Welcome to the
Database for ISCO (DISCO)

THIS DOCUMENT IS A PRODUCT OF THE DEPARTMENT OF DEFENSE (DoD) ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM (ESTCP), PRODUCED UNDER PROJECT ER-0623.

The Database for ISCO (DISCO) is an interactive tool that presents case study data from field-scale ISCO projects. DISCO is intended to be navigated via hyperlinks that appear as yellow boxed buttons, such as the two below. First-time users are encouraged to follow the link at left to the introductory material. Others may proceed directly to the query page.

go to introduction

go to query page

Introduction to DISCO

The Database for ISCO (DISCO) is an interactive database whose purpose is to share data from past ISCO projects as well as to provide some commentary to highlight key results. To query DISCO, users must provide inputs on the two main components that impact ISCO design and performance: Contaminants of Concern (COCs) being treated, including the presence of NAPL; and the subsurface geologic media in the treatment zone. This query format is primarily intended for users (e.g. RPMs, consultants, project owners) who are considering ISCO as a remediation technology at a particular site, and know what contaminants and geologic media must be treated. Those users who are interested in a more global view of ISCO that is independent of COC or geologic conditions may use the “select all” buttons on the query pages.

The contents of DISCO are based upon a collection of case studies compiled by the ER-0623 project team as a component of the ISCO Technology Practices Manual (TPM) project. The methods used are documented in Krembs (2008), a M.S. thesis that is available from the author at fkrembs@aquifersolutions.com, and is also included in the supplementary materials. An overview of the dataset and brief definitions of key metrics are included on the pages that follow. More extensive definitions are available in the DISCO Glossary. [NOTE: Glossary will only function if it is located in the same folder as this main pdf and retains the name “DISCO_Glossary.pdf”.]

As stated in the welcome page, this pdf document is meant to be navigated by hyperlinks, which appear as yellow buttons (e.g. bottom right) or green underlined text (e.g. DISCO Glossary). Reading this document in a linear manner is not advised. When hyperlinks do not appear on a page (e.g. the following pages of the introduction and first three pages of query results) the user should continue forward one page at a time until a hyperlink appears directing them back to the start of the search query. Users begin with the query input where they choose COCs and geologic media. They are then taken to the results of their query, which present case study data specific to their query. After viewing the query results, users may begin another query or return to the definitions pages.

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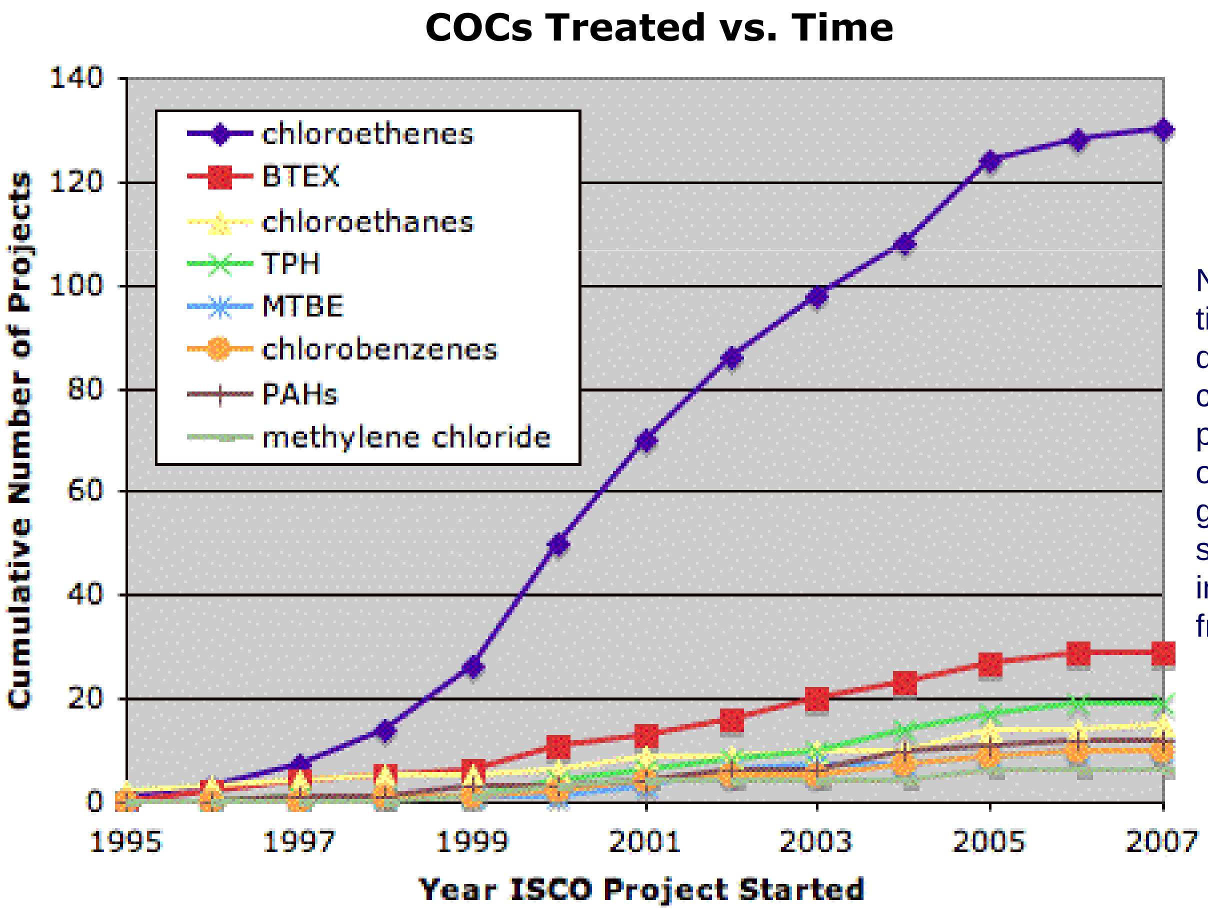
The Dataset Behind DISCO

DISCO is based on the results of a critical analysis of ISCO case studies (Krembs 2008, TPM Part III). This analysis included 242 ISCO projects from 42 U.S. states and 7 nations. An overview of the case study data is presented below and on the following pages. The graph below presents the cumulative number of projects over time subdivided by the COCs treated. Chloroethenes (e.g. PCE, TCE etc.) are the most commonly treated COC. Other organic compounds beyond those eight listed here have been treated with ISCO, but with a lesser frequency than those shown below.

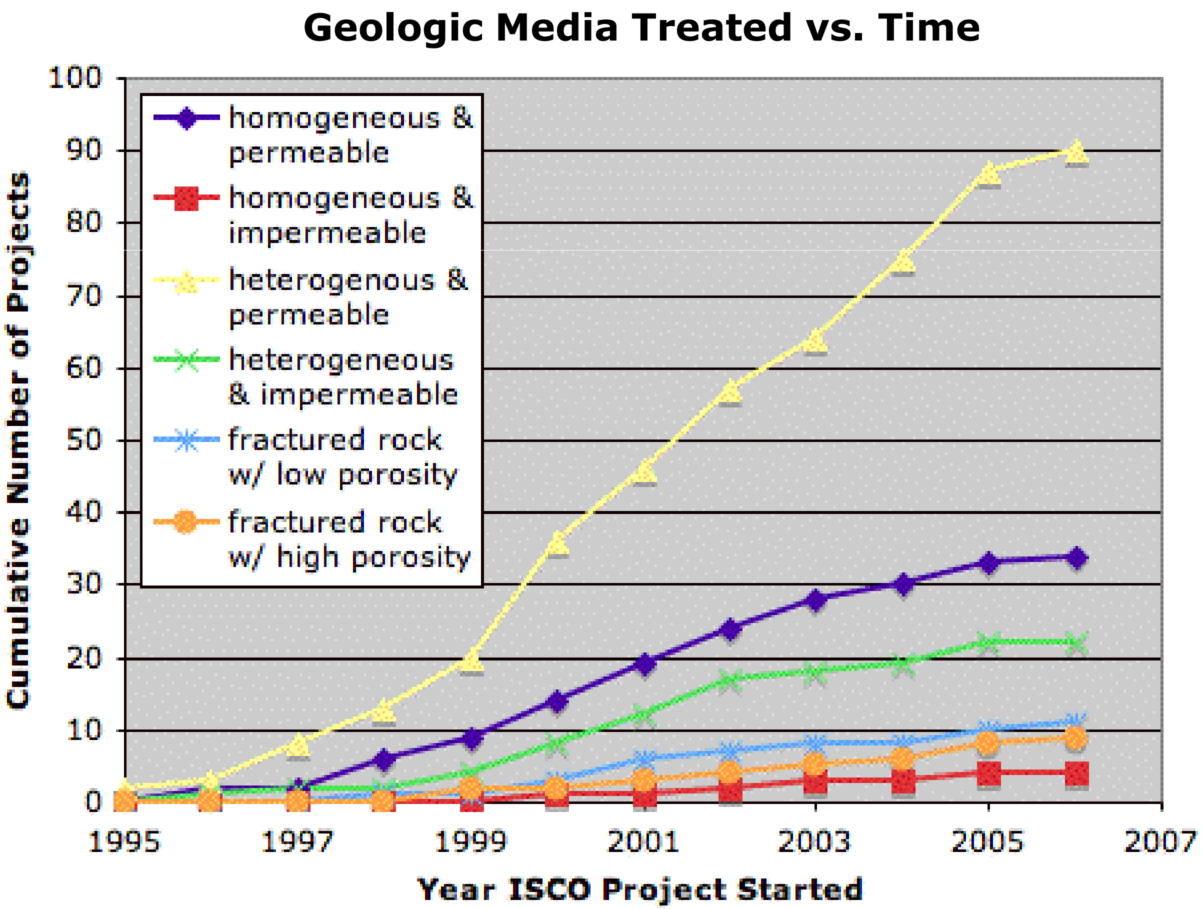


Notes: This graph and other time series data show a decrease in the slope of the curves at recent time periods. This is an artifact of the lag time required to get case study data, and should not be taken as an indication that ISCO's frequency of use is slowing.

(Continued on following page)

The Dataset Behind DISCO (cont.)

The geologic media treated vs. time is shown in the graph below. Permeable unconsolidated media (yellow and purple) have been treated with the greatest frequency, though there is an appreciable number of applications to impermeable soils and fractured rock. The definitions of these groups is shown on the following pages and is available in the DISCO Glossary.



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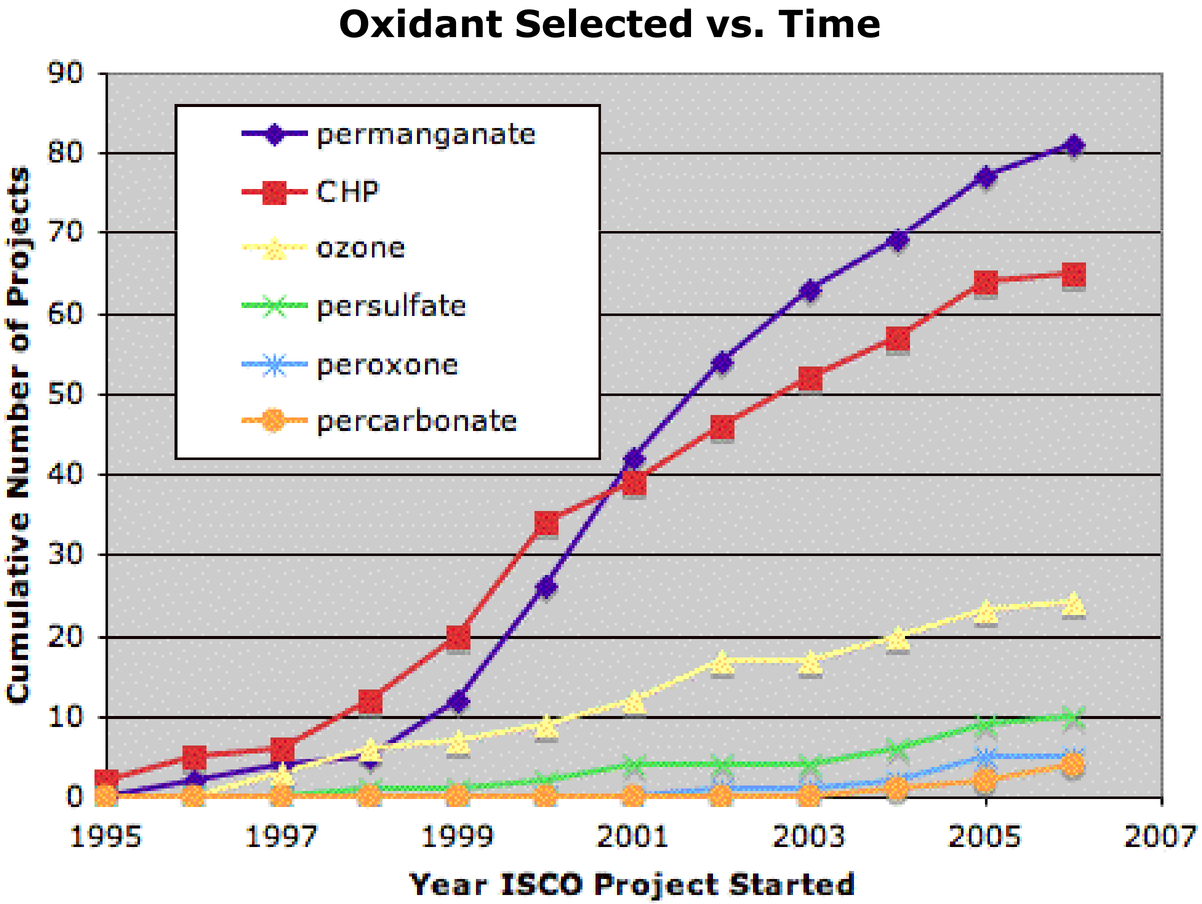
The Dataset Behind DISCO (cont.)

Of the six oxidants included in DISCO, permanganate and CHP were selected with the most frequency, while persulfate, peroxone and percarbonate are more recently developed. Ozone has been used at an intermediate frequency. The shape of these curves are similar to the frequency of oxidant studies presented in the literature and shown in the introduction to the TPM Part I, indicating that oxidants being studied in the laboratory are also being implemented in the field.



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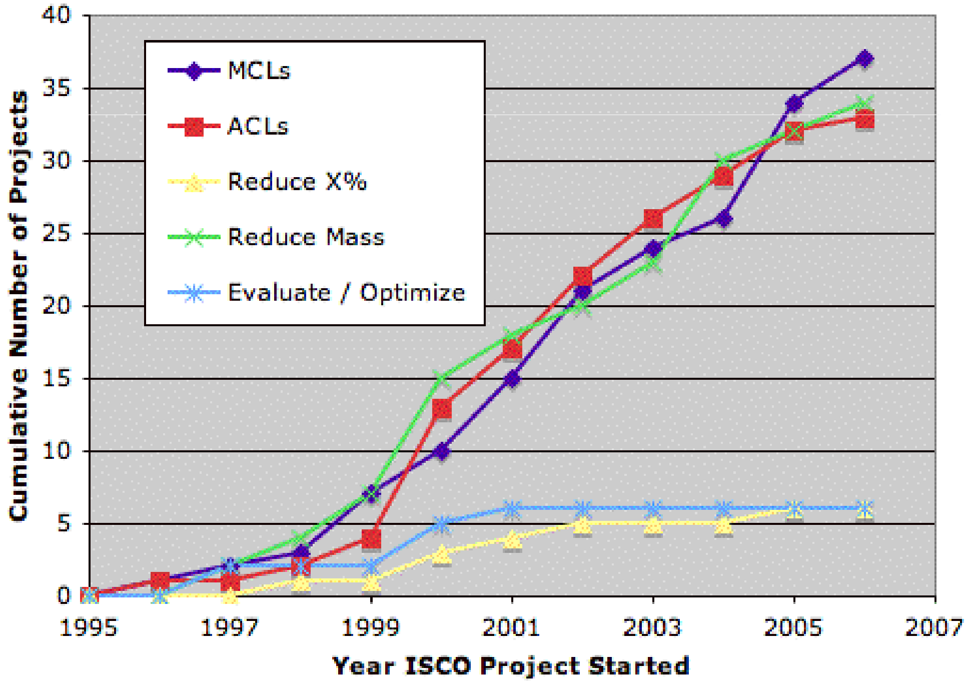
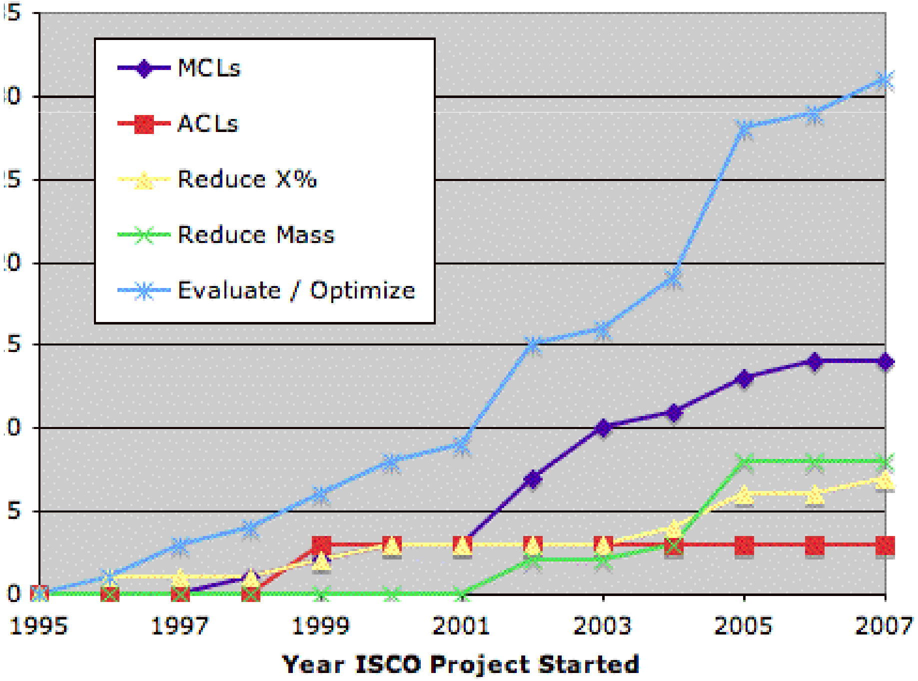
The Dataset Behind DISCO (cont.)

