Survey of ISCO Applications in GA-
A Critical Review of Factors Contributing to Success

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Introduction and Purpose of Talk

- Evaluation included 65 sites in Georgia treated with ISCO.
- Sites obtained from internal databases and state files.
- Review intended to broaden the industry’s understanding of ISCO applications performed without focusing on individual sites.
- Site names and facility ID’s were omitted.

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What is In-Situ Chemical Oxidation?

- Chemical Oxidation involves breaking bonds of organic molecules using aggressive oxidant radicals and oxidative compounds.
- End products are carbon dioxide, water, and harmless salts.
- ISCO generally involves low to moderate pressure injections to treat contaminants in “smear zone” above/below the water table.
- 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! To reach target goals, desorption of contaminants from soil matrix into the groundwater is required.

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Types of Chemical Oxidants

Common oxidants include:

- Catalyzed Hydrogen Peroxide (CHP) or Modified Fenton’s
- Activated Sodium Persulfate
- Sodium and Potassium Permanganate
- Specialty Oxidants/Proprietary Products

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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 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.
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- Can produce Modified Fenton’s through in-situ generation of peroxide using peroxxygen compounds.
Activated Sodium Persulfate

- Oxidation is performed by combining sodium persulfate with a catalyst to release sulfate radicals.
- Reaction: $\text{S}_2\text{O}_8^{-2} + \text{activator} \rightarrow \text{SO}_4^{-} + (\text{SO}_4^{-} \text{ or } \text{SO}_4^{-2})$
- Common activators include: heat, metal catalysts (iron), $\text{H}_2\text{O}_2$, and pH buffers ($<3$ or $>10$), high pH buffering is preferred.
- Sulfate radicals comparable in oxidation strength to $\text{OH}^{-}$ radicals.
- Sulfate radicals have a long persistence in subsurface (30-60 days) and low natural oxidant demand.
- Successful on a variety of VOCs and recalcitrant compounds.
Oxidant Descriptions (cont.)

Sodium or 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).
- Weaker than radical oxidation: 1.7 eV as compared to 2.6 eV for $\text{SO}_4^{2-}$ and 2.7 eV for $\text{OH}^{-}$.
- Long persistence in the subsurface (up to a year).
- Purple color aids in determining radius of influence (ROI).

Potassium Permanganate Candle
for Barrier Treatment

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ISCO Site Evaluation Overview

- Sites were grouped by geologic province, oxidant chemistry, regulatory type/status.

- The data set was biased toward site availability.

- The majority of the sites were UST facilities located in the GA Piedmont province treated using activated persulfate.

- Sites with pilot injections were evaluated as initial or “spot” treatment applications.

- Sites were placed in 4 categories:
  1) Successful in achieving target goals (“spot” clean-up or full scale);
  2) Partially successful or success derived from combining remedial technologies;
  3) Unsuccessful; and
  4) Unknown or confirmatory data not available (5%).

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Geologic Provinces

- Piedmont (75%)
- Piedmont/Blue Ridge (3%)
- Coastal Plains (17%)
- Valley and Ridge (5%)

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ISCO Chemistry

- Permanganate (7%)
- Activated Persulfate (63%)
- H$_2$O$_2$, CHP, Fentons (25%)
- Other (5%)
Site Categories

- UST (65%)
- HSRA (19%)
- VRP (8%)
- Non HSI/Brownfield (4%)
- RCRA (4%)

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Evaluation of ISCO Performance

- Successful (35%)
- Unsuccessful (43%)
- Unknown/Confirmatory results not available (5%)
- Partially/Success with use of another technology (17%)

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Factors Contributing to ISCO Success

- Lower volume of sorbed contamination in saturated soils.
- Higher oxidant doses generally employed with tighter injection spacing.
- 13 of the sites were completed with 1 or 2 injection applications, with 10 sites requiring multiple injections.
- Only 2 sites had “soil only” treatments. Both were successful due to the presence of denser saprolite below the injection zone which aided in horizontal distribution.
- Success occurred using all oxidant chemistries and in different lithologies.
- Delivery methods (i.e. injection through wells vs. DPT rods) did not appear to affect outcome.
Factors Contributing to Partial Success

- This category includes sites where success could only be achieved with supplemental technologies (extraction, mobile MPE, SVE, source removal, soil blending, enhanced bio, etc.)

- These sites often contained higher saturated soil mass or had areas too large to cost effectively treat with ISCO alone.

- Sites containing non-aqueous phase liquids (NAPL) seemed to be more successful when extraction followed ISCO.
Factors Contributing to ISCO Failures

- Underestimating volume of saturated soil in delivery area.
- Low permeability soils- do a pilot first!
- Poor application strategy (injecting into existing wells).
- Too much sorbed mass present to enable treatment with a handful of low volume injections.
- Unreported subsurface conditions (fill, PWR, utilities, etc.)
- Poor combinations of oxidants (1 site used persulfate/permanganate, use of persulfate to treat NAPL etc.)
- Lack of geochemical data to determine oxidant spread (ROI).
Tips for a Successful ISCO Treatment

- Collect saturated soil samples - get enough samples to evaluate saturated source mass.
- Calculate approximate groundwater contamination you expect from saturated soil mass using partitioning coefficients. \( C_w = \frac{S_c}{K_d} \)
- Determine approximate pore volume (several sites reviewed only treated 1-5% of the plume area!)
- Analyze soil samples for TPH or total halogenated compounds to better assess chemical demand.
- Measure effectiveness in the field by taking geochemical readings.
Tips for a Successful ISCO Treatment - cont.

- Size/magnitude of source area often dictates remedial strategy more than plume extent.
- Most assessments focus on plume boundary delineation only.
- Many source areas are more extensive (horizontal/vertical) than suspected (see below).

Before Source Area Delineation

After Source Area Delineation

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Questions?

Please contact Envirorisk Consultants for assistance with ISCO design and support services.