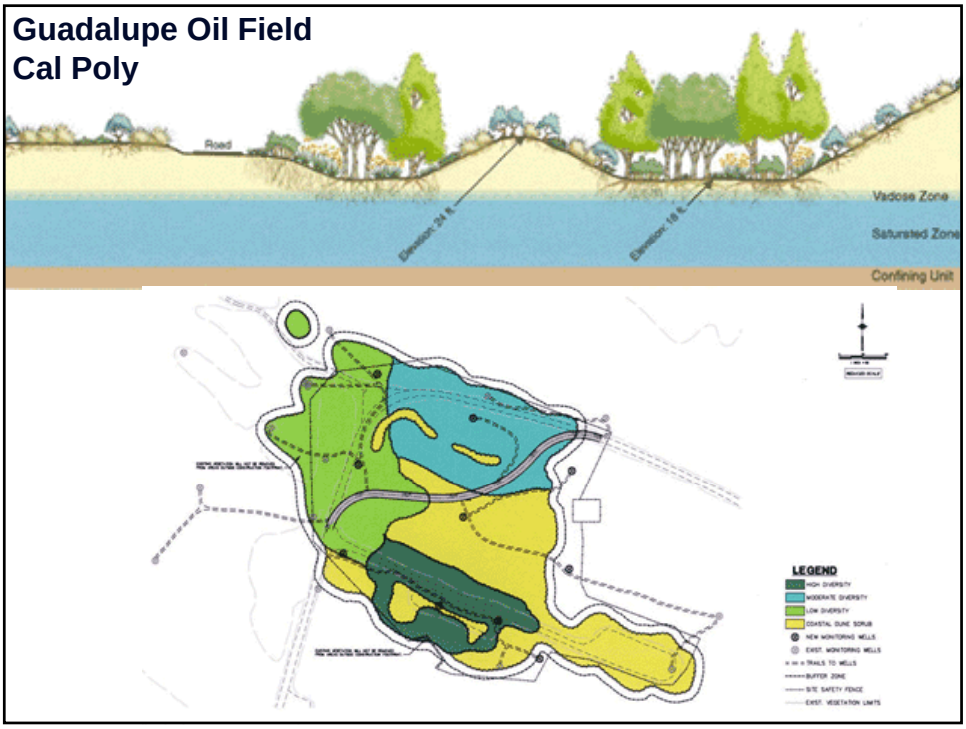
100

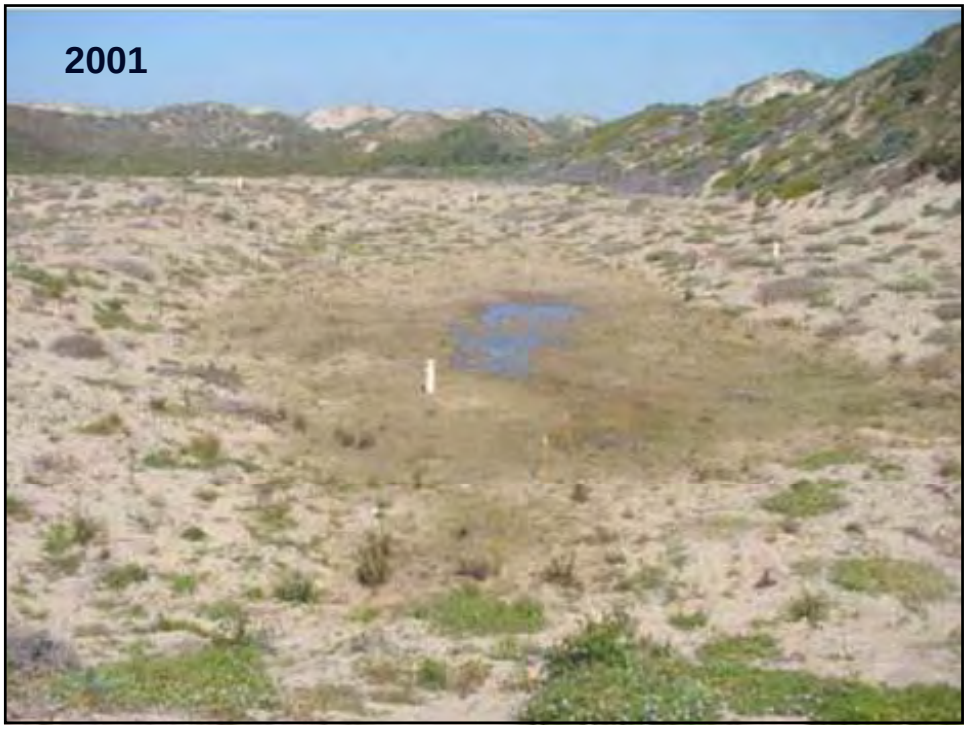
PLANTS USED FOR PHYTOREMEDIATION

Sunflower	Arsenic
Willow	Cadmium
Indian Mustard	Lead
Barley	Salt
Poplars	Chlorinated Solvents Hydrocarbons
Bullrush	Explosives
Beet, sorghum	Cesium