The goals of ISCO projects are shown against time in the graphs below, with full scale applications shown on the left panel and pilot scale applications shown on the right. The legends are ordered from most to least stringent. MCLs, Alternative Cleanup Levels (ACLs), and mass reduction are the most commonly attempted full scale goals while technology evaluation is the most common pilot scale goal. Technology evaluation and attempting to meet a predetermined percent mass reduction (yellow curve) appear to no longer be commonly attempted goals for full scale ISCO applications. In other words, practitioners are attempting to meet a numerical standard (MCLs or ACLs) or just reduce mass as much as possible (green curve) without targeting a specific percentage to attain. Note that some sites attempted to meet multiple goals.

Full Scale Project Goals vs. Time



Pilot Scale Project Goals vs. Time



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How to Use DISCO

DISCO consists of two parts: a “query” entered by the user that dictates what data will be presented; and “results” that show the data produced by the query. The query is performed first, and once it is completed results are displayed. These parts and related terms are explained below.

- **Query** refers to the user’s selection of a subset of the DISCO data that they would like to view.
- **Query Inputs** (or **Query Input Criteria**) are the selections of COC and geologic media made during the query process.
- **Results** (or **Outputs**) are what the users receives once they execute the query. These consist of a series of tables as well as some commentary on the data. The statistics presented in the results are based on the case studies that reported data for a given parameter (e.g. oxidant concentration) and also meet the query input criteria (e.g. COCs and geologic media).

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Key Definitions of DISCO Query Inputs

DISCO is queried based upon COC conditions and geologic conditions. Definitions of how these conditions are subdivided are given below. Further details and additional terms are available in the DISCO Glossary.

- **COCs** (Contaminants Of Concern) refer to the contaminants to be treated by ISCO.
- **NAPL** (Non-Aqueous Phase Liquid) refers to situations in which free product COCs are present in the treatment zone. When present, NAPL often represents the phase in which a majority of the COC mass resides (Pankow and Cherry, 1996), and its presence represents a challenge to ISCO as well as other remediation technologies. Sites with considerable sorbed phase COCs (e.g. high total organic carbon in soil) may react to ISCO treatment in a similar manner to sites containing NAPL.
- **Permeable** geologic materials are those which had an average saturated hydraulic conductivity (K) greater than 10^{-5} cm/s (0.028 ft/day) in the treatment zone as determined through aquifer testing results or inferred from lithologic descriptions and boring logs. This is defined to be the opposite of impermeable (defined below).
- **Impermeable** geologic materials are those which had an average K less than 10^{-5} cm/s (0.028 ft/day) in the treatment zone. This is defined to be the opposite of permeable media, and is applied to unconsolidated media only.
- **Homogeneous** geologic materials are those which were inferred to have less than a factor of 1000 between the most permeable (highest K) and least permeable portions of the treatment zone. This distinction is based upon assessment of specific strata in the treatment zone, and should not be based solely on variations in K values recorded in the field (see example site below).
- **Heterogeneous** geologic materials are those which were inferred to have greater than a factor of 1000 between the most permeable (highest K) and least permeable portions of the treatment zone.
- **Example Geologic Classification:** a predominantly sandy site that contains minor clay stringers would be classified as permeable ($K_{ave} = K_{sand} > 10^{-5}$ cm/s) and heterogeneous ($K_{sand} / K_{clay} > 1000$) even if the clay stringers were thin enough that macro scale aquifer test results (e.g. slug tests) did not vary by a factor of 1000.

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Definitions of DISCO Results Outputs

The results of a DISCO query include data on ISCO design and performance results based upon the case study data. The statistics presented are based only on projects that reported data on a particular parameter and meet the query input criteria with respect to COCs and geologic media. Definitions for key parameters are given below. Further details and additional terms are available in the DISCO Glossary.

- **Treatability Tests** are laboratory scale tests performed on soils and/or groundwater collected from the treatment zone. Tests that were performed at the field scale were not included. Field scale tests were classified as pilot tests even if they were given the name treatability study in project documents.
- **Coupling** refers to use of another remediation technology in addition to ISCO, and includes monitored natural attenuation (MNA). Coupling includes remediation of nearby areas that were contaminated by the same source as the COCs being treated by ISCO (e.g. excavation or SVE in the vadose zone).
- **Program Modification** is changing the injection spacing, oxidant concentration, or other ISCO design parameters during the course of implementation, and is included as a measure to assess the frequency of the use of the Observational Approach.
- **Percent Reduction of COC Concentration** is calculated based upon the maximum concentration recorded anywhere in the treatment zone before ISCO vs. the maximum concentration anywhere in the treatment zone after ISCO. The post-ISCO concentrations include any rebound effect, if any was noted (i.e. are based on highest post-ISCO result).
- **Rebound** was assessed at each monitoring well within the treatment zone using the following formula: (Highest Post-ISCO - Immediately after ISCO) / Pre-ISCO baseline, and rebound was said to occur if this result was greater than 25%. Rebound occurred at a site if one or more monitoring locations exceeded this 25% threshold. One year of post-ISCO COC data was required to perform this calculation. See the DISCO Glossary for further details.

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Definitions of DISCO Results Outputs (cont.)

- **Meet MCLs** are those sites that attempted, met, and maintained Maximum Contaminant Levels for the COCs being treated. This result was not entered in the affirmative unless is could be verified by personal correspondence between the ER-0623 project team and the site regulator.
- **Meet ACLs** are those sites that attempted and met Alternative Cleanup Levels, which are specific concentrations that are greater than MCLs. ACLs are often used with site-specific risk assessments or low risk situations (e.g. low yield aquifers, lack of nearby receptors).
- **Reduce Mass** refers to projects in which mass reduction of COCs was a goal. Failure to meet this goal was assigned when the sampled media (groundwater and/or soil) did not show decreases in COC concentrations as a result of ISCO when compared to concentrations prior to ISCO.
- **Site Closure** refers to situations in which the site regulators did not require additional remediation or monitoring after the use of ISCO because COC concentrations were reduced to the degree required by the regulations under which the work was being performed. For this reason, the ability of ISCO to attain site closure is highly dependent on the regulatory framework in place. Site closure as defined in DISCO includes both “clean closures” in which no restrictions were placed on the property, and closures requiring institutional or engineering controls.

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DISCO: Caveat Emptor

The following caveats should be kept in mind when considering the results presented following a DISCO query.

- The data represent the portion of ISCO sites whose information was available to the ER-0623 team as of the end of the data collection phase of the work in December 2007. These data were collected from any and all available sources, including internal project team reports, journal articles, conference proceedings, publicly available demonstration reports, online site remediation databases, and technology vendor project summaries.
- Some of the data are based upon early ISCO demonstration projects performed when the technology was still rapidly developing. Many of these demonstration projects resulted in important lessons learned, improving the ISCO experience base and perhaps resulting in improved performance during contemporary ISCO applications.
- Relatively few of the case study documents included longer term monitoring data, e.g. more than one year after ISCO was implemented. A lack of relatively longer term post-ISCO data may result in an underestimate of the incidence of site closure and the use of post-ISCO coupled technologies, particularly monitored natural attenuation (MNA).
- The thoroughness of data sources varied considerably, and for this reason the sample size displayed on the results pages will vary as well.
- Several oxidants are more recently developed (e.g. persulfate, percarbonate), and the above caveats with respect to rapid evolution of standard practices and relatively sparse sample sizes are especially applicable to these oxidants.

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DISCO References

A list of selected publicly accessible ISCO case study resources is presented below. A more comprehensive discussion of the data sources used to populated DISCO is available in TPM Part III.

- EPA (1998). In Situ Remediation Technology: In Situ Chemical Oxidation. Office of Solid Waste and Emergency Response, 542-R-98-008, September.
- EPA (2003). The DNAPL Remediation Challenge: Is There a Case for Source Depletion?. Office of Research and Development, 600-R-03-143, December.
- EPA (2004). DNAPL Remediation: Selected Projects Approaching Regulatory Closure. Office of Solid Waste and Emergency Response, 542-R-04-016, December.
- EPA (2008). Chemical Oxidation Site Profiles. web resource at http://www.clu-in.org/products/chemox/ hosted by EPA's Technology Innovation Program, accessed August 11, 2008.
- ESTCP (1999). Technology Status Review: In Situ Oxidation. November.
- Federal Remediation Technology Roundtable (2008). Cost and Performance Case Studies. web resource at http://www.frtr.gov/costperf.htm, accessed August 11, 2008.
- ITRC (2001). Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater. http://www.itrcweb.org/gd_ISCO.asp, accessed October 23, 2007.
- ITRC (2005). Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater: Second Edition. http://www.itrcweb.org/gd_ISCO.asp, accessed October 23, 2007.
- Krembs, F.J. (2008). Critical Analysis of the Field-Scale Application of In Situ Chemical Oxidation for the Remediation of Contaminated Groundwater. M.S. Thesis submitted to Colorado School of Mines ESE Department.
- State Coalition for Remediation of Drycleaners (2008). Drycleaner Site Profiles. web resource at http://www.drycleancoalition.org/profiles/, accessed August 11, 2008.

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Query Part 1: Geology

Click on the category that best describes the geology of the target treatment zone

for unconsolidated media

homogeneous & permeable

homogeneous & impermeable

heterogeneous & permeable

heterogeneous & impermeable

Permeable defined as average saturated hydraulic conductivity (K) > 10^{-5} cm/s **Homogeneous** defined as K_{max} / K_{min} < 1000 as based on assessments of distinct strata (e.g. clay stringer vs. coarse sand is heterogeneous)

for fractured rock

high matrix porosity

low matrix porosity

High Matrix Porosity most sedimentary rocks **Low Matrix Porosity** most igneous and metamorphic rocks

select all six

open DISCO Glossary

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Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

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return to Query Part 1

Design Conditions

(for query of homogeneous, permeable geology & choroethene COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	60	10
performed pilot test (full-scale projects only)	57	7
ISCO coupled w/ other technologies	69	13
any coupled technology before ISCO	67	9
P&T before ISCO	33	9
SVE before ISCO	33	9
any coupled technology during ISCO	33	9
SVE during ISCO	22	9
dual phase extraction during ISCO	11	9
any coupled technology after ISCO	89	9
MNA after ISCO	55	9
enhanced bioremediation after ISCO	44	9
program modified during implementation	67	6

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

16 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	11
direct push	5
sparge points	0
infiltration gallery / trench	0
recirculation	2
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	6
CHP	9
ozone	0
persulfate	2
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & chloroethene COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	7.5	7.5	20	5
# of pore volumes delivered	0.39	0.61	1.2	3
oxidant dose (g oxidant / kg media)	0.48	0.80	2.0	3
design ROI (ft)	7.3	7.5	15	3
# of delivery events	1.0	1.0	4	5
mean duration of delivery events (days)	4	47	110	4
% performing treatability test	50			4
% performing pilot test (full-scale projects only)	50			2

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	595	595	5
# of pore volumes delivered	0.049	0.078	0.16	4
oxidant dose (g oxidant / kg media)	1.2	1.7	1.9	3
design ROI (ft)	13	15	23	3
# of delivery events	2.0	2.5	4.3	8
mean duration of delivery events (days)	5	7	10	6
% performing treatability test	60			5
% performing pilot test (full-scale projects only)	50			4

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of homogeneous, permeable geology & chloroethene COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of homogeneous, permeable geology & chloroethene COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	48	61	90	7
% of sites w/ rebound at one or more locations in TTZ		63		8
at sites where rebound occurred, % of wells w/ rebound	58	72	86	2
total cost (1000s US $)	119	177	243	3
unit cost ($ / cubic yd treated)	187	187	187	2

Attainment of Site Closure

	%	n
percent attaining site closure	17	12

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	3
meet ACLs	20	5
reduce concentration / mass	100	3
evaluate effectiveness	100	4

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Scenario-Specific Commentary

(for query of homogeneous, permeable geology & chloroethene COCs with DNAPL)

DNAPL poses challenges to nearly all remediation technologies. The case studies in this query were generally successful in reducing COC mass and aqueous phase concentrations, MCLs remained elusive for those three sites that attempted this goal, and ACLs were met in only a single instance. However, these sites collectively indicate that both MNA and enhanced bioremediation may be used as polishing technologies after ISCO. And it is possible that some of these sites may have attained closure after the publication of the case study documents reviewed during DISCO's compilation. Some specific items from the data are highlighted below.

- While these projects are classified as homogenous in DISCO, there was likely some degree of heterogeneity present in the treatment area that impacted reagent delivery and contaminant transport.
- Nearly all of these projects used multiple delivery events. Multiple events are recommended when treating DNAPL because (a) the time between events allows COCs to move to the more treatable aqueous phase during re-equilibration, and (b) COC sampling data collected between events can help to identify persistent hot spots, which can then refine subsequent injections.
- One of the sites that attained closure was Sun Belt Precision Products, a site that has been reported in EPA (2003) and ITRC (2005). This site contained residual TCE DNAPL in a sand aquifer that resulted from a spill in the late 1990's. Several applications of permanganate resulted in decreases of TCE concentrations in groundwater from a maximum of 625,000 ug/L to 31,000 ug/L, a reduction of 95%. Subsequent attenuation of TCE reduced the concentration further to concentrations below the ACL that was in place for the site.
- The second site that attained site closure was reported in EPA (1998). This case study site contained a TCA at concentrations indicative of DNAPL, and lesser amounts of cis-DCE and VC. The source documents indicated that land use restrictions were not required after ISCO. Attempts by the creators of DISCO to contact the site contacts listed in the source document were unsuccessful.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of homogeneous, permeable geology & chloroethene COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	2
performed pilot test (full-scale projects only)	25	4
ISCO coupled w/ other technologies	75	4
any coupled technology before ISCO	67	3
P&T before ISCO	33	3
SVE before ISCO	33	3
any coupled technology during ISCO	33	3
SVE during ISCO	33	3
any coupled technology after ISCO	0	3
program modified during implementation	50	2

Delivery Method

	# Sites
injection wells	1
direct push	1
sparge points	2
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	1
ozone	2
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

4 of the 242 DISCO case studies match this query

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Design Conditions

(for query of homogeneous, permeable geology & chloroethene COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	23	23	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	15	15	15	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	45	45	45	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)	0			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	10	10	10	1
# of pore volumes delivered	0.66	0.66	0.66	1
oxidant dose (g oxidant / kg media)	1.1	1.1	1.1	1
design ROI (ft)	7.5	7.5	7.5	1
# of delivery events	1	1	1	2
mean duration of delivery events (days)	2	2	2	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	50			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of homogeneous, permeable geology & chloroethene COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	540	540	540	1
design ROI (ft)	no data			
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	50			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of homogeneous, permeable geology & chloroethene COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	53	61	69	2
% of sites w/ rebound at one or more locations in TTZ	0			3
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	75	121	680	3
unit cost ($ / cubic yd treated) **	320	570	830	2

Attainment of Site Closure

	%	n
percent attaining site closure	67	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

** see commentary page for explanation of unit costs

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	100	3
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & chloroethene COCs without DNAPL)

The projects included within this query were generally quite successful. While the sample size is admittedly small, practitioners appear to be attempting and meeting the most stringent regulatory goal of MCLs, and none of the four projects attempted less stringent goals (e.g. ACLs, mass reduction). Reasons for the high success rate may include that homogeneous, permeable media are ideal with respect to oxidant delivery and that chloroethene contamination is readily oxidized in the aqueous phase when DNAPL is not present. Some additional considerations are given below.

- Pilot tests were performed at half of these sites. In general pilot tests address issues related to oxidant deliverability, and these issues may be relatively less uncertain when treating homogeneous sites relative to heterogeneous ones. Pilot tests can also address the degree of contaminant degradation achieved, and this issue may be less uncertain when a NAPL phase is not present. However, the authors recommend that practitioners consider the benefits and costs of pilot testing on a project-specific basis.
- The unit costs data for this query contained two samples, which were $63 and $1,080 per cubic yard treated. The greater number resulted from the fact that the target treatment zone was beneath a building and was quite small (710 cubic feet). This project was implemented at a total cost of $28,400, and MCLs were met and maintained.
- While these projects are classified as homogenous in DISCO, there was likely some degree of heterogeneity present in the treatment area that impacted reagent delivery and contaminant transport.
- In general, sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & BTEX COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	na	0
ISCO coupled w/ other technologies	100	3
any coupled technology before ISCO	67	3
excavation before ISCO	67	3
P&T before ISCO	33	3
any coupled technology during ISCO	67	3
SVE during ISCO	33	3
P&T during ISCO	33	3
any coupled technology after ISCO	0	3
program modified during implementation	100	2

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

5 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	0
direct push	2
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	3
ozone	1
persulfate	0
peroxone	0
percarbonate	1

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & BTEX COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	56	56	56	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	3	3	3	1
# of delivery events	1	1	1	2
mean duration of delivery events (days)	1.5	2	2.5	2
% performing treatability test	1			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & BTEX COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	240	240	240	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & BTEX COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total BTEX concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	0			1
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	220	220	220	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	50	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	50	2
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & BTEX COCs with LNAPL)

ISCO is applied to BTEX LNAPL sites with relatively less frequency than chlorinated solvent sites, as shown by the data presented on the previous pages. Some general commentary on treatment of BTEX LNAPL sites is presented below.

