In-situ and Ex-situ Soil and Groundwater Remediation using Chemical Oxidation Technologies

Remtech 2006, Banff, Canada

October 13th, 2006

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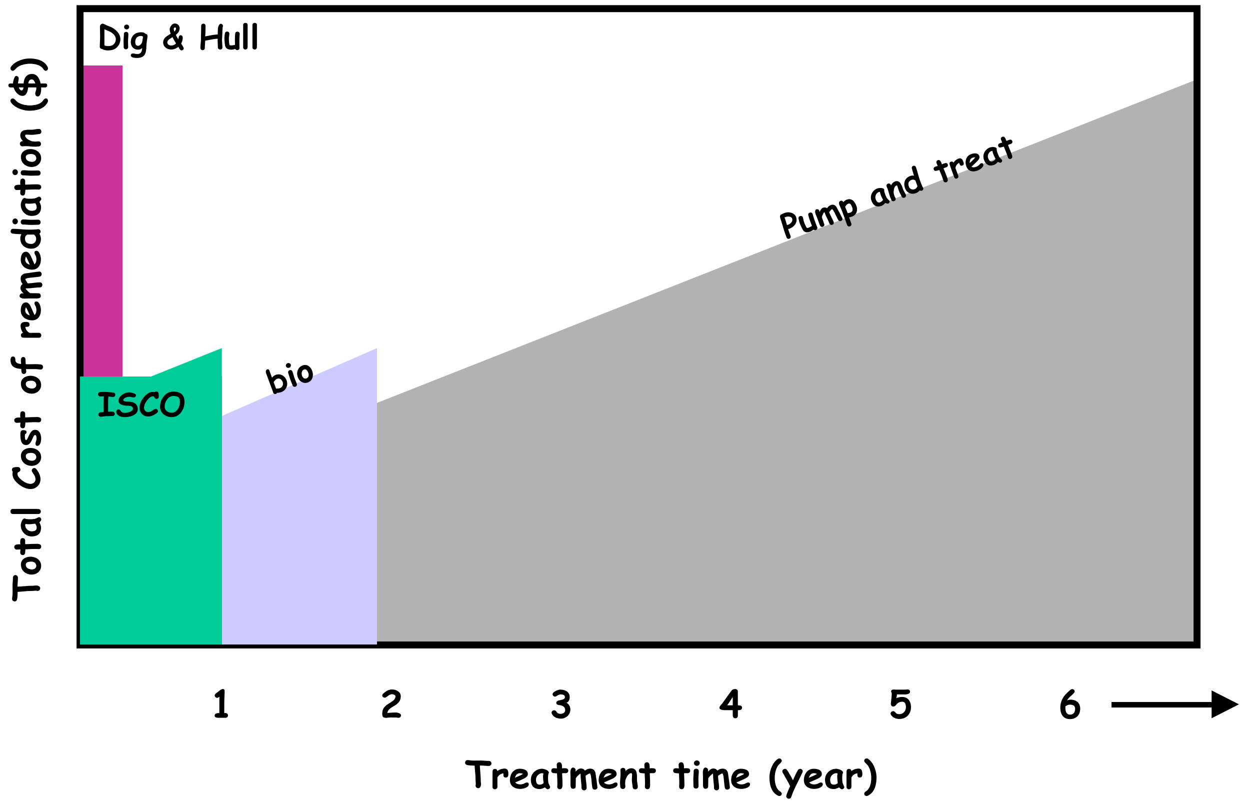
SOLUTIONS AND ENVIRONMENTAL PRODUCTS
WATERS - SOILS - AIR

Typical decontamination techniques

- Dig and Hull
- Pump and Treat
- Soil Vapour Extraction under vacuum with or without air/steam injection
- Chemical Oxidation In-situ//Ex-situ
- Monitored Natural Attenuation
- Reactive Barriers
- Thermal degradation