101

Guadalupe Oil Field
Cal Poly




2001

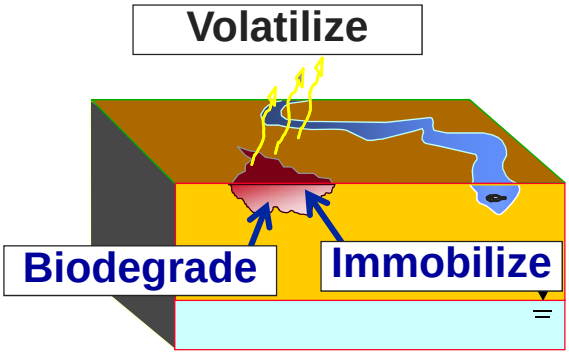

2005
SBL
AW
2005. 04. 18


HOLT
Phys
FOURTH EDITION
CHEMISTRY
The Molecular Nature of Matter and Change
Prentice Hall
Biology
BERG
106

Monitored Natural Attenuation

In Situ Treatment Technologies for Contaminated Soil

ENGINEERING FORUM ISSUE PAPER



EPA United States Environmental Protection Agency

Monitored Natural Attenuation of Inorganic Contaminants in Ground Water

Volume 1

Technical Basis for Assessment

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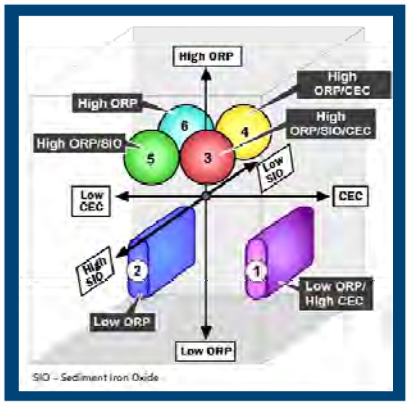
The Scenarios Approach to Attenuation-Based Remedies for Inorganic and Radionuclide Contaminants



Michael Truex, Pat Brady, Charles Newell, Michal Rysz,
Miles Denham, and Karen Vangelas

Three Key Factors for Metals & Rads Immobilization

ORP: ***Oxidation Reduction Potential***
Translation: Oxygen or no oxygen?

CEC: ***Cation Exchange Capacity***
Translation: Lot of reactive clay?

SIO: ***Sediment Iron Oxide***
Translation: Red soil?