- Permanganate was not used to treat these types of sites, which is not surprising given that permanganate has limited reactivity with BTEX compounds, particularly benzene.
- An advantage of treating LNAPL relative to DNAPL is that its location in the subsurface can be more easily predicted (i.e. the NAPL phase remains near the water table). This difference in contaminant morphology is assumed to be a reason why LNAPL sites appeared to be more successfully treated using ISCO relative to DNAPL sites (see TPM Part III).
- In situations in which contamination arises from leaking underground storage tanks (USTs), excavation is commonly used to remove some portion of the contaminated soil. For this reason, ISCO is frequently coupled with excavation in these situations.
- The project that attained closure was a former service station located in Pennsylvania whose project information is included in ITRC (2005). This project used ozone to remediate BTEX and MTBE in order to expedite a property transfer. Attempts to gather additional information from the site regulator made by DISCO's creators were unsuccessful.
- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & BTEX COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
SVE before ISCO	0	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	1
percarbonate	0

2 of the 242 DISCO case studies match this query

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & BTEX COCs without LNAPL)

Because there are only two projects that meet this search criteria, several of the generic tables that are normally displayed by DISCO have been omitted. The two sites will be described briefly here.

- Former Service Station at Days Inn, Lake City, FL This project used a peroxone sparge system to remediate BTEX associated with former gasoline underground storage tanks. ISCO was used after excavation to treat saturated source zone soils. Based on the project documents that were available during DISCO's creation, the peroxone system was successful in meeting MCLs in all monitoring locations in the source zone except one. The system had operated for one year and treatment was ongoing. The sparge frequency and locations were changed during treatment to focus on the recalcitrant monitoring well that continued to exceed MCLs. The total cost for this project was $268,000, and the unit cost $28/ cubic yard of soil treated.
- Utilities Authority, Southern NJ This project used CHP to treat toluene, ethylbenzene, xylenes and several base neutral compounds in groundwater. The project treated a 1,000 square foot area between 10 and 18 ft bgs using two injection points for a duration of five days over two separate injection events. VOCs were reduced by 99%, and project documents stated that a No Further Action letter was expected from the regulator based on these results. The project cost was $50,000 (possibly exclusive of professional fees) and the unit cost $170/ cubic yard of soil treated. ISOTEC was the remediation contractor, and further information on this project is available at their website.

Some general guidance on homogeneous, permeable sites containing BTEX compounds is given below.

- Homogeneous, permeable geologic media is the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & chloroethane COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	no data	
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	no data	
any coupled technology before ISCO		
any coupled technology during ISCO		
any coupled technology after ISCO		
program modified during implementation		

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & chloroethane COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & chloroethane COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & chloroethane COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethane concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)	62	62	62	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	100	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

The preceding tables are based on a single case study.

- The project that reportedly attained site closure was the “Former News Publisher Facility, Framingham, MA” reported in EPA (1998). This case study site contained 1,1,1-TCA at concentrations indicative of DNAPL, and lesser amounts of cis-DCE and VC. The source documents indicated that land use restrictions were not required after ISCO. Attempts by the creators of DISCO to contact the site contacts listed in the source document were unsuccessful.

Some general considerations relating to this query are presented below and on the following page.

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may increase during the post-ISCO monitoring period, a phenomenon termed rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.
- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & chloroethane COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some theoretical considerations regarding this particular query are given below.

- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.
- Homogeneous, permeable geologic media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of homogenous, permeable geology & TPH COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	0
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of homogenous, permeable geology & TPH COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	395	395	395	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	6	6	6	1
mean duration of delivery events (days)	no data			
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogenous, permeable geology & TPH COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum TPH concentration in GW	81	81	81	1
% of sites w/ rebound at one or more locations in TTZ	0			1
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	55	55	55	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	100	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of homogenous, permeable geology & TPH COCs with LNAPL)

The results displayed on the previous pages were based on the one case study that fits these query criteria. This site was a residence in Connecticut that used CHP to treat hydrocarbon contamination resulting from a fuel oil spill, reported in ITRC (2005).

Some additional considerations regarding the use of ISCO at similar types of sites are presented below.

- Homogeneous, permeable geologic materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & TPH COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some theoretical considerations regarding this particular query are given below.

- Homogeneous, permeable materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & MTBE COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	no data	
performed pilot test (full-scale projects only)		
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	100	2
P&T before ISCO	50	2
excavation before ISCO	50	2
SVE before ISCO	50	2
any coupled technology during ISCO	50	2
SVE during ISCO	50	2
P&T during ISCO	50	2
any coupled technology after ISCO	0	2
program modified during implementation	1	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

3 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	2
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	1
persulfate	0
peroxone	1
percarbonate	0

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & MTBE COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & MTBE COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	240	240	240	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & MTBE COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total MTBE concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	0			2
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	194	204	213	2
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	100	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & MTBE COCs with LNAPL)

The preceding tables were based upon a total of three case study sites. These were reportedly successful, though the high level overview provided in the source documents did not provide a great amount of detail. Other projects treating MTBE in different geologic media (e.g. heterogeneous and permeable soils) have attained good results as well. Selected projects are briefly described below.

- The projects that attained closure were both reported in ITRC (2005). One was a former service station located in Pennsylvania whose project information is included in ITRC (2005). This project used ozone to remediate BTEX and MTBE in order to expedite a property transfer. Attempts to gather additional information from the site regulator made by DISCO's creators were unsuccessful. The second was the "Kenton" site located in Delaware. This site used peroxone, delivered over a period of 210 days, to treat gasoline related contamination. The thickness of the LNAPL at these two sites was not included within these case study source documents.

Some theoretical considerations regarding these query criteria are given below.

- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.
- Homogeneous, permeable geology is the most amenable to ISCO, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & MTBE COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some theoretical considerations regarding this particular query are given below.

- Free radical based oxidants (CHP, ozone, peroxone, persulfate, and percarbonate) are reactive with MTBE.
- MTBE is highly soluble in groundwater, and is therefore mobile once released. The high solubility makes MTBE more available to be treated by injected oxidants relative to more hydrophobic compounds. Sparge barriers are one means through which practitioners take advantage of MTBE’s mobility, as such barriers may be installed upgradient of a receptor or compliance point and treat the MTBE as it flows through the barrier.
- Homogeneous, permeable materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	na	
ISCO coupled w/ other technologies	no data	
any coupled technology before ISCO		
any coupled technology during ISCO		
any coupled technology after ISCO		
program modified during implementation		

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	23	23	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	10	10	10	1
mean duration of delivery events (days)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	na			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chlorobenzenes concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

The data presented on the previous pages is based upon a single pilot study. The pilot study evaluated the use of permanganate to treat monochlorobenzene and 1,2-dichlorobenzene in a situation in which DNAPL was presumed to be present. Bench scale testing indicated that permanganate was capable of degrading these COCs. The case study source documents indicated that permanganate was successfully distributed through the treatment zone. However, most monitoring locations did not show sustained decreases in COC concentrations. The project team suggested using a higher concentration of permanganate, citing the fact that the reaction between the oxidant and COCs is second order overall, and would therefore react more quickly if the permanganate concentration was higher.

Some additional commentary is provided on treating these COCs in this geologic setting.

- Homogeneous, permeable geologic media is the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.

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Scenario-Specific Commentary (cont.)

(for query of homogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & chlorobenzenes COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some theoretical considerations regarding this particular query are given below.

- Homogeneous, permeable materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & PAH COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	2
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	0	1
any coupled technology before ISCO	0	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	0	2

Delivery Method

	# Sites
injection wells	2
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	2
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & PAH COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	13	17	20	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)	4.5	4.5	4.5	1
design ROI (ft)	15	15	15	1
# of delivery events	3	4	5	2
mean duration of delivery events (days)	1	1	1	1
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	0			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & PAH COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total PAH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	0			1
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & PAH COCs with NAPL)

The two projects described on the previous slides were both relatively unique ISCO applications in that they attempted to both oxidize the COCs and encapsulate the unoxidized residuals in manganese dioxide (a solid that forms during the reaction of permanganate with organic compounds). While a relatively specific situation, this process did appear to successfully reduce COC flux into the groundwater phase due to oxidation and/or encapsulation of the creosote source zones being treated.

Some additional considerations regarding ISCO treatment of PAHs in homogeneous, permeable materials are given below.

- Homogeneous, permeable geologic materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Based on laboratory studies, the commonly available oxidants are equally capable of degrading these types of contaminants (a caveat to this statement is that many compounds may fall under the umbrella of PAHs, and the ISCO screening section of the TPM and references therein should be consulted).
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- NAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & PAH COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	no data	
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	0	1
any coupled technology during ISCO	100	1
SVE during ISCO	100	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	0
ozone	1
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & PAH COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	56	56	56	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & PAH COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total PAH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)	150	150	150	1
unit cost ($ / cubic yd treated)	28	25	25	1

Attainment of Site Closure

	%	n
percent attaining site closure	no data	

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & PAH COCs without NAPL)

The preceding tables are based upon a single case study of a project conducted at a former fuel oil distributor in Ilion, NY, reported in ITRC (2005). This project reportedly met the applicable regulatory requirements after operating a nominal 50 lbs/day ozone generator for eight weeks. ISCO using ozone was selected over excavation as the remedation technology due to ozone's faster timeframe.

Some additional considerations regarding ISCO treatment of PAHs in homogeneous, permeable materials are given below.

- Homogeneous, permeable geologic materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Based on laboratory studies, the commonly available oxidants are equally capable of degrading these types of contaminants (a caveat to this statement is that many compounds may fall under the umbrella of PAHs, and the ISCO screening section of the TPM and references therein should be consulted).
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & methylene chloride COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some theoretical considerations regarding this particular query are given below.

- Free radical based oxidants (CHP, ozone, peroxone, persulfate, and percarbonate) are reactive with methylene chloride, whereas permanganate is not.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Homogeneous, permeable materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & methylene chloride COCs with DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some theoretical considerations regarding this particular query are given below.

- Free radical based oxidants (CHP, ozone, peroxone, persulfate, and percarbonate) are reactive with methylene chloride, whereas permanganate is not.
- Homogeneous, permeable materials are the most amenable to ISCO treatment, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While oxidants will react directly with the DNAPL phase, obtaining contact between the oxidant and the DNAPL is difficult. Reactions between the oxidant and the COCs will occur primarily in the aqueous phase. It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may increase, or rebound, during the post-ISCO monitoring period. It is recommended that practitioners use rebound to refine the Conceptual Site Model (e.g. better locate DNAPL) and to plan for multiple oxidant delivery events when treating DNAPL.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of homogeneous, permeable geology & all COC types without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	3
performed pilot test (full-scale projects only)	20	5
ISCO coupled w/ other technologies	83	6
any coupled technology before ISCO	60	5
excavation before ISCO	40	5
SVE before ISCO	20	5
any coupled technology during ISCO	40	5
SVE during ISCO	40	5
air sparging during ISCO	20	5
any coupled technology after ISCO	0	5
program modified during implementation	75	4

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

7 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	1
sparge points	4
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	2
ozone	3
persulfate	0
peroxone	1
percarbonate	0

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & all COC types without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	23	23	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	15	15	15	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	45	45	45	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)	0			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	10	10	10	1
# of pore volumes delivered	0.66	0.66	0.66	1
oxidant dose (g oxidant / kg media)	1.1	1.1	1.1	1
design ROI (ft)	7.5	7.5	7.5	1
# of delivery events	1.3	1.5	1.8	2
mean duration of delivery events (days)	2.2	2.3	2.5	2
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & all COC types without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	180	300	420	2
design ROI (ft)	no data			
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	50			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & all COC types without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	61	77	88	3
% of sites w/ rebound at one or more locations in TTZ	0			3
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	121	151	268	5
unit cost ($ / cubic yd treated)	27	46	320	4

Attainment of Site Closure

	%	n
percent attaining site closure	75	4

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	100	3
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & all COC types without NAPL)

The case studies returned by this query include several sites that attained MCLs or site closure. This result is consistent with conventional wisdom, which predicts that homogeneous and permeable geology is relatively less challenging to ISCO that other geologic conditions, and that sites without NAPL are more easily treated than sites with LNAPL or DNAPL. Further specific information on these case studies and some general guidance are included below.

- The case studies returned by this query also included less frequent use of pilot tests and fewer delivery events compared to sites containing NAPL or treating heterogeneous geologic materials.
- Among the sites that met MCLs, both contained chloroethenes at pre-ISCO maximum concentrations between 6 and 70 ug/L.
- The sites that obtained closure included two of those that met MCLs, and two other sites that reportedly met the required standard, but whose project source documents did not include regulatory contact information nor whether the required standard was a MCL or ACL. The site that met MCLs but did not gain site closure was an ozone sparge curtain that treated the downgradient plume.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of homogeneous, permeable geology & all COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	67	15
performed pilot test (full-scale projects only)	44	9
ISCO coupled w/ other technologies	74	19
any coupled technology before ISCO	71	14
excavation before ISCO	43	14
P&T before ISCO	28	14
any coupled technology during ISCO	36	14
SVE during ISCO	21	14
enhanced bioremediation during ISCO	7	14
any coupled technology after ISCO	57	14
MNA after ISCO	36	14
enhanced bioremediation after ISCO	29	14
program modified during implementation	64	11

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

27 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	14
direct push	7
sparge points	2
infiltration gallery / trench	1
recirculation	2
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	9
CHP	13
ozone	1
persulfate	2
peroxone	1
percarbonate	1

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & all COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	7.5	9.8	22	7
# of pore volumes delivered	0.39	0.61	1.2	3
oxidant dose (g oxidant / kg media)	0.63	2.0	3.5	4
design ROI (ft)	7.3	11	17	4
# of delivery events	1.0	3.0	4.5	8
mean duration of delivery events (days)	4	4	89	5
% performing treatability test	71			7
% performing pilot test (full-scale projects only)	33			3

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	110	395	595	7
# of pore volumes delivered	0.049	0.078	0.16	4
oxidant dose (g oxidant / kg media)	1.2	1.7	1.9	3
design ROI (ft)	8.3	13	19	4
# of delivery events	1.5	2.0	4.5	11
mean duration of delivery events (days)	3.8	5.5	8.5	8
% performing treatability test	57			7
% performing pilot test (full-scale projects only)	50			6

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of homogeneous, permeable geology & all COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	240	240	240	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, permeable geology & all COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	48	61	90	7
% of sites w/ rebound at one or more locations in TTZ	42			12
at sites where rebound occurred, % of wells w/ rebound	58	72	86	2
total cost (1000s US $)	90	181	213	6
unit cost ($ / cubic yd treated)	187	187	188	2

Attainment of Site Closure

	%	n
percent attaining site closure	29	17

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	5
meet ACLs	29	7
reduce concentration / mass	100	4
evaluate effectiveness	100	5

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, permeable geology & all COCs with NAPL)

While the type of geology returned by this query is generally the most amenable to ISCO, the presence of NAPL poses a challenge to ISCO, as it does to other remediation technologies. Though MCLs were elusive among this sample, ACLs and site closure were attained. Some additional considerations regarding this query are provided below.

- Homogeneous, permeable geologic media is the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- NAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

The projects attaining site closure and citations containing further information are provided below. With the exception of Sun Belt Precision Products, attempts made by DISCO's creators to attain further information on these sites from site contacts were unsuccessful.

- Sun Belt Precision Products (EPA 2003, ITRC 2005). This case study used multiple applications of permanganate to reduce TCE concentrations from a known DNAPL spill by over 99.9%. Subsequent attenuation led to attainment of Florida's Natural Attenuation Default Criteria (300 ug/L) and subsequent site closure.
- Former News Publishing Facility (EPA 1998). TCA at concentrations indicative of DNAPL was treated using CHP.
- Former Pennsylvania Service Station (ITRC 2005) used ozone to treat TPH and BTEX.
- Kenton, Delaware (ITRC 2005) used ozone to treat TPH and BTEX.
- Residential Fuel Oil (ITRC 2005) CHP to treat TPH beneath residence via infiltration gallery.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

open DISCO Glossary

return to Query Part 1

Scenario-Specific Commentary

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

NOTES: There are only **five** sites total in DISCO that have this type of geologic media. For this reason, the results are not subdivided by COCs or NAPL conditions (i.e. once you clicked this geology group on Query page 1, you would have ended up here regardless of what you clicked on Query page 2).