Remediation time and cost



Chemical Oxidation In-situ//Ex-situ

- Oxidants are introduced or mixed into the soil and groundwater to attack the organic contaminants
- Chemical oxidation treatments are commonly used in potable and wastewater applications
- Oxidants are non-specific and will react with the targeted contaminants AND with the soil organic content.
- Chemical oxidation reactions involve the transfer of electrons and the breaking of chemical bonds
- Water is the carrier for the oxidants used in chemical oxidation (except for ozone)

Common Chemical Oxidants

- **Potassium or sodium permanganate**
- **Hydrogen Peroxide alone**
- **Catalyzed Hydrogen Peroxide**
  - Hydrogen Peroxide with iron (regular Fenton reagent reaction)
  - Need to establish acidic conditions (ideal pH between 4 and 6)
  - Modified Fenton Reagent with chelated species (neutral pH)
- **Ozone**
  - Ozone is a gas and must be produced on site
  - The gas must be injected into the soil
- **Persulfate**
  - Requires activation to generate free sulfate radicals.
  - Heat, chelated metal, high pH or hydrogen peroxide can be used to activate the persulfate. Activation method can be adapted to site conditions.
- **Percarbonate**
  - Requires activation to generate free radicals

- **NOTES:**
  1. **ALL THESE PRODUCTS REQUIRE ADEQUATE HANDLING PRATICES AND SAFETY EQUIPMENT.**
  2. **Chemical oxidation can slow down the biological activity but will NOT sterilize the soil completely (benefit because of lower toxicity after the Chem-Ox)**

Oxidant	Potential (V)	Form	Persistence in soil
Fenton Reagent (OH*)	2.8	Liquid	Low 2 to 5 days
Perozone (O_3 + OH*)	2.8	gas/Liquid	Very Low 20 min to 2 days
Persulfate activé (SO_4^-)	2.6	Liquid/ suspension	Medium 10 to 30 days
Ozone (O_3)	2.42 2.07	gas	Very Low 20 min to 2 days
Persulfate (S_2O_8 2-)	2.01	Liquid/ suspension	Medium 10 to 30 days
Hydrogen Peroxide (H_2O_2)	1.78	Liquid	Low 2 to 5 days
Permanganate (MnO_4^-)	1.68	Salt/Liquid	High More than 3 month

Ref. John Cherry & M. Marley, U. of Waterloo Workshop, 2003

Conditions for Selecting Chemical Oxidation

	Chemical Oxidation Applicability	Limitation / Disadvantages	Possible Alternative Options
Mobile NAPL	Probably not the best choice	High oxidant requirement ($)	Liquid Extraction Thermal degradation
Residual NAPL (10,000's ppm)	Yes, but difficult	High oxidant requirement ($)	Extraction with air/steam injection Thermal degradation
High conc. in soil/groudwater (10's – 1,000's ppm)	Yes, good conditions	Normal considerations	Extraction with air/steam injection Bioremediation
Dissolved plume (< 1 mg/L)	Yes, but could be costly	Higher cost due to SOD	Bioremediation, Reactive barriers