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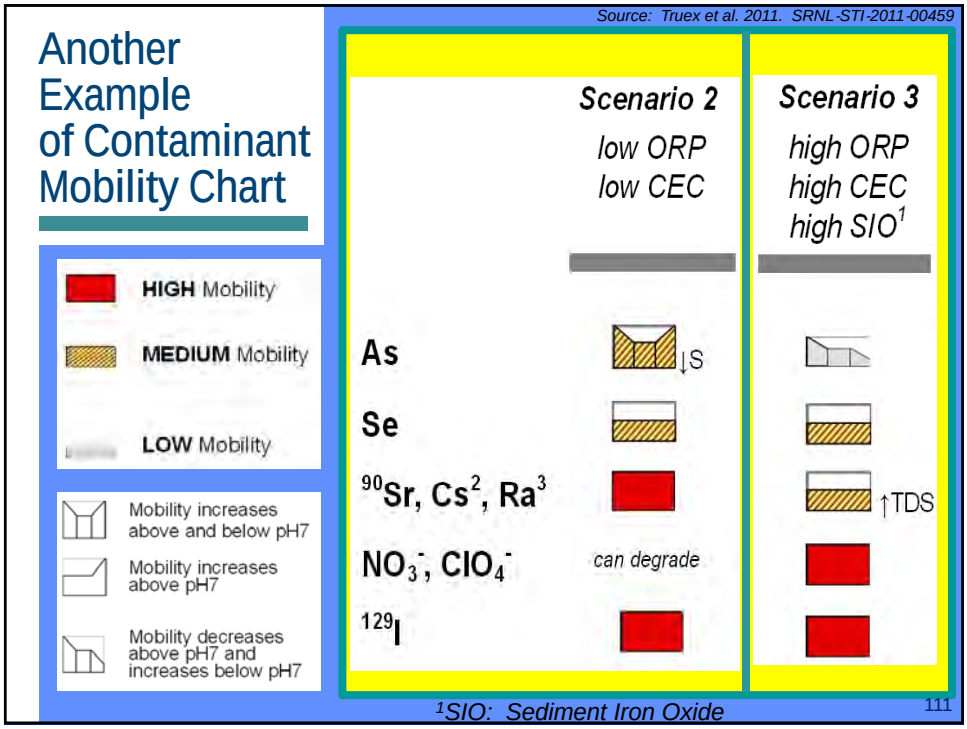
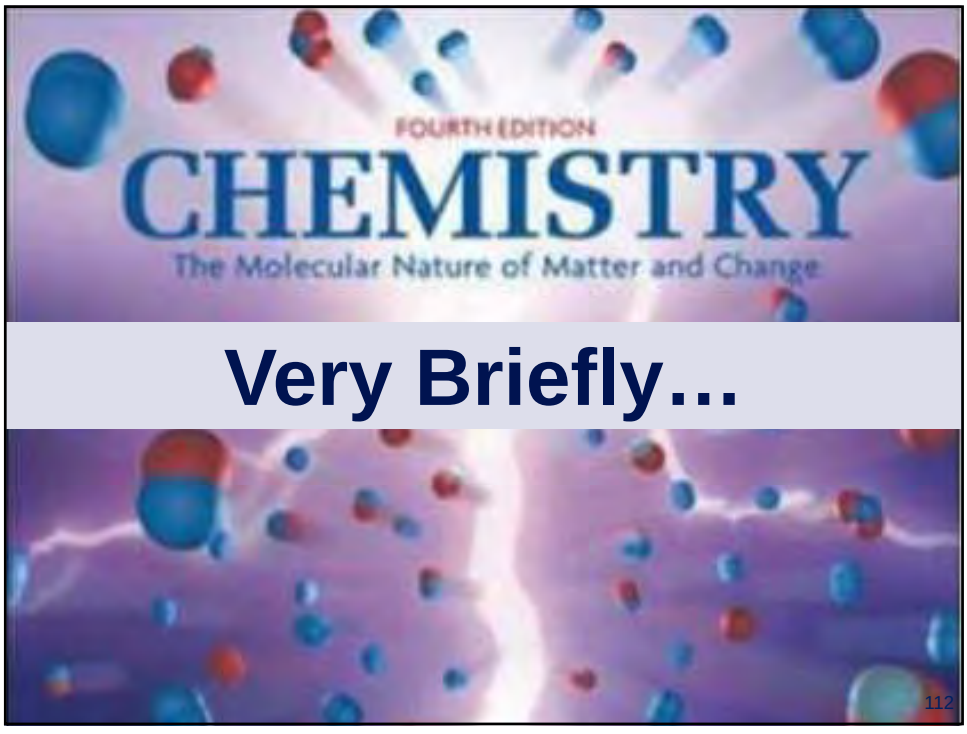

Another Example of Contaminant Mobility Chart
Source: Truex et al. 2011. SRNL-STI-2011-00459
HIGH Mobility
MEDIUM Mobility
LOW Mobility
Mobility increases above and below pH7
Mobility increases above pH7
Mobility decreases above pH7 and increases below pH7
Scenario 2
low ORP
low CEC
Scenario 3
high ORP
high CEC
high SIO1
As
↓S
Se
90Sr, Cs2, Ra3
↑TDS
NO3-, ClO4-
can degrade
129I
1SIO: Sediment Iron Oxide
111


FOURTH EDITION
CHEMISTRY
The Molecular Nature of Matter and Change
Very Briefly…
112

Very briefly….

- Solidification / Stabilization

- Electrokinetic Separation

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When Do I Use What Hammer?

