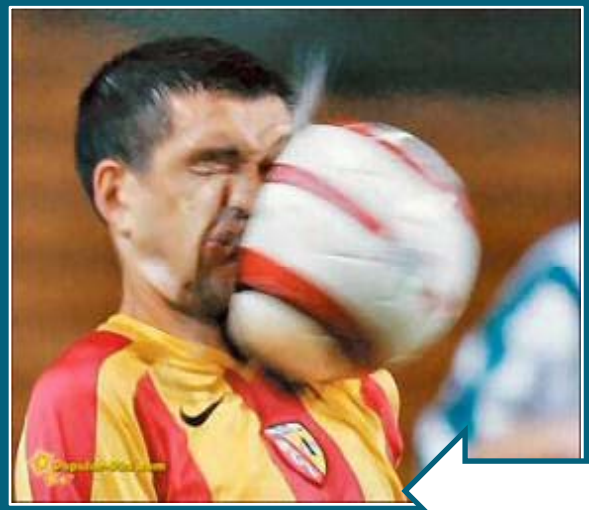
EXO TECH, INC.
Remediation Solutions Provider

- Specialize in innovative chemical delivery-based solutions (completed over 125 injections/blending applications at 75 + sites since 2006).
- We provide ISCO/ISCR/Enhanced Bioremediation/ In-Situ/Ex-Situ Blending/In-house treatability/ Remedial characterizations (DPT-Mobile Lab, MIP, LIF, etc.) & closure strategies.

- Offer “best fit” solutions tailored to each site.
- Sites treated include industrial (RCRA), fuel spill sites, dry cleaners, brownfields, wood treatment facilities, etc.

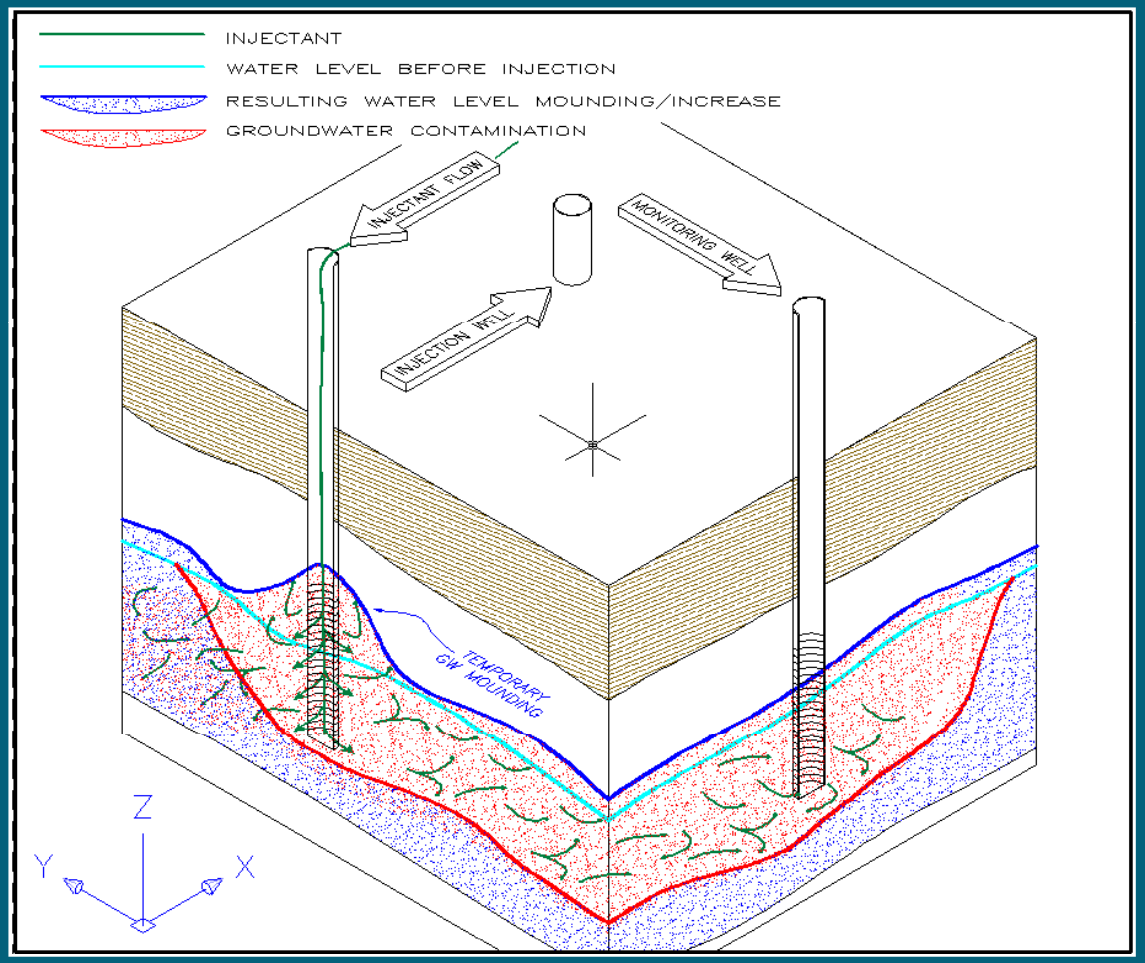
What is Chemical Oxidation?