Source : ITRC 2004

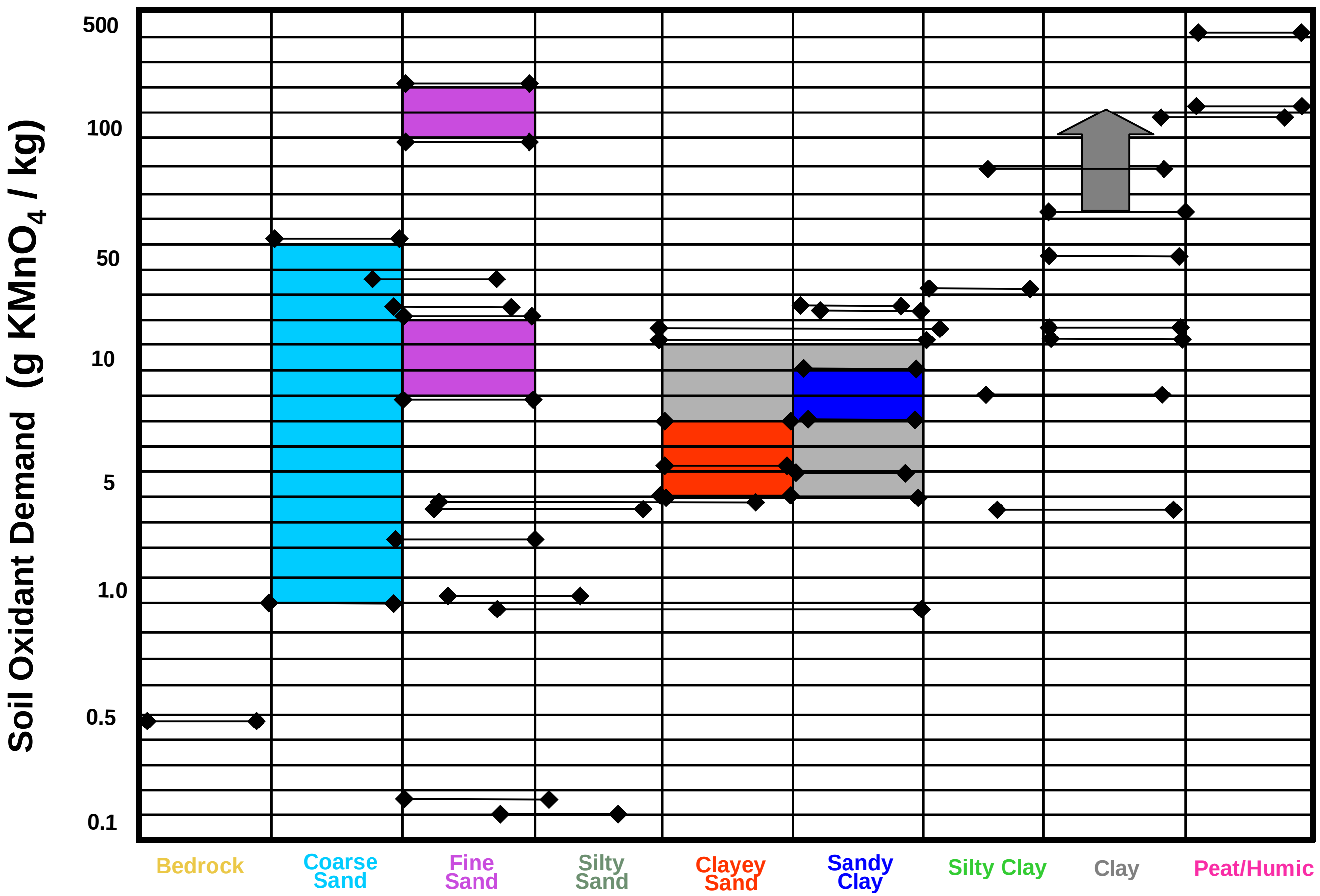
NAPL: Non-Aqueous Phase Liquid

Soil Oxidant Demand (SOD)