Usually Look at Excavation

- Reliable, proven technology
- Sometimes cost, community concerns

In-situ Remediation - Immobilization

- Can be complicated – lots of physics, chemistry, biology
- Lots of rules (and exceptions!) (see next slides)

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Better ○
Average ◑
Worse ●

	Nonhalogenated VOCs	Halogenated VOCs	Nonhalogenated SVOCs	Halogenated SVOCs	Fuels	Inorganics	Radionuclides[1]	Explosives
In Situ Physical/Chemical								
Soil Vapor Extraction	○	○	●	●	○	●	●	●
Solidification/Stabilization	●	●	◗	◗	●	○	○	●
Chemical Oxidation	◗	◗	●	◗	●	S	●	◗
Soil Flushing	○	○	◗	◗	◗	○	●	●
Electrokinetic Separation	◗	◗	◗	◗	●	○	◗	●
In Situ Biological Treatment								
Bioremediation	○	○	○	S	○	S	S	○
Bioventing	○	○	○	●	○	●	●	●
Phytoremediation	◗	◗	◗	S	◗	◗	●	●
In Situ Thermal								
Thermal Treatment (electrical resistivity heating, steam injection and extraction, conductive heating, radiofrequency heating, and in situ vitrification)	○	○	○	○	○	●	●	●

www.epa.gov/tio/tsp/download/542f06013.pdf

115

	Fuels (F)
Soil Vapor Extraction	○ Light ● Heavy
Chemical Oxidation	○
Bioremediation	○
Phytoremediation	◑
Thermal	○

Better ○ Average ◑ Worse ●

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For detailed info, see EPA's 1996 Technology Screening Guide for Radioactive Sites.	**Radionuclides (R)**
Soil Vapor Extraction	
Solidification/Stabilization	
Bioremediation	*Depends*
Phytoremediation	
Electrokinetic Stabilization	

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Key Resources Regarding Hammers

1. **EPA Citizen's Guide to Technology**

   Google: epa Citizen's Guide remediation technology

2. **Federal Remediation Technologies Roundtable**

   http://www.frtr.gov/

3. **U.S. EPA's In-Situ Treatment Technologies for Contaminated Soil**

   www.epa.gov/tio/tsp/download/542f06013.pdf

4. **Environmental Consultants and Vendors**
5. **Regulatory Agencies**
6. **Universities**
7. **Interstate Technology & Regulatory Council**

   http://www.itrcweb.org/

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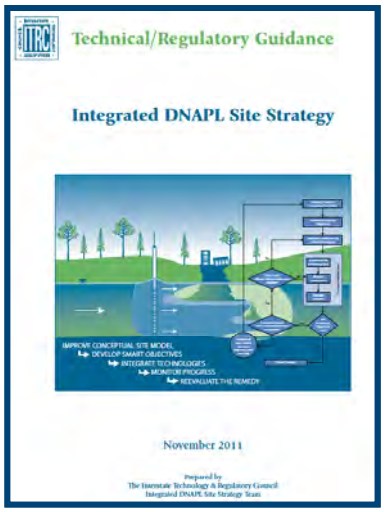
Functional Objectives Should be SMART

SMART means:

- Specific
- Measureable
- Attainable
- Relevant
- Time-bound



http://www.itrcweb.org/guidancedocument.asp?TID=70

119

What's the Game, What Are the Rules

1. Releases Happened
2. You've Got Find It
3. Pick the Hammer You Are Going To Use
4. Use the Hammer

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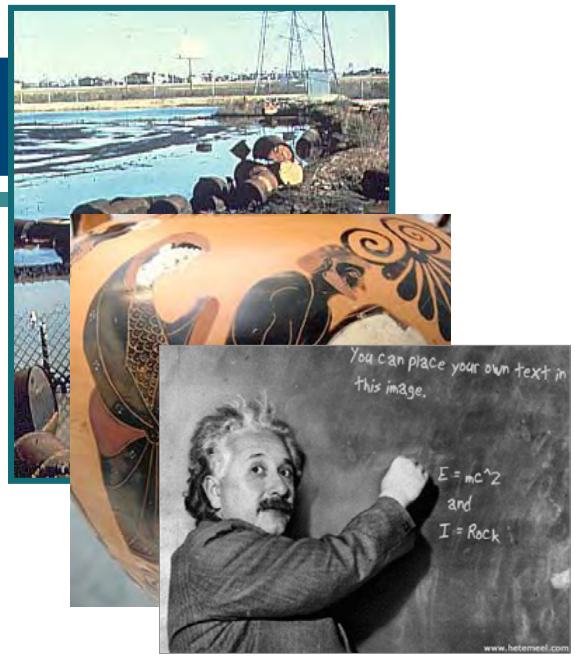
THERE'S A PROBLEM..



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Four Main Hammers..

Dig and haul

Change and move to surface

Convert with bugs or chemicals

Immobilize

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We Can Make It Better