- Chemical Oxidation: Breaking bonds of organic molecules and inserting oxygen.
- End products are carbon dioxide, water, and harmless salts.
- Application methods include ISCO (direct injection), In-place soil blending, and Ex-Situ soil blending.
- Used for source area or small area ("spot" treatments) as well as larger plume sites.
- Treatment works on contact – need full oxidant contact for success.

In-Situ Chemical Oxidation (ISCO)

- ISCO involves low pressure injection to treat contaminants in “smear zone” above/below water table.
- Successful ISCO clean-ups involve proper oxidant selection and testing to determine dosing requirements.
- To reach target goals, desorption of contaminants from soil matrix into the groundwater is required.



Conceptual Drawing of ISCO Process

In-Place Soil Blending/Ex-Situ Blending

- In-place soil blending utilizes high speed blending technology to mix oxidants or other amendments directly into vadose zone and saturated soils.
- Ex-Situ soil blending generally utilizes modified pug mill for chemical treatment prior to returning to the excavation. This method offers maximum oxidant contact.
- Treated soils can be stabilized using lime derivative chemical blends to allow re-use. Performance guarantees are available for some sites.
- Soil blending methods are "green friendly" promoting recycling vs. dig-n'-haul and off-site land filling.

Types of Chemical Oxidants

Common oxidants include:

- Catalyzed hydrogen peroxide (CHP)
- Activated sodium persulfate

- Sodium and potassium permanganate
- Surfactant enhanced oxidation

Oxidant Descriptions

Catalyzed Hydrogen Peroxide (CHP)/Modified Fenton's

- CHP or modified Fenton's consists of hydrogen peroxide combined with an iron catalyst (chelates, iron salts), producing hydroxyl radicals (OH^-).
- Basic chemical reaction: **$H_2O_2 + Fe^{+2} \rightarrow OH^- + OH^- + Fe^{+3}$.**
- Efficient in a short period of time/breaks down soil structure.
- Effective on a variety of hydrocarbons including NAPL.
- Effective on recalcitrant compounds including PAHs, PCBs, and Dioxins.
- Exo Tech's citrus based chemical stabilizers increase longevity of reaction.
- Long-term CHP reactions may also be produced using calcium peroxide.
- Can easily combine use of CHP with mechanical extraction. ***High viscosity products (i.e. coal tar and creosote) may be "thinned" using CHP and extracted***.

Oxidant Descriptions (cont.)