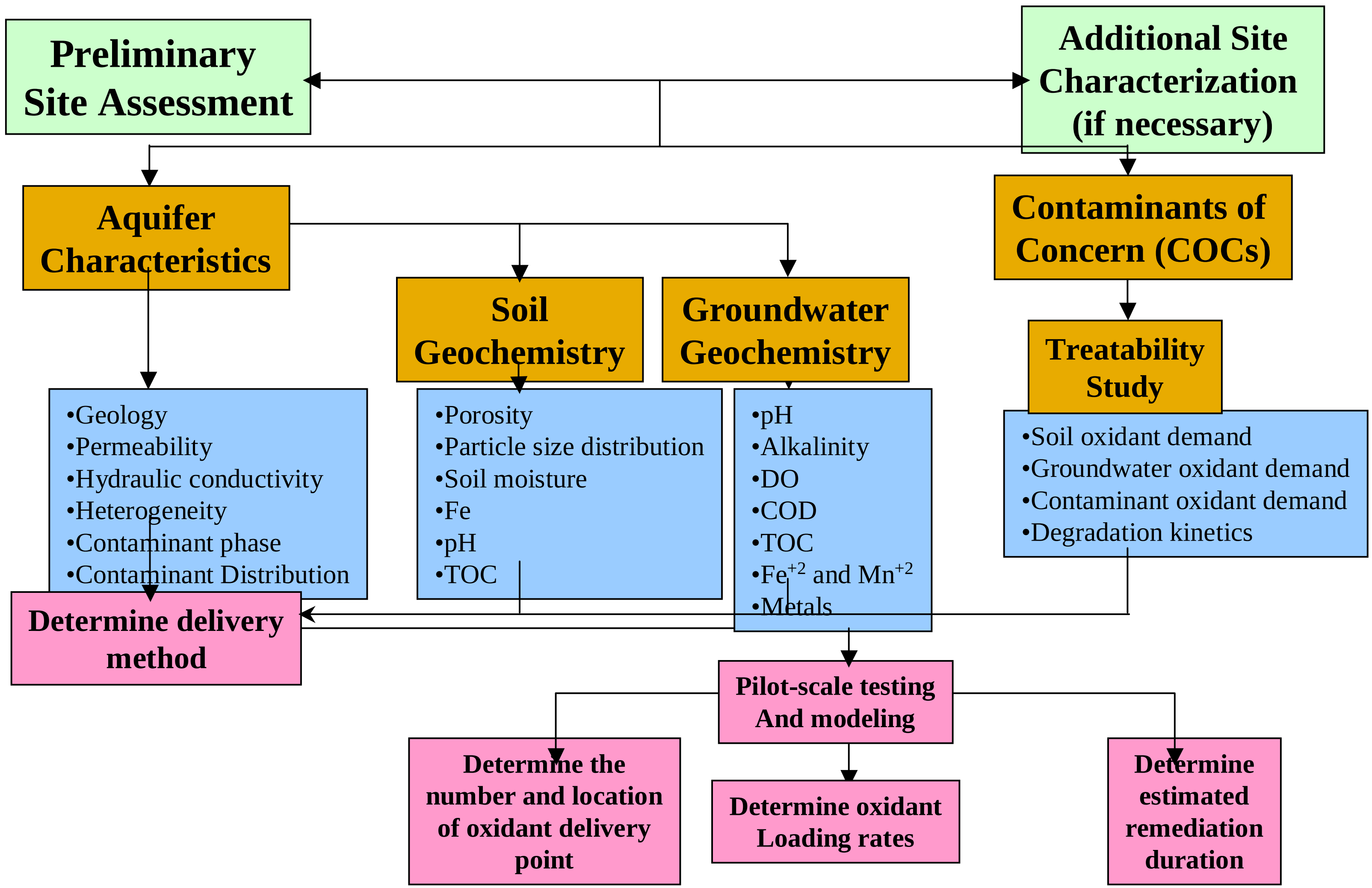
- Any oxidant will react and be consumed by the organic material contained in the soil and by some minerals.
- Bench scale testing and/or pilot testing are recommended for better and more exact SOD evaluation

Soil Oxidant Demand (SOD)

(adapted from Shaw E & I presentation - 2003)



Carus Haz Rem Assessment Process



(Adapted from R. L. Siegrist et al., "Principles and Practices of In Situ Chemical Oxidation Using Permanganate", p. 202.)