- In some situations, case study documents reported fracturing of clay or silt materials. These types of sites were classified as fractured rock because they would behave as such from a hydrogeologic perspective. When considering treatment of clay or silt sites, advection of COCs through fractures may be the dominant COC transport process. An example in support of this is observing DNAPL at considerable depth in a clay material. Diffusion through clay is slow, hence fractures were likely responsible for delivering the DNAPL to depth.
- Other sites reported sand or silt stringers or lenses in clay. These were classified in DISCO as heterogeneous, impermeable materials.
- The statistics on the five case studies classified within this geology group are included on the following pages, followed by some commentary on this type of situation. Users are also encouraged to view results of ISCO remediation in fractured rock and/or impermeable, heterogeneous materials.
- Four of the case studies on the pages that follow treated chloroethenes. The fifth treated a mixture of chloroethenes and BTEX.

(Continued on following page)

Design Conditions

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	no data	
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	0
direct push	4
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	1
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	3
CHP	0
ozone	0
persulfate	1
peroxone	0
percarbonate	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

5 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	53	83	110	2
# of pore volumes delivered	0.80	1.2	1.5	2
oxidant dose (g oxidant / kg media)	17	31	46	2
design ROI (ft)	5	5	5	1
# of delivery events	4	4	4	1
mean duration of delivery events (days)	4	4	4	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration	70	70	70	1
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)	109	109	109	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure (see next page)	50	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	100	1
reduce concentration / mass	0	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

Some general commentary on this query is provided below. Further commentary on the five case studies in DISCO is presented on the following page.

- Transport of aqueous or gaseous oxidants via advection after delivery through direct push points, injections wells, or infiltration galleries is likely an unreliable means to deliver oxidants through homogeneous, impermeable materials. The degree to which this statement holds true is of course dependent upon the saturated hydraulic conductivity.
- Oxidant may travel via diffusion, though this is generally a slow process. Injection of oxidant solutions under pressure may fracture the geologic media, which in turn may or may not be beneficial to achieving the desired end result. In short, ensuring the necessary contact between oxidant and COCs is difficult when treating impermeable media.
- Soil mixing may be a valuable means through which contact between oxidants and COCs can be improved.
- Solid or slurry phase oxidant may be emplaced via fracturing. Diffusion of oxidant into the soil matrix may then occur after emplacement. The distance the oxidant will travel due to diffusion is dependent upon the soil characteristics, the oxidant depletion rate, the time elapsed since delivery, and other factors.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary

(for query of homogeneous, impermeable geology & all COCs with and without NAPL)

Some additional details on the five case studies in DISCO with homogeneous, permeable geology are given below.

- Four of the case studies within this geology group treated chloroethenes. The fifth treated a mixture of chloroethenes and BTEX.
- The site that obtained closure did so under unique circumstances. An ISCO remediation consisting of a permanganate pilot test followed by two full scale injection events was performed. Project source documents reported that the state regulatory agency promulgated a new risk-based framework after the second full scale injection event that would allow for ACLs provided they would be protective of receptors. This project was closed after the second full scale injection event because the risk-based standard calculated based on predicted impacts to indoor air was greater than pre-ISCO COC concentrations. However, the project source documents also reported that PCE concentrations were reduced “significantly” and groundwater concentrations approached MCLs in some locations. The name of this project is “Paramount Cleaners” in Florissant, MO, and further details may be found at the State Coalition for Remediation of Drycleaners’ website.
- The site that failed to demonstrate a reduction in the mass of COCs was a project that injected permanganate into a layer of lagoon sludge that contained chloroethene DNAPL. The arithmetic mean of soil samples after the ISCO remediation was greater than that pre-ISCO. These data should not be interpreted to mean that ISCO increased the mass of COCs present in the treatment zone, just that the monitoring methods were not able to demonstrate that mass was reduced.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

open DISCO Glossary

return to Query Part 1

Design Conditions

(for query of heterogeneous, permeable geology & chloroethene COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	85	20
performed pilot test (full-scale projects only)	63	8
ISCO coupled w/ other technologies	59	17
any coupled technology before ISCO	60	10
excavation before ISCO	30	10
P&T before ISCO	10	10
any coupled technology during ISCO	30	10
excavation during ISCO	10	10
P&T during ISCO	10	10
any coupled technology after ISCO	40	10
enhanced bioremediation after ISCO	20	10
excavation after ISCO	20	10
program modified during implementation	70	10

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

23 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	7
direct push	5
sparge points	2
infiltration gallery / trench	2
recirculation	1
fracturing	3
soil mixing	0
horizontal wells	1

Oxidant Selected

	# Sites
permanganate	14
CHP	7
ozone	3
persulfate	0
peroxone	1
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethene COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	9.4	24	62	11
# of pore volumes delivered	0.050	0.090	0.16	9
oxidant dose (g oxidant / kg media)	0.089	0.25	0.29	8
design ROI (ft)	15	25	33	7
# of delivery events	1	1	2	11
mean duration of delivery events (days)	2	7	9	7
% performing treatability test	82			11
% performing pilot test (full-scale projects only)	80			5

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	130	200	4
# of pore volumes delivered	0.029	0.031	0.032	2
oxidant dose (g oxidant / kg media)	0.38	0.74	0.92	3
design ROI (ft)	13	24	25	6
# of delivery events	2	2	3.5	7
mean duration of delivery events (days)	2	3.5	5	6
% performing treatability test	100			7
% performing pilot test (full-scale projects only)	33			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethene COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	165	180	250	3
design ROI (ft)	31	38	44	2
% performing treatability test	67			3
% performing pilot test (full-scale projects only)	na			0

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, permeable geology & chloroethene COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration	47	59	64	10
% of sites w/ rebound at one or more locations in TTZ		60		10
at sites where rebound occurred, % of wells w/ rebound	21	25	56	3
total cost (1000s US $)	156	216	368	12
unit cost ($ / cubic yd treated)	23	42	220	10

Attainment of Site Closure

	%	n
percent attaining site closure	20	10

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	7
meet ACLs	50	2
reduce concentration / mass	100	4
evaluate effectiveness	100	6

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chloroethene COCs without DNAPL)

Treatment of heterogeneous media is a challenge to remediation technologies that rely on the delivery of aqueous phase reagents, particularly for relatively older spills in which the contamination is presumably associated with low permeability materials. A comparison of the various goals of remediation and the success in reaching them shows that MCLs remained elusive among the ISCO applications included in this analysis, while mass reduction and technology evaluation were met in all cases.

While ISCO requires design engineering to be based upon site-specific guidance, the following general statements can be made based upon the data in DISCO that is specific to this query (aqueous or sorbed phase chloroethene without DNAPL in heterogeneous, permeable media).

- The median number of pore volumes delivered was 0.042 (n=8) and the median number of delivery events was 1 (n=16). As stated in the body of the TPM, ISCO is often an iterative process requiring a sufficient volume of oxidant to be delivered in multiple events, especially when preferential flow paths are likely present (i.e. heterogeneous media). Given the modest percent reductions and difficulty in reaching MCLs shown in the preceding tables, it is recommended that practitioners deliver a greater volume of oxidant in heterogeneous situations, even if DNAPL is not present.
- Pilot testing appears to provide benefit in terms of percent reduction in total chloroethenes compared to similar sites not performing a pilot test.
- Rebound occurred at roughly half of these type of sites. However, the rebound appeared to be localized in specific locations as opposed to being a site-wide phenomenon. As stated in the body of the TPM, contaminant rebound presents an opportunity to revise the Conceptual Site Model and to refine subsequent remediation activities, and both rebound prevalence and the time elapsed prior to its manifestation are valuable considerations.
- Though MCLs were not met and maintained among the projects included in this analysis, ISCO may be used toward the front end of a treatment train, followed by bioremediation or MNA.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & chloroethene COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	81	26
performed pilot test (full-scale projects only)	44	18
ISCO coupled w/ other technologies	78	27
any coupled technology before ISCO	71	21
P&T before ISCO	38	21
SVE before ISCO	33	21
any coupled technology during ISCO	38	21
excavation during ISCO	14	21
P&T during ISCO	14	21
any coupled technology after ISCO	57	21
MNA after ISCO	38	21
enhanced bioremediation after ISCO	24	21
program modified during implementation	55	20

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

38 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	14
direct push	9
sparge points	1
infiltration gallery / trench	4
recirculation	5
fracturing	4
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	18
CHP	14
ozone	3
persulfate	3
peroxone	0
percarbonate	1

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethene COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	15	25	34	14
# of pore volumes delivered	0.021	0.34	0.64	9
oxidant dose (g oxidant / kg media)	0.23	0.90	1.5	10
design ROI (ft)	11	14	28	11
# of delivery events	2	2	4	17
mean duration of delivery events (days)	2	4	15	13
% performing treatability test	75			16
% performing pilot test (full-scale projects only)	46			13

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	120	160	220	9
# of pore volumes delivered	0.043	0.10	0.23	7
oxidant dose (g oxidant / kg media)	1.3	3.7	5.7	6
design ROI (ft)	5	12	15	9
# of delivery events	2	3	5	10
mean duration of delivery events (days)	4	5	8	7
% performing treatability test	100			9
% performing pilot test (full-scale projects only)	50			6

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethene COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)				0
design ROI (ft)				0
% performing treatability test		0		1
% performing pilot test (full-scale projects only)		0		1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & chloroethene COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration	26	69	90	20
% of sites w/ rebound at one or more locations in TTZ		78		18
at sites where rebound occurred, % of wells w/ rebound	28	48	72	10
total cost (1000s US $)	270	462	1,060	14
unit cost ($ / cubic yd treated)	62	130	220	11

Attainment of Site Closure

	%	n
percent attaining site closure	10	29

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	5
meet ACLs	50	8
reduce concentration / mass	62	13
evaluate effectiveness	90	10

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chloroethene COCs with DNAPL)

Both chlorinated solvent DNAPL and heterogeneous treatment zones are challenges to remediation technologies, including ISCO. As the previous data show, none of the sites in DISCO where chloroethene (e.g. PCE, TCE) DNAPL was presumed to be present met MCLs. However, half of the sites that attempted to meet ACLs were successful, and a percentage attained site closure. Nearly all the projects coupled ISCO with another technology, and a majority used a post-ISCO coupled technology (e.g. enhanced bioremediation or monitored natural attenuation [MNA] as a polishing step).

While ISCO requires design engineering to be based upon site-specific guidance, the following general statements can be made based upon the data in DISCO that is specific to this query (chloroethene DNAPL sites in heterogeneous, permeable media).

- Multiple delivery events will almost certainly be required.
- Pilot testing is a valuable tool when treating heterogeneous formations containing DNAPL, as heterogeneous formations with DNAPL treated with ISCO campaigns including a pilot test have performed much better than ISCO treatments at similar sites where pilot testing was not performed.
- Ensuring subsurface contact between the contaminants and oxidant reagent is of particular importance in heterogeneous media. Larger injection volumes, closer well spacing, and/or a greater frequency of delivery events are means through which this may be accomplished.
- Rebound should be anticipated, though the prevalence and timing of rebound after ISCO implementation will be site specific. The timing and location of contaminant rebound both offer opportunities to refine the Conceptual Site Model and focus subsequent ISCO events or other remediation activities.
- While attainment of MCLs immediately after ISCO has been elusive in this situation, other goals have been achieved in this situation. Other less intensive remediation technologies (e.g. MNA) have been used successfully after ISCO in a treatment train approach.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of heterogeneous, permeable geology & BTEX COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	100	3
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	0	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	100	1
P&T after ISCO	100	1
program modified during implementation	no data	

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	2
ozone	2
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

4 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & BTEX COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	10	10	10	1
# of delivery events	1.8	2.5	3.3	2
mean duration of delivery events (days)	65	125	185	2
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of heterogeneous, permeable geology & BTEX COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	180	180	180	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, permeable geology & BTEX COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration	no data			
% of sites w/ rebound at one or more locations in TTZ	0			1
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	155	170	185	2
unit cost ($ / cubic yd treated)	94	94	94	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

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Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & BTEX COCs with LNAPL)

Heterogeneous materials pose a challenge to remediation technologies such as ISCO that rely on the delivery of reagents in situ. While LNAPL is more readily located in the subsurface relative to DNAPL, this property also makes it more amenable to remediation through other means which may be more economical than ISCO. The choice of what ISCO reagent to use will depend on the mass of the COCs present. For example, ozone or peroxone systems are relatively more limited with respect to the at which oxidant can be delivered to the treatment zone, and hence may not be a viable solution when a large mass of LNAPL is present.

- The results displayed on the preceding pages were based upon two remediations conducted at service stations, one at a former manufactured gas plant (MGP), and one at an industrial facility. The LNAPL thickness were not included in the source documents.
- One of the CHP sites was a remediation of a former MGP located in a historical area of Savannah, GA. The remediation system consisted of 1,238 injection wells. A single injection event conducted over a period of 245 days was performed. The goal of the project was to reduce the COC mass to the extent practicable, and this project was successful in doing so. Geo-Cleanse was the ISCO contractor, and further information on this project may be found on their website.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

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Design Conditions

(for query of heterogeneous, permeable geology & BTEX COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	100	2
excavation before ISCO	50	2
SVE before ISCO	50	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	0	2
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	0
ozone	1
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & BTEX COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & BTEX COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	no data			
design ROI (ft)	20	20	20	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, permeable geology & BTEX COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration	80	80	80	1
% of sites w/ rebound at one or more locations in TTZ	no data			
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

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Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & BTEX COCs without LNAPL)

The preceding tables are based upon two projects.

- The ozone project was ongoing at the time of DISCO's preparation, hence performance results were not available.
- The persulfate project was successful in meeting the case study project team's mass reduction goal, but fell short of MCLs. The 80% reduction in maximum BTEX concentration in groundwater includes the impact of the rebound effect (i.e. concentrations were reduced by more than 80% initially, then stabilized at a concentration that was 80% of the pre-ISCO baseline).

Some theoretical considerations relating to the query criteria are provided below.

- The contaminants in BTEX are more amenable to the free radical based oxidants than they are to permanganate, and this is particularly true of benzene.
- The relatively lower concentrations of COCs that are present when LNAPL is not observed at a site can be readily degraded by both gaseous and liquid phase oxidants.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	2
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	67	3
any coupled technology before ISCO	100	2
P&T before ISCO	100	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	0	2
program modified during implementation	no data	

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	1
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	1
ozone	0
persulfate	2
peroxone	0
percarbonate	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

4 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)	15	15	15	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	2	2	2	1
mean duration of delivery events (days)	15	15	15	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration (see notes)	98	98	98	1
% of sites w/ rebound at one or more locations in TTZ	67			3
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)	235	235	235	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	0	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable. The project that reported a 98% TCA reduction did not state how long after ISCO application the post-ISCO sample was collected.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	50	2
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

The four projects included those in which chloroethanes were present as a primary contaminant, and did not include projects in which a minor amount of a chloroethane compounds was present (e.g. as a degradation product of PCE). Some additional details on the case studies are provided below.

- The project that used permanganate did so to treat chloroethenes (TCE) that were present at the site. Persulfate was used at this site to treat the chloroethanes (1,1,1-TCA). Chloroethanes (e.g. 1,1,1-TCA) are generally accepted as being unreactive with permanganate.
- The project that reported the 98% reduction of TCA (from 101,000 to 2,000 ug/L) did not state how long after the end of ISCO reagent delivery the post-ISCO samples were collected. This project is known as “Active Industrial Facility, Clifton, NJ” and was reported in EPA (1998).

Some additional theoretical considerations relating to this query are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, permeable geology & chloroethane COCs with DNAPL)

- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & chloroethane COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	no data	
any coupled technology before ISCO		
any coupled technology during ISCO		
any coupled technology after ISCO		
program modified during implementation		

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	0
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethane COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	23	23	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	1	1	1	1
mean duration of delivery events (days)	25	25	25	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chloroethane COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & chloroethane COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethane concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chloroethane COCs without DNAPL)

The preceding statistics were based upon a single case study. This project site included chloroethenes at greater concentrations than the chloroethanes. The project used permanganate to treat the chloroethenes. Some general considerations relating to the query criteria are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & TPH COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	2
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	50	2
any coupled technology before ISCO	0	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	100	1
P&T after ISCO	100	1
program modified during implementation	no data	

Delivery Method

	# Sites
injection wells	1
direct push	1
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	2
persulfate	0
peroxone	0
percarbonate	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

4 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & TPH COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	10	10	10	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	245	245	245	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & TPH COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	180	180	180	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & TPH COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum TPH concentration in GW	-51	-51	-51	1
% of sites w/ rebound at one or more locations in TTZ	0			1
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	152	164	178	2
unit cost ($ / cubic yd treated)	510	510	510	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & TPH COCs with LNAPL)

Some description of selected specific case studies as well as general theoretical considerations relating to this query are presented below.

- One of the ozone projects was the “Former Service Station, Commerce City, CO” reported in EPA (1998). This project reportedly reduced TPH concentrations from 37 mg/L to non-detect levels. Four quarters of confirmatory groundwater sampling had just begun after ozone system shutdown at the time of this source document’s publication.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble. This may be the reason for the increases in aqueous phase TPH concentrations shown on the previous page.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & TPH COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	2
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	3
any coupled technology before ISCO	67	3
P&T before ISCO	33	3
SVE before ISCO	67	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	33	3
excavation after ISCO	33	3
enhanced bioremediation after ISCO	33	3
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	2
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	1
persulfate	0
peroxone	1
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

3 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & TPH COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	124	124	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	10	10	10	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	2	2	2	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & TPH COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	no data			
design ROI (ft)	20	20	20	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & TPH COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum TPH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)	144	144	144	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	50	2
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & TPH COCs without LNAPL)

In DISCO, an example of the type of situation in which TPH was present but LNAPL was not would be a smear zone in which TPH was sorbed to soils yet liquid phase product was not present. Such situations are in general amenable to ISCO when using certain oxidants. However, only three case studies in DISCO match these query criteria. Additional details on the project meeting MCLs and general theoretical considerations are presented below and on the following page.