Activated Sodium Persulfate

- Oxidation is performed by combining sodium persulfate with a catalyst to release sulfate radicals.
- Reaction: **$S_2O_8^{-2}$ + activator → $SO_4^{\cdot -}$ + ($SO_4^{\cdot -}$ or SO_4^{-2}).**
- Common activators include: heat, metal catalysts (iron), H_2O_2, and pH buffers (<3 or >10), high pH buffering is preferred.
- Sulfate radicals comparable in oxidation strength to OH^- radicals.
- Sulfate radicals have a long persistence in subsurface (30-60 days) and lower natural oxidant demand.
- Successful utilized on recalcitrant compounds such as PAHs, PCBs, and Dioxins.
- Can be combined with oxygen release compounds to facilitate in "treatment train" approach using aerobic bioremediation.

Oxidant Descriptions (cont.)

Sodium of Potassium Permanganate

- The permanganate ion is a selective oxidant that works well on double-bonded chlorinated ethenes (PCE, TCE) and can also treat phenols, PAHs, pesticides, explosives, and some aromatics (not benzene).
- Basic reaction for TCE oxidation:

$$2KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3Cl^- + H^+$$

- Weaker than radical oxidation: 1.7 eV as compared to 2.6 eV for $SO_4^{\cdot -}$ and 2.7 eV for OH^-.
- Long persistence in the subsurface (up to a year).
- Purple color aids in determining radius of influence (ROI).
- Current research focuses on surfactant use with permanganates and slow release applications.
- Exo Tech has successfully used permanganate for treatment of PAHs.

Oxidant Descriptions (cont.)

Surfactant Enhanced Oxidant Blends

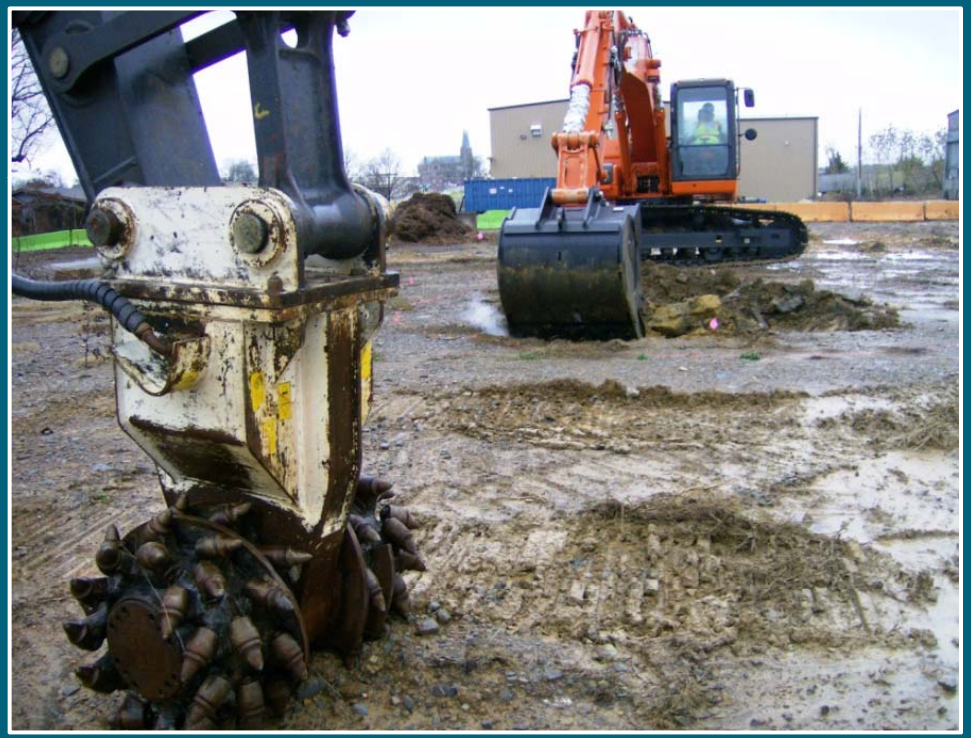
- Surfactants are utilized to break down the interfacial tension between the fuel/oil and soil particles, creating an emulsion.
- Emulsions allow more effective oxidant treatment of NAPL/“hot” pockets.
- Oxidant and surfactant must be compatible to avoid excessive oxidant degradation (in some cases separate applications of surfactant followed by oxidant may be preferred).
- Surfactants may consist of biodegradable (proprietary products like Verusol®) or commercially available products.