Compatibility oxidant/contaminant

Contaminant/Oxydant	MnO_4	S_2O_8	SO_4*	Fenton's	Ozone
Petroleum Hydrocarbon	L	G/E	E	E	E
Benzene	L	G	G/E	E	E
Phenols	G	L/G	G/E	E	E[1]
Polycyclic Aromatic Hydrocarbon (PAH)	L	G	E	E	E
MTBE	L	L/G	E	G	G
Chlorinated Ethenes (PCE, TCE, DCE, VC)	E	G	E	E	E
Carbon Tetrachloride	L	G	L/G	L/G	L/G
Chlorinated Ethanes (TCA, DCA)	L	G	G/E	G/E	G
Polychlorinated Biphenyls (PCB)	L	L	L	G/E	G[1]
Energetics (RDX, HMX)	E	G	E	E	E

L=Low G=Good E=Excellent 1=Perozone

Source: Carus Chemical Company

Geological Considerations

Geological Considerations	MnO_4	S_2O_8	SO_4^*	Fenton's	Ozone
Non-consolidated material					
• Sand and gravel	E	E	E	E	E
• Silty sand	G/E	G	G	L	L
• Mixed	G/E	G/E	G	L	L
Consolidated material					
• High flow	E	E	L/G	L/G	L/G
• Low Flow	G	G	G	L	L

L=Low G=Good E=Excellent

Source: Carus Chemical Company

Hydrogeological considerations

Hydrogeological considerations	MnO_4	S_2O_8	SO_4*	Fenton's	Ozone
Saturated Zone	E	E	G	G	G
Non-saturated Zone	G *	L/G	L/G	L/G	G
with groundwater flux:					
• slow	G	G	G	L	L
• fast	G	G	G	G	G

L=Low G=Good E=Excellent * If temporarily flooded.

Source: Carus Chemical Company

Geochemical Considerations

Geochemical Considerations	MnO_4	S_2O_8	SO_4^{*}	Fenton	Ozone
Presence of carbonates	E	E	G	L	L
High dissolved metal content	L	G	E	E	L
High organic matter content	L	G	G	L	L

L=Low G=Good E=Excellent

Source: Carus Chemical Company

Additional Considerations

Criteria	MnO_4	S_2O_8	SO_4*	Fenton	Ozone
Gas Production	Low	Low	Low	High	High
Heat Production	Low	Low	Low	High	Low
Fugitive Emissions	Low	Low	Low	High	High
Availability	E	E	E	E	G
Ease of handling	G/E *	E	E	G	G
Impact on water quality	Mod.	Mod.	Mod.	Mod.	Low
Patent Restrictions	Low	High	High	High	High
Technological Development	E	L	G	E	G
Information availability	G	L	G	G	G
Field trial	G	L	G	G	G

L=Low G=Good E=Excellent Mod. = Moderate * Sodium

Source: Carus Chemical Company

Additional considerations (2)

- **All oxidants can change the oxidation state of metals and thus increase their solubility and mobility**
- **Metals of particular concern are: chrome, lead, uranium, selenium, vanadium**
- **In most of these cases, the metals will come back in their reduced state once all of the oxidant has been consumed by the environment**
- **Impurities contained in the oxidant must be evaluated**
- **In the case of arsenic, oxidation will help immobilizing the metal by reducing its solubility**

Who we are

CHEMCO inc.

SOLUTIONS AND ENVIRONMENTAL PRODUCTS
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- Canadian Company founded in 1988
- Production and warehouse facilities in Quebec and throughout Canada vs Strategic Business Alliances
- Sectors of activity
  - Industrial and Municipal Waste Water
  - Contaminated Soil and Groundwater
  - Air, Odours and Atmospheric Emissions
  - Process Water
- Products: coagulants, flocculants, nutrients, preparations of bacterial strains, oxidants, catalysts, oxygen and hydrogen release compounds, odour control agents
- Services: technical support, product supply and sourcing, logistics, laboratories, design, and staff training.

Acknowledgements

- Carus Chemical
- ERM Corporation
- FMC Corporation
- Progressive Engineering & Construction

Thank you for your attention !

Have a good day !!!

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