- The one case study that met MCLs but did not (at the time of DISCO's creation) lead to site closure was an ozone sparge curtain designed to provide containment at a gasoline service station. MCLs were met downgradient of the sparge curtain.
- Heterogeneous geology is an additional challenge to thorough oxidant contact due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, permeable geology & TPH COCs without LNAPL)

- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & MTBE COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	no data	
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
air sparging before ISCO	100	1
SVE before ISCO	100	1
any coupled technology during ISCO	no data	
any coupled technology after ISCO		
program modified during implementation		

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	0
ozone	1
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & MTBE COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & MTBE COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	no data			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & MTBE COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total MTBE concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	no data	

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & MTBE COCs with LNAPL)

The single project on which these results are based was ongoing at the time of DISCO's creation, hence no performance data are available. The following briefly describes this case study.

- An ozone sparge system was installed in a source zone after the implementation of both SVE and air sparging to remediate TPH, BTEX, and MTBE impacts resulting from a leaking gasoline UST. It is unknown whether the air sparging system was retrofitted to sparge ozone, though this approach has been used at other case studies in DISCO.

Some general considerations regarding this scenario are presented below.

- MTBE is highly soluble, and therefore highly mobile, relative to other commonly found COCs. For this reason, downgradient oxidative barriers, generally using ozone or peroxone, have been used in this situation. Though the oxidant would likely follow preferential flow paths in a barrier delivery method, the COCs will also generally follow these same preferential flow paths in such situations.
- Given MTBE's solubility, it will travel more quickly in the subsurface relative to the LNAPL. This will cause it to pose different regulatory and technical issues than treatment of the LNAPL source. (For these reasons, treatment of the MTBE may be more of a plume treatment issue than a source zone treatment issue. DISCO users may find value in repeating this query and selecting MTBE without LNAPL.)
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & MTBE COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	2
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	100	4
any coupled technology before ISCO	100	4
excavation before ISCO	75	4
SVE before ISCO	75	4
any coupled technology during ISCO	0	4
any coupled technology after ISCO	0	4
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	4
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	0
ozone	3
persulfate	0
peroxone	1
percarbonate	0

4 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & MTBE COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)		na		
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)		na		
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & MTBE COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	655	710	765	2
design ROI (ft)	23	25	28	2
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, permeable geology & MTBE COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total MTBE concentration in GW	99	99.1	99.9	2
% of sites w/ rebound at one or more locations in TTZ		50		2
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	263	263	263	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	0	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	50	2
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & MTBE COCs without LNAPL)

The reductions in MTBE concentration were both greater than 99% among the two sites that had such performance data. One site was confirmed through correspondence with the site regulator to have met MCLs. The regulatory officials for the other project could not be reached to provide such confirmation. Site closure had not yet been achieved because ISCO using ozone or peroxone sparge barriers was the ISCO design used in these case studies. Because such remediations do not intend to address the source zone, they cannot be expected to achieve site closure.

The data on the preceding pages speak for themselves, collectively indicating the success of ISCO in addressing this particular scenario. Some additional narrative commentary is provided below.

- The four case studies included in this query utilize the fact that MTBE is highly soluble relative to other COCs. The sparge barrier is installed, the MTBE plume moves through it, and in almost every case had non-detect concentrations of MTBE on the downgradient side.
- The mobilization of metals, most notably chromium, is a potential issue that may arise when continuously providing oxidant to the subsurface. One case study in DISCO was successful in abating downgradient chromium exceedances by reducing the oxidant loading rate such that the COCs moving through the sparge curtain were oxidized while chromium was no longer being mobilized.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower COC mass density relative to NAPL sites. Low COC mass density sites can pose the difficulty that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(This is the end of your query. Please start over with the link below.)

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Design Conditions

(for query of heterogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	2
performed pilot test (full-scale projects only)	50	2
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	50	2
excavation before ISCO	50	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	50	2
enhanced bioremediation after ISCO	50	2
program modified during implementation	100	2

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	2
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	2
ozone	0
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	596	596	596	1
# of pore volumes delivered	0.04	0.04	0.04	1
oxidant dose (g oxidant / kg media)	4	4	4	1
design ROI (ft)	12	12	12	1
# of delivery events	3	3	3	1
mean duration of delivery events (days)	no data			
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chlorobenzenes concentration in GW	-7	1	8	2
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	60	60	60	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

The preceding tables are based upon two case studies. These are described briefly below. General theoretical considerations relating to this query are presented on the following page.

- Eastland Woolen Mills Superfund Site, Corinna, ME. This project used ISCO to treat chlorobenzene contamination that could not be removed by excavation. A pilot test evaluating both CHP and persulfate was performed at the site (this is why 3 oxidants were returned on page 1 of these results). Pilot testing showed that persulfate could achieve a greater radius of influence than CHP at this particular site. Full scale persulfate injections resulted in a mass destruction of approximately 73% as determined from soil sampling results. However, localized hot spots remained as of the publication date of DISCO, thus the modest reduction in maximum total chlorobenzenes concentration. The project team is considering additional injections in this area. ISCO injection was also performed at two other areas at this site, one in the overburden in an area in which DNAPL was not assumed to be present, and another in fractured bedrock. These two applications are located elsewhere in DISCO.
- SWMU 196. This project used CHP to remediate chlorobenzene and dicholorbenzene isomers. The design parameters for this project are those reported on the previous pages. The full scale injections resulted in significant contaminant concentration reductions in groundwater. However, contaminant rebound was observed post-ISCO. Enhanced bioremediation was used as a polishing technology at this site.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, permeable geology & chlorobenzenes COCs with DNAPL)

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

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Design Conditions

(for query of heterogeneous, permeable geology & chlorobenzenes COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	3
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	100	2
excavation before ISCO	100	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	50	2
enhanced bioremediation after ISCO	50	2
program modified during implementation	100	2

Delivery Method

	# Sites
injection wells	2
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	2
ozone	0
persulfate	1
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

3 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chlorobenzenes COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	124	124	1
# of pore volumes delivered	0.051	0.067	0.084	2
oxidant dose (g oxidant / kg media)	0.74	0.74	0.74	1
design ROI (ft)	23	23	23	1
# of delivery events	2.8	3.5	4.3	2
mean duration of delivery events (days)	4	4	4	1
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & chlorobenzenes COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & chlorobenzenes COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	63	72	81	2
% of sites w/ rebound at one or more locations in TTZ	no data			
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & chlorobenzenes COCs without DNAPL)

One of the case studies is the Eastland Woolen Mills Superfund Site, Corinna, ME. This project used ISCO to treat chlorobenzene contamination that could not be removed by excavation. Pilot testing showed that persulfate could achieve a greater radius of influence than CHP at this particular site. Full scale persulfate injections resulted in a mass destruction of approximately 73% as determined from soil sampling results and an 80% reduction in maximum chlorobenzenes concentration in groundwater. DNAPL was not believed to be present in the portion of this site described in the preceding tables.

Some general considerations relating to the treatment of chlorobenzenes in heterogeneous, permeable geologic materials without DNAPL is presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

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return to query page

Design Conditions

(for query of heterogeneous, permeable geology & PAH COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	4
performed pilot test (full-scale projects only)	67	3
ISCO coupled w/ other technologies	50	4
any coupled technology before ISCO	0	2
any coupled technology during ISCO	50	2
P&T during ISCO	50	2
any coupled technology after ISCO	100	2
P&T after ISCO	100	2
program modified during implementation	0	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

4 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	2
direct push	1
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	2
ozone	1
persulfate	0
peroxone	0
percarbonate	1

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & PAH COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	10	10	10	2
# of delivery events	1	1	1	2
mean duration of delivery events (days)	120	160	200	2
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of heterogeneous, permeable geology & PAH COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	365	365	365	1
design ROI (ft)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & PAH COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)	188	188	188	1
unit cost ($ / cubic yd treated)	510	510	510	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	4

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	2
evaluate effectiveness	100	2

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & PAH COCs with NAPL)

The preceding tables are based on four case studies, with selected additional details provided below.

- The “Former Wood Treatment Facility, Sonoma, CA” reported in ITRC (2001) used ozone to treat pentachlorophenol (PCP) and PAHs. Significant reductions (up to 98%) in COCs in both soil and soil gas were reported after one year of ozone application.
- Two large scale CHP applications were performed at former manufactured gas plants, one located in Savannah, GA and the other in Augusta, GA. The goal of these projects was to reduce the mass of contaminants to the extent practicable, and these projects were successful in doing so. Geo-Cleanse was the ISCO contractor for this work, and further details regarding these projects may be found at their website.

Some general considerations related to these query criteria are provided below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- NAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & PAH COCs without NAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general guidance relating to the query criteria is listed below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, permeable geology & methylene chloride COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	2
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	50	2
P&T before ISCO	50	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	50	2
MNA after ISCO	50	2
program modified during implementation	0	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & methylene chloride COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	214	214	214	1
# of pore volumes delivered	0.22	0.22	0.22	1
oxidant dose (g oxidant / kg media)	5.5	5.5	5.5	1
design ROI (ft)	5	5	5	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of heterogeneous, permeable geology & methylene chloride COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, permeable geology & methylene chloride COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum methylene chloride concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	0	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & methylene chloride COCs with DNAPL)

The preceding tables were based upon two case studies. One used persulfate to treat COCs that were predominantly chloroethenes and chloroethanes, with methylene chloride present at lower concentrations. The second used CHP to treat a source zone consisting of roughly equal proportions of chloroethenes and methylene chloride. This project noted decreases of over 99% in methylene chloride concentrations immediately after ISCO, but also noted rebound to an unspecified post-ISCO concentration at a later time.

Some general considerations relating to this query are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

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Scenario-Specific Commentary (cont.)

(for query of heterogeneous, permeable geology & methylene chloride COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes). This may mitigate some of the challenges relating to DNAPL listed in the bullets above, though DNAPL always presents a challenge to remediation.
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & methylene chloride COCs without NAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general guidance relating to the query criteria is listed below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

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Design Conditions

(for query of heterogeneous, permeable geology & all COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	83	35
performed pilot test (full-scale projects only)	55	29
ISCO coupled w/ other technologies	78	36
any coupled technology before ISCO	71	28
P&T before ISCO	32	28
SVE before ISCO	29	28
any coupled technology during ISCO	32	28
P&T during ISCO	14	28
excavation during ISCO	11	28
any coupled technology after ISCO	54	28
MNA after ISCO	29	28
enhanced bioremediation after ISCO	18	28
program modified during implementation	58	24

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

51 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	20
direct push	12
sparge points	4
infiltration gallery / trench	4
recirculation	5
fracturing	4
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	19
CHP	22
ozone	7
persulfate	4
peroxone	0
percarbonate	2

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & all COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	16	26	33	15
# of pore volumes delivered	0.021	0.34	0.64	9
oxidant dose (g oxidant / kg media)	0.23	0.90	1.5	10
design ROI (ft)	11	14	28	11
# of delivery events	2	2	4	18
mean duration of delivery events (days)	2.5	4.5	14	14
% performing treatability test	76			17
% performing pilot test (full-scale projects only)	0.5			14

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	214	595	13
# of pore volumes delivered	0.04	0.10	0.23	9
oxidant dose (g oxidant / kg media)	1.7	4.8	10	8
design ROI (ft)	10	10	15	13
# of delivery events	2	3	4	17
mean duration of delivery events (days)	4.8	8.0	14	12
% performing treatability test	93			15
% performing pilot test (full-scale projects only)	64			14

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & all COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	270	370	410	3
design ROI (ft)	no data			
% performing treatability test	50			2
% performing pilot test (full-scale projects only)	33			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, permeable geology & all COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	14	55	78	25
% of sites w/ rebound at one or more locations in TTZ	75			20
at sites where rebound occurred, % of wells w/ rebound	31	55	69	11
total cost (1000s US $)	175	361	829	19
unit cost ($ / cubic yd treated)	72	130	240	13

Attainment of Site Closure

	%	n
percent attaining site closure	8	36

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	7
meet ACLs	44	9
reduce concentration / mass	69	16
evaluate effectiveness	92	12

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & all COCs with NAPL)

The preceding tables show some interesting trends.

- When compared with homogeneous geology, the performance results shown here are generally less successful, providing empirical evidence supporting the intuitive statement that heterogeneity is a challenge to the delivery of ISCO reagents.
- While MCLs eluded practioners using ISCO at these types of sites, nearly half of sites that attempted to meet ACLs were successful in doing so.
- Rebound was more prevalent (75%) at heterogeneous, permeable DNAPL sites when compared to homogeneous, permeable DNAPL sites (42%).

Some general guidance is presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, permeable geology & all COCs with NAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

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Design Conditions

(for query of heterogeneous, permeable geology & all COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	79	24
performed pilot test (full-scale projects only)	73	11
ISCO coupled w/ other technologies	68	22
any coupled technology before ISCO	73	15
excavation before ISCO	47	15
SVE before ISCO	27	15
any coupled technology during ISCO	20	15
excavation during ISCO	7	15
P&T during ISCO	7	15
any coupled technology after ISCO	27	15
excavation after ISCO	13	15
enhanced bioremediation after ISCO	13	15
program modified during implementation	75	12

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

29 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	8
direct push	6
sparge points	6
infiltration gallery / trench	2
recirculation	1
fracturing	3
soil mixing	0
horizontal wells	1

Oxidant Selected

	# Sites
permanganate	14
CHP	8
ozone	6
persulfate	1
peroxone	2
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & all COCs without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	9.4	24	62	11
# of pore volumes delivered	0.050	0.090	0.16	9
oxidant dose (g oxidant / kg media)	0.089	0.25	0.29	8
design ROI (ft)	15	25	33	7
# of delivery events	1	1	2	11
mean duration of delivery events (days)	2	7	9	7
% performing treatability test		82		11
% performing pilot test (full-scale projects only)		80		5

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	130	200	4
# of pore volumes delivered	0.031	0.034	0.067	3
oxidant dose (g oxidant / kg media)	0.38	0.74	0.92	3
design ROI (ft)	13	24	25	6
# of delivery events	2	2	2.8	8
mean duration of delivery events (days)	2	4	5	7
% performing treatability test		100		8
% performing pilot test (full-scale projects only)		33		3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, permeable geology & all COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	180	320	600	5
design ROI (ft)	24	28	35	4
% performing treatability test	50			4
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, permeable geology & all COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	52	61	74	12
% of sites w/ rebound at one or more locations in TTZ		58		12
at sites where rebound occurred, % of wells w/ rebound	23	29	46	4
total cost (1000s US $)	160	246	358	13
unit cost ($ / cubic yd treated)	23	42	220	10

Attainment of Site Closure

	%	n
percent attaining site closure	15	13

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	10	10
meet ACLs	50	2
reduce concentration / mass	100	5
evaluate effectiveness	100	7

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Scenario-Specific Commentary

(for query of heterogeneous, permeable geology & all COCs without NAPL)

There are some trends worth noting when comparing the results of this query to other similar scenarios.

- Rebound is more prevalent at heterogeneous, permeable sites without NAPL (58%) relative to homogeneous, permeable sites without NAPL (0%).
- When considering sites with heterogeneous, permeable geology, sites without NAPL had a greater percent reduction in maximum contaminant concentrations, a lower incidence of rebound, and a lower cost relative to sites where NAPL was present. Sites without NAPL also appear to be more likely to meet their treatment goals.

Some general considerations relating to this query are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

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return to query page

Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

open DISCO Glossary

return to Query Part 1

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethene COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	83	6
performed pilot test (full-scale projects only)	67	6
ISCO coupled w/ other technologies	50	8
any coupled technology before ISCO	100	4
excavation before ISCO	75	4
enhanced bioremediation before ISCO	25	4
any coupled technology during ISCO	0	4
any coupled technology after ISCO	25	4
MNA after ISCO	25	4
program modified during implementation	67	6

Delivery Method

	# Sites
injection wells	5
direct push	2
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	2
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	8
CHP	2
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

10 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethene COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	39	59	7
# of pore volumes delivered	0.017	0.12	0.22	5
oxidant dose (g oxidant / kg media)	0.18	0.59	3.1	6
design ROI (ft)	2.5	3	7.5	3
# of delivery events	1	1	1.5	7
mean duration of delivery events (days)	3.5	5.0	8.5	7
% performing treatability test	100			5
% performing pilot test (full-scale projects only)	50			4

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	0.04	0.04	0.04	1
oxidant dose (g oxidant / kg media)	5	5	5	1
design ROI (ft)	15	15	15	1
# of delivery events	2	2	2	2
mean duration of delivery events (days)	14	14	14	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	100			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethene COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & chloroethene COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	41	47	53	6
% of sites w/ rebound at one or more locations in TTZ	100			4
at sites where rebound occurred, % of wells w/ rebound	38	42	71	3
total cost (1000s US $)	201	201	201	1
unit cost ($ / cubic yd treated)	4,700	4,700	4,700	1

Attainment of Site Closure

	%	n
percent attaining site closure	14	7

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	50	4
reduce concentration / mass	100	1
evaluate effectiveness	100	2

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chloroethene COCs with DNAPL)

Some additional details on the case studies presented in the previous tables are included below.