Enhanced Bioremedial/Chemical Reduction

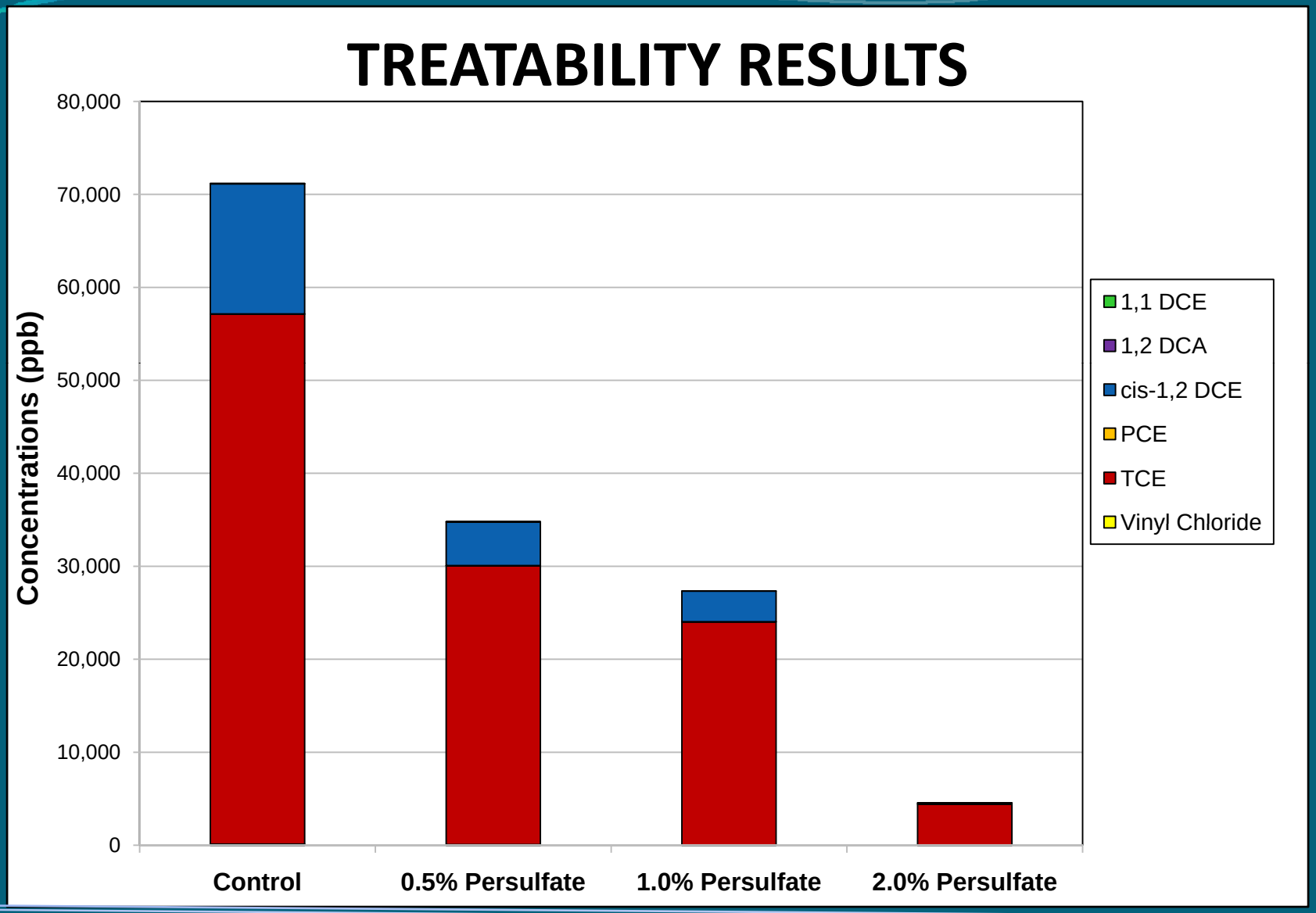
- Enhanced bioremedial and chemical reduction/ISCR applications may be applied through direct injection or via In-Situ/Ex-Situ soil blending methods as described.
- Oxygen release products provide aerobic treatment of BTEX, fuels, PAHs, etc. and can be combined chemical oxidation.
- Emulsified oils, lactate-release products, ZVI, etc. are used to supply a hydrogen source for anaerobic reductive de-chlorination.
- ZVI and nZVI are also used in chemical reduction applications which are generally slower than chemical oxidation but faster than bioremediation. The reduction process involves adding electrons often used for substitution (i.e. H^+ for Cl^-) under strongly reducing conditions.
- Chemical reduction is commonly used for the treatment of large chlorinated plumes, metals, explosives, and related contaminants.