- The project that had a unit cost of $4,700 / cubic yard was a permanganate injection performed partially beneath a dry cleaning building. The target treatment zone was 1,150 cubic feet in volume. The goal of the project was to reduce the concentrations of PCE in the clay soil to beneath the threshold at which the soils would be considered hazardous waste if excavated. This project was successful in doing so. This project is called “Barb and Ron’s Cleaners” and was reported at the State Coalition for Remediation of Drycleaners’ website.
- The project that attained site closure did so by reducing the PCE concentrations in groundwater to below a site-specific risk-based standard. The site closure was contingent upon a deed notice specifying non-residential use of this property. This project is called “Cowboy Cleaners” and was reported in EPA (2004).

Some general theoretical considerations regarding this scenario are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & chloroethene COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethene COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	6
performed pilot test (full-scale projects only)	100	4
ISCO coupled w/ other technologies	33	1
any coupled technology before ISCO	50	2
excavation before ISCO	50	2
SVE before ISCO	50	2
any coupled technology during ISCO	50	2
P&T during ISCO	50	2
any coupled technology after ISCO	50	2
MNA after ISCO	50	2
enhanced bioremediation after ISCO	50	2
program modified during implementation	75	4

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

6 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	3
direct push	2
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	1
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	4
CHP	3
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethene COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	38	53	67	2
# of pore volumes delivered	0.010	0.010	0.055	3
oxidant dose (g oxidant / kg media)	0.21	0.28	0.34	2
design ROI (ft)	13	20	35	3
# of delivery events	1.8	2.5	3.3	4
mean duration of delivery events (days)	14	15	38	3
% performing treatability test	100			4
% performing pilot test (full-scale projects only)	100			4

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	135	135	135	1
# of pore volumes delivered	0.020	0.030	0.040	2
oxidant dose (g oxidant / kg media)	no data			
design ROI (ft)	13	15	18	2
# of delivery events	1.0	1.0	2.5	3
mean duration of delivery events (days)	8	10	13	2
% performing treatability test	100			3
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med.** is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethene COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & chloroethene COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	-1	3	7	2
% of sites w/ rebound at one or more locations in TTZ		50		2
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	2
meet ACLs	0	1
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chloroethene COCs without DNAPL)

Some general considerations relating to the query criteria are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, impermeable geology & BTEX with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	0	1

Delivery Method

	# Sites
injection wells	0
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & BTEX with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	156	156	156	1
# of pore volumes delivered	0.086	0.086	0.086	1
oxidant dose (g oxidant / kg media)	1.1	1.1	1.1	1
design ROI (ft)	15	15	15	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	7.5	7.5	7.5	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & BTEX with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & BTEX with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total BTEX concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	0	1
reduce concentration / mass	na	0
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & BTEX with LNAPL)

The preceding tables were based on a single case study.

- This project encountered difficulty in delivering the CHP reagents into the dense, impermeable “hardpan” materials in which the contamination resided. Surfacing of reagents through poorly grouted remedial investigation boreholes also hindered delivery.

Some general considerations relating to this query are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds are more reactive with the free radical based oxidants than they are with permanganate, particularly benzene.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, impermeable geology & BTEX COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
P&T before ISCO	100	1
excavation before ISCO	100	1
DPE before ISCO	100	1
any coupled technology during ISCO	100	1
P&T during ISCO	100	1
any coupled technology after ISCO	0	1
program modified during implementation	no data	

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	0
ozone	1
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & BTEX COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & BTEX COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	56	56	56	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & BTEX COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total BTEX concentration in GW	99.9	99.9	99.9	1
% of sites w/ rebound at one or more locations in TTZ	0			1
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	35	35	35	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure (see next page)	100	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & BTEX COCs without LNAPL)

The preceding tables were based upon a single case study, which is described briefly below.

- The project that attained site closure was the “Former Automobile Sales and Service Center” reported in ITRC (2005). Source documents indicated that total BTEX was reduced from 11,600 to 7.6 ug/L in the source area monitoring well. Rebound did not occur in this well after the cessation of ozone delivery. The total project cost was reportedly $35,000. The site contacts could not be reached for further information on this project.

Some general considerations relating to this scenario are provided below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- BTEX compounds are more reactive with the free radical based oxidants than they are with permanganate, particularly benzene.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chloroethane COCs with DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to this scenario are provided below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chloroethane COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethane COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
P&T before ISCO	100	1
SVE before ISCO	100	1
any coupled technology during ISCO	100	1
P&T during ISCO	100	1
any coupled technology after ISCO	100	1
enhanced bioremediation after ISCO	100	1
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethane COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	3	3	3	1
mean duration of delivery events (days)	60	60	60	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & chloroethane COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & chloroethane COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	11	11	11	1
% of sites w/ rebound at one or more locations in TTZ	no data			
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chloroethane COCs without DNAPL)

The single case study meeting the query criteria is the Union Chemical NPL site in Knox, ME, that was contaminated with a mixture of chloroethenes and chloroethanes. Permanganate injections resulted in significant reductions of chloroethenes, while concentrations of chloroethanes remained unchanged (as should be expected). Enhanced bioremediation using sodium lactate was used as a polishing step to treat the chloroethanes.

Some general considerations relating to the query are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require use greater injection volumes relative to more soluble COCs.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of heterogeneous, impermeable geology & TPH with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	0	1

Delivery Method

	# Sites
injection wells	0
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & TPH with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	156	156	156	1
# of pore volumes delivered	0.086	0.086	0.086	1
oxidant dose (g oxidant / kg media)	1.1	1.1	1.1	1
design ROI (ft)	15	15	15	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	7.5	7.5	7.5	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of heterogeneous, impermeable geology & TPH with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of heterogeneous, impermeable geology & TPH with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total BTEX concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	0	1
reduce concentration / mass	na	0
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & TPH with LNAPL)

The preceding tables were based on a single case study. This project encountered difficulty in delivering the CHP reagents into the dense impermeable “hardpan” materials in which the contamination resided. Surfacing of reagents through poorly grouted remedial investigation boreholes also hindered delivery.

Some general considerations relating to this query are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & TPH COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & TPH COCs without LNAPL)

- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & MTBE COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & MTBE COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower COC mass density relative to NAPL sites. Low COC mass density sites can pose the difficulty that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chlorobenzenes COCs with DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & chlorobenzenes COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & chlorobenzenes COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & chlorobenzenes COCs without DNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & PAH COCs with NAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & PAH COCs with NAPL)

- NAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & PAH COCs without NAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & PAH COCs without NAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of heterogeneous, impermeable geology & methylene chloride COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	0	1
any coupled technology before ISCO	na	0
any coupled technology during ISCO	na	0
any coupled technology after ISCO	na	0
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & methylene chloride COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	0.040	0.040	0.040	1
oxidant dose (g oxidant / kg media)	5.0	5.0	5.0	1
design ROI (ft)	15	15	15	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	14	14	14	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & methylene chloride COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & methylene chloride COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum methylene chloride concentration in GW	45	45	45	1
% of sites w/ rebound at one or more locations in TTZ	no data			
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	0	1
reduce concentration / mass	na	0
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & methylene chloride COCs with DNAPL)

The preceding tables were based upon a single case study, the SWMU 12 at Anniston Army Depot. The work was performed to remediate both chloroethene and methylene chloride DNAPL. An initial vadose zone application was performed, after which it was discovered that the depth of contamination was greater than expected. A second saturated zone ISCO application (that described here and on the preceding tables) was performed to treat the deeper contamination.

Some additional considerations relating to the query criteria are included below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (i.e. chloroethenes).
- Methylene chloride is not reactive with permanganate.

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Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & methylene chloride COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & methylene chloride COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & methylene chloride COCs without DNAPL)

- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of heterogeneous, impermeable geology & all COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	71	7
performed pilot test (full-scale projects only)	71	7
ISCO coupled w/ other technologies	56	9
any coupled technology before ISCO	100	5
excavation before ISCO	80	5
enhanced bioremediation before ISCO	20	5
any coupled technology during ISCO	0	5
any coupled technology after ISCO	20	5
MNA after ISCO	20	5
program modified during implementation	57	7

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

11 of the 242 DISCO case studies match this query

Project ER-0623 - DISCO - May 17, 2009

Delivery Method

	# Sites
injection wells	5
direct push	3
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	2
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	8
CHP	3
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & all COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	39	59	7
# of pore volumes delivered	0.017	0.12	0.22	5
oxidant dose (g oxidant / kg media)	0.18	0.59	3.1	6
design ROI (ft)	2.5	3.0	7.5	3
# of delivery events	1.0	1.0	1.5	7
mean duration of delivery events (days)	3.5	5.0	8.5	7
% performing treatability test	100			5
% performing pilot test (full-scale projects only)	50			4

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	266	375	485	2
# of pore volumes delivered	0.052	0.063	0.075	2
oxidant dose (g oxidant / kg media)	2.1	3.1	4.0	2
design ROI (ft)	15	15	15	2
# of delivery events	2	2	2	3
mean duration of delivery events (days)	9.1	11	12	2
% performing treatability test	0			2
% performing pilot test (full-scale projects only)	100			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & all COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & all COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	41	47	53	6
% of sites w/ rebound at one or more locations in TTZ	100			4
at sites where rebound occurred, % of wells w/ rebound	38	42	71	3
total cost (1000s US $)	201	201	201	1
unit cost ($ / cubic yd treated)	4,700	4,700	4,700	1

Attainment of Site Closure

	%	n
percent attaining site closure	14	7

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	40	5
reduce concentration / mass	100	1
evaluate effectiveness	100	2

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & all COCs with NAPL)

Some additional details on selected case studies returned by this query and presented on the preceding pages are included below.

- The project that had a unit cost of $4,700 / cubic yard was a permanganate injection performed partially beneath a dry cleaning building. The target treatment zone was 1,150 cubic feet in volume. The goal of the project was to reduce the concentrations of PCE in the clay soil to beneath the threshold at which the soils would be considered hazardous waste if excavated. This project was successful in doing so. This project is called "Barb and Ron's Cleaners" and was reported at the State Coalition for Remediation of Drycleaners' website.
- The project that attained site closure did so by reducing the PCE concentrations in groundwater to below a site-specific risk-based standard. The site closure was contingent upon a deed notice specifying non-residential use of this property. This project is called "Cowboy Cleaners" and was reported in EPA (2004).

Additional theoretical considerations regarding treatment of NAPL in heterogeneous, impermeable materials follow below and on the next page.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of heterogeneous, impermeable geology & all COCs with NAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of heterogeneous, impermeable geology & all COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	6
performed pilot test (full-scale projects only)	100	4
ISCO coupled w/ other technologies	50	4
any coupled technology before ISCO	67	3
excavation before ISCO	67	3
P&T before ISCO	67	3
any coupled technology during ISCO	67	3
SVE during ISCO	33	3
P&T during ISCO	33	3
any coupled technology after ISCO	33	3
MNA after ISCO	33	3
enhanced bioremediation after ISCO	33	3
program modified during implementation	75	4

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

7 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	3
direct push	2
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	1
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	4
CHP	3
ozone	1
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & all COCs without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	38	53	67	2
# of pore volumes delivered	0.010	0.010	0.055	3
oxidant dose (g oxidant / kg media)	0.21	0.28	0.34	2
design ROI (ft)	13	20	35	3
# of delivery events	1.8	2.5	3.3	4
mean duration of delivery events (days)	14	15	38	3
% performing treatability test	100			4
% performing pilot test (full-scale projects only)	100			4

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	135	135	135	1
# of pore volumes delivered	0.020	0.030	0.040	2
oxidant dose (g oxidant / kg media)	no data			
design ROI (ft)	13	15	18	2
# of delivery events	1.0	1.0	2.5	3
mean duration of delivery events (days)	8	10	13	2
% performing treatability test	100			3
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of heterogeneous, impermeable geology & all COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	56	56	56	1
design ROI (ft)	na			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of heterogeneous, impermeable geology & all COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	3	11	55	3
% of sites w/ rebound at one or more locations in TTZ	33			3
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	35	35	35	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	25	4

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	2
meet ACLs	0	1
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of heterogeneous, impermeable geology & all COCs without NAPL)

The project that attained site closure was the “Former Automobile Sales and Service Center” reported in ITRC (2005). Source documents indicated that total BTEX was reduced from 11,600 to 7.6 ug/L in the source area monitoring well. Rebound did not occur in this well after the cessation of ozone delivery. The total project cost was reportedly $35,000. The site contacts could not be reached for further information on this project.

Additional theoretical considerations relating to this query include those below.

- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs.
- Diffusive transport may be a possible oxidant transport mechanism, though oxidant persistence and the required travel distance must be considered.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

open DISCO Glossary

return to Query Part 1

Design Conditions

(for query of low porosity fractured rock & chloroethene COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	2
performed pilot test (full-scale projects only)	100	3
ISCO coupled w/ other technologies	100	4
any coupled technology before ISCO	75	4
excavation before ISCO	50	4
P&T before ISCO	25	4
any coupled technology during ISCO	25	4
P&T during ISCO	25	4
any coupled technology after ISCO	50	4
P&T after ISCO	50	4
program modified during implementation	no data	

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

6 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	4
direct push (see commentary)	1
sparge points	0
infiltration gallery / trench	1
recirculation	2
fracturing	1
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	6
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chloroethene COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	26	37	90	4
# of pore volumes delivered	56	56	56	1
oxidant dose (g oxidant / kg media)	0.026	0.026	0.026	1
design ROI (ft)	40	40	40	1
# of delivery events	1	3	5	5
mean duration of delivery events (days)	5	5	5	1
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			3

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chloroethene COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & chloroethene COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	53	61	69	2
% of sites w/ rebound at one or more locations in TTZ	100			2
at sites where rebound occurred, % of wells w/ rebound	25	25	25	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	5

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	0	1
reduce concentration / mass	67	3
evaluate effectiveness	100	3

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & chloroethene COCs with DNAPL)

Some additional information regarding selected case studies follows below.

- The case study that used a direct push delivery technique did so in the weathered portion of the bedrock in combination with recirculation wells to treat the more competent bedrock. Direct push technology should not be relied upon to penetrate fractured rock.

Theoretical considerations relating to this query include those below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & chloroethene COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of low porosity fractured rock & chloroethene COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chloroethene COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	1.1	1.1	1.1	1
oxidant dose (g oxidant / kg media)	no data			
design ROI (ft)	14	14	14	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	11	11	11	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chloroethene COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & chloroethene COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & chloroethene COCs without DNAPL)

The preceding tables were based upon a single case study. This project used CHP to remediate a mixture of chloroethenes, BTEX, and chloroform in fractured crystalline bedrock. Some theoretical considerations relating to this scenario are listed below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of low porosity fractured rock & BTEX COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of low porosity fractured rock & BTEX COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & BTEX COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	1.1	1.1	1.1	1
oxidant dose (g oxidant / kg media)	no data			
design ROI (ft)	14	14	14	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	11	11	11	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & BTEX COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & BTEX COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & BTEX COCs without LNAPL)

The preceding tables were based upon a single case study. This project used CHP to remediate a mixture of chloroethenes, BTEX, and chloroform in fractured crystalline bedrock. Some theoretical considerations regarding these query criteria are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of low porosity fractured rock & chloroethane COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
P&T before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	no data	

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chloroethane COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	31	31	31	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	40	40	40	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chloroethane COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & chloroethane COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethane concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	0	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & chloroethane COCs with DNAPL)

The one case study on which the preceding tables are based is a pilot study that treated a presumed DNAPL source zone with TCE at a concentration of 100,000 ug/L, 1,1,1-TCA at a concentration of 930 ug/L, and methylene chloride at a concentration of 1,600 ug/L. Permanganate was selected as an oxidant due to its persistence in the subsurface and because chloroethenes (e.g. TCE) are amenable to oxidation with permanganate. In general, the pilot study was able to effect short term destruction of some contaminants. Rebound occurred in most monitoring wells in the treatment zone and was attributed in part to back diffusion of COCs from the rock matrix.

Some additional general considerations relating to this type of site are included below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & chloroethane COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

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return to query page

Scenario-Specific Commentary

(for query of low porosity fractured rock & chloroethane COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & chloroethane COCs without DNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for ISCO reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Scenario-Specific Commentary

(for query of low porosity fractured rock & TPH COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & TPH COCs with LNAPL)

- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require use of greater injection volumes or a greater number of delivery events relative to more soluble COCs.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of low porosity fractured rock & TPH COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & TPH COCs without LNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require use of greater injection volumes or a greater number of delivery events relative to more soluble COCs.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of low porosity fractured rock & MTBE COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of low porosity fractured rock & MTBE COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower COC mass density relative to NAPL sites. Low COC mass density sites can pose the challenge in that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of low porosity fractured rock & chlorobenzenes COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	50	2
P&T before ISCO	50	2
excavation before ISCO	50	2
any coupled technology during ISCO	50	2
P&T during ISCO	50	2
any coupled technology after ISCO	50	2
P&T after ISCO	50	2
program modified during implementation	no data	

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	1
ozone	0
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chlorobenzenes COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	10	10	10	1
# of pore volumes delivered	56	56	56	1
oxidant dose (g oxidant / kg media)	0.026	0.026	0.026	1
design ROI (ft)	no data			
# of delivery events	1	1	1	1
mean duration of delivery events (days)	5	5	5	5
% performing treatability test	no data			
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	248	248	248	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	2	2	2	1
mean duration of delivery events (days)	3	3	3	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & chlorobenzenes COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & chlorobenzenes COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	24	24	24	1
% of sites w/ rebound at one or more locations in TTZ	no data			
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & chlorobenzenes COCs with DNAPL)

One of the case studies on which the preceding tables are based is the bedrock portion of the Eastland Woolen Mills NPL site in Corinna, ME. Some conceptual considerations regarding these query criteria are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & chlorobenzenes COCs with DNAPL)

- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of low porosity fractured rock & chlorobenzenes COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & chlorobenzenes COCs without DNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of low porosity fractured rock & PAH COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies		
any coupled technology before ISCO		
any coupled technology during ISCO		
any coupled technology after ISCO		
program modified during implementation		

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & PAH COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	191	191	191	1
# of pore volumes delivered	0.60	0.60	0.60	1
oxidant dose (g oxidant / kg media)	1.5	1.5	1.5	1
design ROI (ft)	no data			
# of delivery events	1	1	1	1
mean duration of delivery events (days)	39	39	39	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & PAH COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & PAH COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total PAH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	no data	

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & PAH COCs with NAPL)

Some general theoretical considerations relating to this type of scenario are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- NAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of low porosity fractured rock & PAHs COCs without NAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general theoretical considerations relating to this type of scenario are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower COC mass density relative to NAPL sites. Low COC mass density sites can pose the challenge that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require use of greater injection durations relative to more soluble COCs. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of low porosity fractured rock & methylene chloride COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
P&T before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	no data	

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & methylene chloride COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	31	31	31	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	40	40	40	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & methylene chloride COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & methylene chloride COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethane concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	0	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & methylene chloride COCs with DNAPL)

The one case study on which the preceding tables are based is a pilot study that treated a presumed DNAPL source zone with TCE at a concentration of 100,000 ug/L, 1,1,1-TCA at a concentration of 930 ug/L, and methylene chloride at a concentration of 1,600 ug/L. Permanganate was selected as an oxidant due to its persistence in the subsurface and because chloroethenes (e.g. TCE) are amenable to oxidation with permanganate. In general, the pilot study was able to effect short term destruction of some contaminants. Rebound occurred in most monitoring wells in the treatment zone and was attributed in part to back-diffusion of COCs from the rock matrix.

Some additional theoretical considerations regarding methylene chloride treatment in low porosity bedrock are given below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & methylene chloride COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of low porosity fractured rock & methylene chloride COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & methylene chloride COCs without DNAPL)

- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of low porosity fractured rock & all COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	4
performed pilot test (full-scale projects only)	100	4
ISCO coupled w/ other technologies	100	6
any coupled technology before ISCO	83	6
excavation before ISCO	67	6
P&T before ISCO	33	6
any coupled technology during ISCO	33	6
P&T during ISCO	33	6
any coupled technology after ISCO	50	6
P&T after ISCO	33	6
enhanced bioremediation after ISCO	17	6
program modified during implementation	no data	

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

8 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	6
direct push	1
sparge points	0
infiltration gallery / trench	1
recirculation	2
fracturing	1
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	6
CHP	2
ozone	0
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & all COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	26	37	90	4
# of pore volumes delivered	56	56	56	1
oxidant dose (g oxidant / kg media)	0.026	0.026	0.026	1
design ROI (ft)	40	40	40	1
# of delivery events	1	3	5	5
mean duration of delivery events (days)	5	5	5	1
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			3

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	119	162	205	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	2	2	2	1
mean duration of delivery events (days)	3	3	3	1
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & all COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med.** is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & all COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	35	45	61	3
% of sites w/ rebound at one or more locations in TTZ	100			2
at sites where rebound occurred, % of wells w/ rebound	25	25	25	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	7

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	2
meet ACLs	0	1
reduce concentration / mass	75	4
evaluate effectiveness	100	4

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & all COCs with NAPL)

Of note among the previous statistics are the following.

- While appreciable reductions in COC concentrations in groundwater were noted, numeric standards (MCLs and ACLs) were not met at these sites. Mass reduction was met with a greater frequency, though estimating the mass of COCs present in fractured rock is a challenging task.
- P&T was used as a coupled technology with considerable frequency. In situations in which P&T systems are already in place, this existing infrastructure can be leveraged to implement ISCO at a lower cost than installing an ISCO system with no infrastructure in place.
- Rebound occurred in at least one location in the TTZ of both sites whose data records were extensive enough to perform the required calculations despite the rock matrix having a relatively low porosity.

Some additional general considerations relating to the treatment of NAPL in fractured rock are listed below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of low porosity fractured rock & all COCs with NAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of low porosity fractured rock & all COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & all COCs without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	1.1	1.1	1.1	1
oxidant dose (g oxidant / kg media)	no data			
design ROI (ft)	14	14	14	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	11	11	11	1
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of low porosity fractured rock & all COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of low porosity fractured rock & all COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	no data			
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of low porosity fractured rock & all COCs without NAPL)

The preceding tables were based upon a single case study. This project used CHP to remediate a mixture of chloroethenes, BTEX, and chloroform in fractured crystalline bedrock. Some additional general commentary relating to these query criteria are listed below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

open DISCO Glossary

return to Query Part 1

Design Conditions

(for query of high porosity fractured rock & chloroethene COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	4
performed pilot test (full-scale projects only)	33	3
ISCO coupled w/ other technologies	75	4
any coupled technology before ISCO	100	3
excavation before ISCO	100	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	0	3
program modified during implementation	33	3

Delivery Method

	# Sites
injection wells	2
direct push	1
sparge points	1
infiltration gallery / trench	3
recirculation	1
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	4
CHP	2
ozone	1
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

7 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & chloroethene COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	12	52	105	4
# of pore volumes delivered	0.12	0.21	0.31	2
oxidant dose (g oxidant / kg media)	15	30	45	2
design ROI (ft)				
# of delivery events	1.0	1.0	1.5	3
mean duration of delivery events (days)	1.0	1.0	1.5	3
% performing treatability test	0			2
% performing pilot test (full-scale projects only)	50			2

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	243	361	479	2
# of pore volumes delivered	0.014	0.023	0.032	2
oxidant dose (g oxidant / kg media)	0.054	0.056	0.058	2
design ROI (ft)	30	30	30	2
# of delivery events	1.8	2.5	3.3	2
mean duration of delivery events (days)	6.2	8.8	11.4	2
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & chloroethene COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of high porosity fractured rock & chloroethene COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	12	21	31	3
% of sites w/ rebound at one or more locations in TTZ	100			2
at sites where rebound occurred, % of wells w/ rebound	50	50	50	1
total cost (1000s US $)	1,670	1,670	1,670	1
unit cost ($ / cubic yd treated)	5	5	5	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	4

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	2
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & chloroethene COCs with DNAPL)

Among the sites matching this query with a data record that allowed the assessment of project performance, MCLs remained elusive while mass reduction goals were successfully met. Rebound of COCs, either from the rock matrix, DNAPL phase, or both, was common. Coupling with P&T was not used among these sites, which is somewhat anomalous when compared to the low matrix porosity bedrock sites, among which coupling with P&T was ubiquitous.

Some general commentary regarding this query is listed below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & chloroethene COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of high porosity fractured rock & chloroethene COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	50	2
excavation before ISCO	50	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	50	2
MNA after ISCO	50	2
program modified during implementation	no data	

Delivery Method

	# Sites
injection wells	2
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	2
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & chloroethene COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	10	20	29	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	1.3	1.5	1.8	2
mean duration of delivery events (days)	2	2	2	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & chloroethene COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of high porosity fractured rock & chloroethene COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	0	1

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & chloroethene COCs without DNAPL)

The preceding tables are based on two case studies, both of which were lacking performance data. Some general considerations relating to the treatment of chloroethenes without DNAPL in high porosity fractured rock are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & BTEX COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Scenario-Specific Commentary

(for query of high porosity fractured rock & BTEX COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of high porosity fractured rock & chloroethane COCs with DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & chloroethane COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & chloroethane COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & chloroethane COCs without DNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chloroethanes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & TPH COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & TPH COCs with LNAPL)

- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Scenario-Specific Commentary

(for query of high porosity fractured rock & TPH COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & TPH COCs without LNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & MTBE COCs with LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of high porosity fractured rock & MTBE COCs without LNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the "select all" button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the "select all" button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower COC mass density relative to NAPL sites. Low COC mass density sites can pose a challenge in that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of high porosity fractured rock & chlorobenzenes COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & chlorobenzenes COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	126	126	126	1
# of pore volumes delivered	0.041	0.041	0.041	1
oxidant dose (g oxidant / kg media)	0.059	0.059	0.059	1
design ROI (ft)	30	30	30	1
# of delivery events	4	4	4	1
mean duration of delivery events (days)	14	14	14	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & chlorobenzenes COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of high porosity fractured rock & chlorobenzenes COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chlorobenzene concentration in GW	12	12	12	1
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	50	50	50	1
total cost (1000s US $)	1,670	1,670	1,670	1
unit cost ($ / cubic yd treated)	5	5	5	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & chlorobenzenes COCs with DNAPL)

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & chlorobenzenes COCs with DNAPL)

- Chlorobenzenes generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & chlorobenzenes COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & chlorobenzenes COCs without DNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of high porosity fractured rock & PAH COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	0	1
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	0	1
any coupled technology after ISCO	0	1
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	0
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

1 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & PAH COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	126	126	126	1
# of pore volumes delivered	0.041	0.041	0.041	1
oxidant dose (g oxidant / kg media)	0.059	0.059	0.059	1
design ROI (ft)	30	30	30	1
# of delivery events	4	4	4	1
mean duration of delivery events (days)	14	14	14	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & PAH COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of high porosity fractured rock & PAH COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total PAH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	50	50	50	1
total cost (1000s US $)	1,670	1,670	1,670	1
unit cost ($ / cubic yd treated)	5	5	5	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & PAH COCs with NAPL)

Some general considerations relating to these query criteria are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- NAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Scenario-Specific Commentary

(for query of high porosity fractured rock & PAH COCs without NAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower COC mass density relative to NAPL sites, which may pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be consumed by non-target compounds (e.g. NOD) relative to sites with NAPL.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require a greater injection duration relative to more soluble COCs. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & methylene chloride COCs with DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & methylene chloride COCs with DNAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of high porosity fractured rock & methylene chloride COCs without DNAPL)

There are no sites within DISCO that meet this particular set of query criteria. To access some information on sites that may be relevant to this search, please do one or both of the following:

- Return to the query page and use the “select all” button in the geology portion of the query and then the COC group in which you are interested.
- Return to the query page, select the specific geologic media type in which you are interested, and then use the “select all” button on for the COC portion of the query.

Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant’s persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & methylene chloride COCs without DNAPL)

- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of high porosity fractured rock & all COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	4
performed pilot test (full-scale projects only)	33	3
ISCO coupled w/ other technologies	75	4
any coupled technology before ISCO	100	3
excavation before ISCO	100	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	0	3
program modified during implementation	33	3

Delivery Method

	# Sites
injection wells	2
direct push	1
sparge points	1
infiltration gallery / trench	3
recirculation	1
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	4
CHP	2
ozone	1
persulfate	0
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

7 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & all COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	12	52	110	4
# of pore volumes delivered	0.12	0.21	0.31	2
oxidant dose (g oxidant / kg media)	15	30	45	2
design ROI (ft)	no data			
# of delivery events	1.0	1.0	1.5	3
mean duration of delivery events (days)	1.0	1.0	1.5	3
% performing treatability test	0			2
% performing pilot test (full-scale projects only)	50			2

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	244	361	479	2
# of pore volumes delivered	0.014	0.023	0.032	2
oxidant dose (g oxidant / kg media)	0.054	0.056	0.057	2
design ROI (ft)	30	30	30	1
# of delivery events	1.8	2.5	3.3	2
mean duration of delivery events (days)	6.1	8.8	11	2
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & all COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	no data			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of high porosity fractured rock & all COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	12	21	31	3
% of sites w/ rebound at one or more locations in TTZ	100			2
at sites where rebound occurred, % of wells w/ rebound	50	50	50	1
total cost (1000s US $)	1,670	1,670	1,670	1
unit cost ($ / cubic yd treated)	5	5	5	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	4

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	2
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & all COCs with NAPL)

The data presented in the preceding tables showed that mass reductions goals were successfully met when treating this type of fractured rock while MCLs were not in the one case study that attempted that goal. Some general considerations relating to these query criteria are presented below and on the following page.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of high porosity fractured rock & all COCs with NAPL)

- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of high porosity fractured rock & all COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	1
performed pilot test (full-scale projects only)	no data	
ISCO coupled w/ other technologies	100	3
any coupled technology before ISCO	67	3
excavation before ISCO	67	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	33	3
MNA after ISCO	33	3
program modified during implementation	no data	

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

3 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	2
direct push	0
sparge points	0
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	2
CHP	0
ozone	0
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & all COCs without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	10	20	29	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	1.3	1.5	1.8	2
mean duration of delivery events (days)	2	2	2	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of high porosity fractured rock & all COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of high porosity fractured rock & all COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	50	2

(Continued on following page)

Scenario-Specific Commentary

(for query of high porosity fractured rock & all COCs without NAPL)

The preceding tables were based upon three case studies with limited performance data. Some general considerations relating to these query criteria are presented below.

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Oxidant diffusion through the rock matrix is conceptually possible but careful consideration must be given to the oxidant's persistence in situ and the oxidant demand of the rock matrix.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Query Part 2: Contaminants of Concern (COCs)

Click on the COC / NAPL conditions to be treated

(pick one button, and run again if multiple groups are present)

chloroethenes (PCE, TCE, cis-DCE etc.)	w/ DNAPL	w/out DNAPL
BTEX (Benzene, Ethylbenzene etc.)	w/ LNAPL	w/out LNAPL
chloroethanes (1,1,1-TCA, 1,1-DCA etc.)	w/ DNAPL	w/out DNAPL
TPH (e.g. DRO, RRO)	w/ LNAPL	w/out LNAPL
MTBE	w/ LNAPL	w/out LNAPL
chlorobenzenes (dichlorobenzene isomers etc.)	w/ DNAPL	w/out DNAPL
PAHs (pyrene, anthracene etc.)	w/ NAPL	w/out NAPL
methylene chloride	w/ DNAPL	w/out DNAPL
select all	w/ NAPL	w/out NAPL

open DISCO Glossary

return to Query Part 1

Design Conditions

(for query of all geology groups & chloroethene COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	76	50
performed pilot test (full-scale projects only)	55	38
ISCO coupled w/ other technologies	74	57
any coupled technology before ISCO	76	42
excavation before ISCO	40	42
P&T before ISCO	29	42
any coupled technology during ISCO	28	42
P&T during ISCO	10	42
SVE during ISCO	7	42
any coupled technology after ISCO	55	42
MNA after ISCO	33	42
enhanced bioremediation after ISCO	21	42
program modified during implementation	58	36

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

80 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	37
direct push	20
sparge points	2
infiltration gallery / trench	8
recirculation	10
fracturing	6
soil mixing	2
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	45
CHP	28
ozone	4
persulfate	5
peroxone	0
percarbonate	1

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethene COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	15	30	44	37
# of pore volumes delivered	0.021	0.34	1.7	21
oxidant dose (g oxidant / kg media)	0.15	0.80	2.8	23
design ROI (ft)	6	12	24	19
# of delivery events	1	2	4	40
mean duration of delivery events (days)	2	4	11	31
% performing treatability test	74			31
% performing pilot test (full-scale projects only)	56			25

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	214	595	17
# of pore volumes delivered	0.033	0.058	0.19	14
oxidant dose (g oxidant / kg media)	0.66	1.8	5.1	12
design ROI (ft)	10	15	19	14
# of delivery events	2	3	4	22
mean duration of delivery events (days)	4	7	11	16
% performing treatability test	82			17
% performing pilot test (full-scale projects only)	57			14

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethene COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	no data			
design ROI (ft)				
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & chloroethene COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	30	55	81	36
% of sites w/ rebound at one or more locations in TTZ		79		34
at sites where rebound occurred, % of wells w/ rebound	33	44	75	17
total cost (1000s US $)	173	376	1,030	20
unit cost ($ / cubic yd treated)	62	160	220	15

Attainment of Site Closure

	%	n
percent attaining site closure	10	59

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	10
meet ACLs	37	19
reduce concentration / mass	65	23
evaluate effectiveness	95	20

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & chloroethene COCs with DNAPL)

The preceding tables show that when treating chloroethene DNAPL sites, MCLs have remained elusive, while ACLs have been achieved at nearly half the sites attempting this goal, and that mass reduction and technology evaluation are achieved with considerable success. Rebound is a prevalent occurrence, but the degree to which it is a site wide vs. localized phenomenon is variable.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & chloroethene COCs with DNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of all geology groups & chloroethene COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	80	31
performed pilot test (full-scale projects only)	67	18
ISCO coupled w/ other technologies	61	28
any coupled technology before ISCO	61	18
excavation before ISCO	39	18
SVE before ISCO	17	18
any coupled technology during ISCO	28	18
P&T during ISCO	11	18
excavation during ISCO	6	18
any coupled technology after ISCO	33	18
MNA after ISCO	17	18
enhanced bioremediation after ISCO	17	18
program modified during implementation	67	18