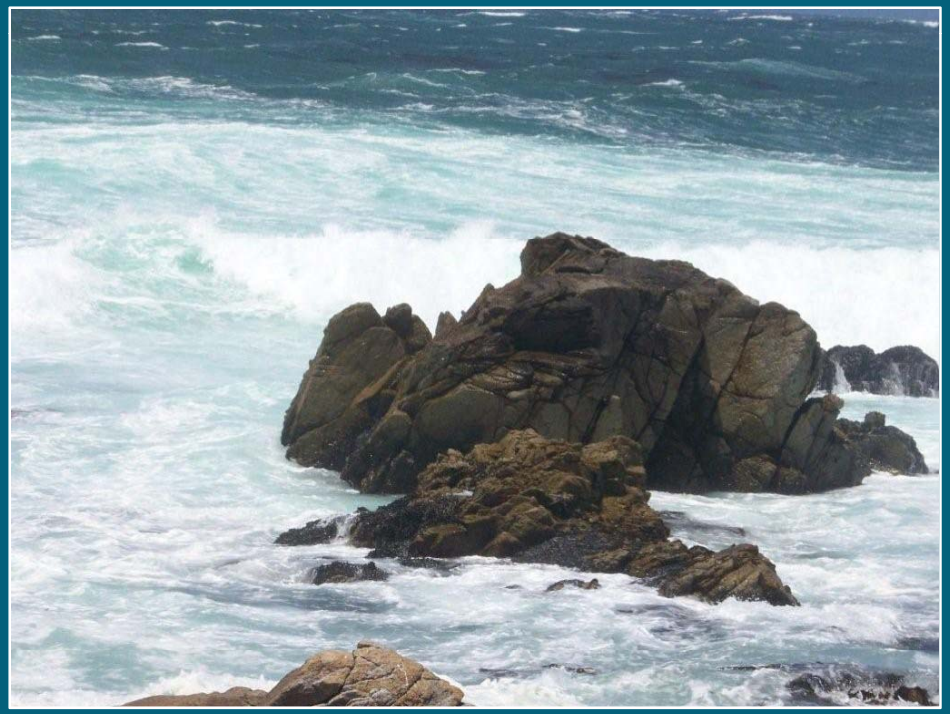
Select Case Studies

1) Brownfield Site – Cullman, AL



Brownfield Site – Cullman, AL



Other Case Studies

- Additional case studies can be found under FMC's website:
  - http://www.envsolutions.fmc.com/Klozur/ResourceCenter.aspx