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

39 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	15
direct push	9
sparge points	4
infiltration gallery / trench	3
recirculation	1
fracturing	4
soil mixing	0
horizontal wells	1

Oxidant Selected

	# Sites
permanganate	24
CHP	12
ozone	5
persulfate	0
peroxone	1
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethene COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	8.5	24	71	18
# of pore volumes delivered	0.010	0.073	0.15	12
oxidant dose (g oxidant / kg media)	0.11	0.25	0.30	10
design ROI (ft)	14	20	33	11
# of delivery events	1	1	3	20
mean duration of delivery events (days)	2	8	15	13
% performing treatability test	88			17
% performing pilot test (full-scale projects only)	83			12

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	135	265	7
# of pore volumes delivered	0.029	0.042	0.51	6
oxidant dose (g oxidant / kg media)	0.56	0.92	1.1	4
design ROI (ft)	10	17	25	10
# of delivery events	1	2	2.5	12
mean duration of delivery events (days)	2	5	10	10
% performing treatability test	83			12
% performing pilot test (full-scale projects only)	40			5

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethene COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	173	251	376	4
design ROI (ft)	31	38	44	2
% performing treatability test	50			4
% performing pilot test (full-scale projects only)	50			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & chloroethene COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethene concentration in GW	18	50	61	14
% of sites w/ rebound at one or more locations in TTZ	56			18
at sites where rebound occurred, % of wells w/ rebound	25	33	33	5
total cost (1000s US $)	137	177	368	16
unit cost ($ / cubic yd treated)	28	56	360	12

Attainment of Site Closure

	%	n
percent attaining site closure	26	19

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	21	14
meet ACLs	50	4
reduce concentration / mass	100	6
evaluate effectiveness	86	7

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & chloroethene COCs without DNAPL)

While the range in concentration reductions among these sites is lower than chloroethene contaminated sites where DNAPL was present, sites shown in this query where DNAPL was not present were more successful in meeting their goals, including several sites that met MCLs. Rebound was also less prevalent at sites without DNAPL, and when it did occur it was generally a more localized phenomenon.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & chloroethene COCs without DNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of all geology groups & BTEX COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	67	3
performed pilot test (full-scale projects only)	100	4
ISCO coupled w/ other technologies	100	5
any coupled technology before ISCO	60	5
excavation before ISCO	60	5
P&T before ISCO	20	5
any coupled technology during ISCO	40	5
SVE during ISCO	20	5
P&T during ISCO	20	5
any coupled technology after ISCO	20	5
P&T after ISCO	20	5
program modified during implementation	67	3

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

10 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	3
sparge points	2
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	6
ozone	3
persulfate	0
peroxone	0
percarbonate	1

(Continued on following page)

Design Conditions

(for query of all geology groups & BTEX COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	106	156	376	3
# of pore volumes delivered	0.086	0.086	0.086	1
oxidant dose (g oxidant / kg media)	1.1	1.1	1.1	1
design ROI (ft)	6.5	10	13	3
# of delivery events	1	1	2	5
mean duration of delivery events (days)	3	5	8	5
% performing treatability test	67			3
% performing pilot test (full-scale projects only)	100			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & BTEX COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	195	210	225	2
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & BTEX COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total BTEX concentration in GW	81	81	81	1
% of sites w/ rebound at one or more locations in TTZ	0			2
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	170	200	211	3
unit cost ($ / cubic yd treated)	94	94	94	1

Attainment of Site Closure

	%	n
percent attaining site closure	33	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	33	3
reduce concentration / mass	100	2
evaluate effectiveness	na	0

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Scenario-Specific Commentary

(for query of all geology groups & BTEX COCs with LNAPL)

Among the sites meeting these query criteria, ISCO performance seemed to have resulted in fair success, though the performance data were incomplete for many of these sites.

- The project that attained closure was a former service station located in Pennsylvania whose project information is included in ITRC (2005). This project used ozone to remediate BTEX and MTBE in order to expedite a property transfer. Attempts to gather additional information from the site regulator made by DISCO's creators were unsuccessful.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & BTEX COCs with LNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Design Conditions

(for query of all geology groups & BTEX COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	4
performed pilot test (full-scale projects only)	50	2
ISCO coupled w/ other technologies	100	5
any coupled technology before ISCO	100	5
excavation before ISCO	80	5
P&T before ISCO	20	5
SVE before ISCO	20	5
any coupled technology during ISCO	20	5
SVE during ISCO	20	5
any coupled technology after ISCO	0	5
program modified during implementation	100	3

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

7 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	2
direct push	0
sparge points	3
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	3
ozone	2
persulfate	1
peroxone	1
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & BTEX COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	1.1	1.1	1.1	1
oxidant dose (g oxidant / kg media)	no data			
design ROI (ft)	14	14	14	1
# of delivery events	1.5	2	2	3
mean duration of delivery events (days)	4.6	6.8	8.9	2
% performing treatability test	50			2
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & BTEX COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	56	56	56	1
design ROI (ft)	20	20	20	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & BTEX COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total BTEX concentration in GW	90	99	99.5	3
% of sites w/ rebound at one or more locations in TTZ	50			2
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	93	151	209	2
unit cost ($ / cubic yd treated)	28	28	28	1

Attainment of Site Closure

	%	n
percent attaining site closure	33	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & BTEX COCs without LNAPL)

The reductions in maximum concentrations of BTEX in groundwater were high for projects treating BTEX without LNAPL relative to other types of projects. Use of coupling during and after ISCO was also less frequent for these types of projects relative to others.

- The project that attained site closure was the “Former Automobile Sales and Service Center” reported in ITRC (2005). Source documents indicated that total BTEX was reduced from 11,600 to 7.6 ug/L in the source area monitoring well. Rebound did not occur in this well after the cessation of ozone delivery. The total project cost was reportedly $35,000. The site contacts could not be reached for further information on this project.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & BTEX COCs without LNAPL)

- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- BTEX compounds, particularly benzene, are more reactive with the free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of all geology groups & chloroethane COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	4
performed pilot test (full-scale projects only)	100	3
ISCO coupled w/ other technologies	60	5
any coupled technology before ISCO	100	3
P&T before ISCO	100	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	0	3
program modified during implementation	0	1

Delivery Method

	# Sites
injection wells	3
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	1
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	2
CHP	2
ozone	0
persulfate	3
peroxone	0
percarbonate	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

7 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethane COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	31	31	31	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	21	28	34	2
# of delivery events	1.3	1.5	1.8	2
mean duration of delivery events (days)	no data			
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	1.3	1.5	1.8	2
mean duration of delivery events (days)	15	15	15	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)	100			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethane COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & chloroethane COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethane concentration in GW	37	68	83	3
% of sites w/ rebound at one or more locations in TTZ	75			4
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)	105	148	192	2
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	17	6

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	33	3
evaluate effectiveness	100	3

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & chloroethane COCs with DNAPL)

Among the few case studies meeting these query criteria, some projects appeared to have performed well.

- The project that reportedly attained site closure was the “Former News Publisher Facility, Framingham, MA” reported in EPA (1998). This case study site contained 1,1,1-TCA at concentrations indicative of DNAPL, and lesser amounts of cis-DCE and VC. The source documents indicated that land use restrictions were not required after ISCO. Attempts by the creators of DISCO to contact the site contacts listed in the source document were unsuccessful.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & chloroethane COCs with DNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- DNAPL dissolution is a potentially slow process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chloroethanes generally have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require use of greater injection durations to allow desorption to occur. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of all geology groups & chloroethane COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	2
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	100	1
P&T before ISCO	100	1
SVE before ISCO	100	1
excavation before ISCO	100	1
any coupled technology during ISCO	100	1
P&T during ISCO	100	1
any coupled technology after ISCO	100	1
enhanced bioremediation after ISCO	100	1
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	0
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	2
CHP	0
ozone	0
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethane COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	23	23	23	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events	1.5	2	2.5	2
mean duration of delivery events (days)	34	43	51	2
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			2

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & chloroethane COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & chloroethane COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chloroethane concentration in GW	86	86	86	1
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

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Scenario-Specific Commentary

(for query of all geology groups & chloroethane COCs without DNAPL)

Both the case studies reported in the previous tables treated a mixture of chloroethenes and chloroethanes. Permanganate was used to treat the chloroethenes, and this oxidant is not reactive with chloroethanes. The 86% reduction of TCA seen at this site was likely due to other processes besides chemical oxidation by permanganate.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & chloroethane COCs without DNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chloroethanes generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chloroethanes are not reactive with permanganate. In situations in which chloroethanes are present as a co-contaminant (e.g. dichloroethane isomers resulting from TCE degradation), permanganate may be used to reduce risk by degrading the primary contaminants, but should not be expected to reduce chloroethane concentrations.

(This is the end of your query. Please start over with the link below.)

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return to query page

Design Conditions

(for query of all geology groups & TPH COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	4
performed pilot test (full-scale projects only)	75	4
ISCO coupled w/ other technologies	75	4
any coupled technology before ISCO	67	3
excavation before ISCO	67	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	33	3
P&T after ISCO	33	3
program modified during implementation	50	2

Delivery Method

	# Sites
injection wells	1
direct push	2
sparge points	1
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	3
ozone	2
persulfate	0
peroxone	0
percarbonate	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

6 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of all geology groups & TPH COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	276	395	495	3
# of pore volumes delivered	0.086	0.086	0.086	1
oxidant dose (g oxidant / kg media)	1.1	1.1	1.1	1
design ROI (ft)	11	13	14	2
# of delivery events	1.5	2	4	3
mean duration of delivery events (days)	67	126	186	2
% performing treatability test	33			3
% performing pilot test (full-scale projects only)	67			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & TPH COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	180	180	180	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & TPH COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum TPH concentration in GW	-18	15	48	2
% of sites w/ rebound at one or more locations in TTZ	0			2
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	98	140	164	3
unit cost ($ / cubic yd treated)	510	510	510	1

Attainment of Site Closure

	%	n
percent attaining site closure	33	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	2
meet ACLs	0	1
reduce concentration / mass	100	1
evaluate effectiveness	100	1

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & TPH COCs with LNAPL)

The performance of the sites returned by this query span a range between successful and less than successful. The selected case studies matching this query are discussed below.

- One project used CHP to treat COCs resulting from a gasoline UST. The project encountered difficulty injecting reagents into the "hardpan" soils at the site. After ISCO injections, LNAPL up to one foot thick was discovered for the first time, presumably after migration from the crushed stone ballast underlying an adjacent highway.
- One of the ozone projects was the "Former Service Station, Commerce City, CO" reported in EPA (1998). This project reportedly reduced TPH concentrations from 37 mg/L to non-detect levels. Four quarters of confirmatory groundwater sampling had just begun after ozone system shutdown at the time of this source document's publication.
- A CHP treatment at a former MGP located in Savannah, GA resulted in the determination that COCs had been reduced to the extent practicable.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous and permeable media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & TPH COCs with LNAPL)

- Low permeability media may preclude advective delivery of oxidants.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & TPH COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	50	2
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	4
any coupled technology before ISCO	75	4
SVE before ISCO	75	4
excavation before ISCO	50	4
any coupled technology during ISCO	0	4
any coupled technology after ISCO	25	4
excavation after ISCO	25	4
enhanced bioremediation after ISCO	25	4
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

5 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	2
direct push	0
sparge points	3
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	2
ozone	2
persulfate	0
peroxone	1
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & TPH COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	242	360	477	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	10	10	10	1
# of delivery events	2	2	2	1
mean duration of delivery events (days)	2	2	2	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & TPH COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	no data			
design ROI (ft)	20	20	20	1
% performing treatability test	no data			
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of all geology groups & TPH COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum TPH concentration in GW	99.9	99.9	99.9	1
% of sites w/ rebound at one or more locations in TTZ	100			1
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)	144	144	144	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	50	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	67	3
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	na	0

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Scenario-Specific Commentary

(for query of all geology groups & TPH COCs without LNAPL)

The projects shown in the previous tables include some that were quite successful. Those that met MCLs did so in the downgradient portion of gasoline plumes using ozone or peroxone sparge curtains.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & TPH COCs without LNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- TPH components generally have a lower solubility and are more highly sorptive to soil than chloroethenes. This may require use of greater injection volumes or a greater number of delivery events relative to more soluble COCs.
- Alkaline activation methods (e.g. with percarbonate or persulfate) or the addition (e.g. heat activated persulfate) or generation of heat (e.g. CHP) may make certain TPH components more soluble.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- TPH components are more reactive with free radical based oxidants than they are with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & MTBE COCs with LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	no data	
performed pilot test (full-scale projects only)	100	1
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	100	2
excavation before ISCO	50	2
P&T before ISCO	50	2
SVE before ISCO	50	2
any coupled technology during ISCO	50	2
SVE during ISCO	50	2
P&T during ISCO	50	2
any coupled technology after ISCO	0	2
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	3
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	2
persulfate	0
peroxone	1
percarbonate	0

4 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of all geology groups & MTBE COCs with LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	no data			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & MTBE COCs with LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	240	240	240	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of all geology groups & MTBE COCs with LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum MTBE concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ	0			2
at sites where rebound occurred, % of wells w/ rebound	na			
total cost (1000s US $)	194	204	213	2
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	100	2

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & MTBE COCs with LNAPL)

The two projects that reportedly attained site closure were the Kenton Delaware project and the Former Service Station project in Pennsylvania, both of which were reported in ITRC (2005). These projects used ozone to remediate fuel related COCs including MTBE. The conditions of the site closures were not reported, and attempts by DISCO's creators to gather more information from the site contacts listed in source documents were unsuccessful. Note that ISCO has also been highly successful (99+% reductions and attainment of MCLs) in treating MTBE in situations in which LNAPL was not present in the treatment zone.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & MTBE COCs with LNAPL)

- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- LNAPL presents a challenge to ISCO in that a large oxidant dose may be required to oxidize the potentially large mass of COCs present. Alternative remediation technologies, or use of a coupled pre-ISCO mass recovery technology, may be more economical than ISCO alone.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of all geology groups & MTBE COCs without LNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	0	2
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	100	5
any coupled technology before ISCO	100	5
excavation before ISCO	80	5
SVE before ISCO	50	5
any coupled technology during ISCO	0	5
any coupled technology after ISCO	0	5
program modified during implementation	100	1

Delivery Method

	# Sites
injection wells	0
direct push	0
sparge points	5
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	0
ozone	4
persulfate	0
peroxone	1
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

5 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of all geology groups & MTBE COCs without LNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & MTBE COCs without LNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	655	710	765	2
design ROI (ft)	23	25	28	2
% performing treatability test	0			1
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of all geology groups & MTBE COCs without LNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum MTBE concentration in GW	99.0	99.1	99.1	2
% of sites w/ rebound at one or more locations in TTZ	50			2
at sites where rebound occurred, % of wells w/ rebound	33	33	33	1
total cost (1000s US $)	263	263	263	1
unit cost ($ / cubic yd treated)	no data			

Attainment of Site Closure

	%	n
percent attaining site closure	33	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	67	3
meet ACLs	na	0
reduce concentration / mass	na	0
evaluate effectiveness	na	0

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & MTBE COCs without LNAPL)

The projects reported on the previous tables were ozone or peroxone sparge curtains designed to mitigate the migration of MTBE, though one project also included a source zone treatment component. These projects collectively were quite successful, including the attainment of site closure and meeting and maintaining MCLs downgradient of the sparge curtain. Two projects noted elevated concentrations of chromium downgradient of the treatment zone. One mitigated these exceedences by reducing the hydrogen peroxide loading rate to the peroxone sparge system. The other system was shut down and not restarted because MTBE concentrations had been reduced to below the MCL. The latter project was reported at the 2006 University of Massachusetts Annual International Conference on Contaminated Soils, Sediments and Water by Kent Zenobia of URS Corporation.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & MTBE COCs without LNAPL)

- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- MTBE is highly soluble, hence is highly mobile in the subsurface. This property can be leveraged by using ISCO barrier strategies that continuously inject reagents and allow the MTBE to migrate into the treatment zone. Such barriers can also be used to protect downgradient receptors or compliance points.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	80	5
performed pilot test (full-scale projects only)	50	4
ISCO coupled w/ other technologies	100	5
any coupled technology before ISCO	60	5
excavation before ISCO	60	5
P&T before ISCO	20	5
any coupled technology during ISCO	20	5
P&T during ISCO	20	5
any coupled technology after ISCO	40	5
P&T after ISCO	20	5
SVE after ISCO	20	5
enhanced bioremediation after ISCO	20	5
program modified during implementation	100	2

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

6 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	5
direct push	0
sparge points	0
infiltration gallery / trench	1
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	2
CHP	4
ozone	0
persulfate	2
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	10	10	10	1
# of pore volumes delivered	56	56	56	1
oxidant dose (g oxidant / kg media)	0.026	0.026	0.026	1
design ROI (ft)	no data			
# of delivery events	3.3	5.5	7.8	2
mean duration of delivery events (days)	5	5	5	1
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	181	224	335	4
# of pore volumes delivered	0.041	0.041	0.043	3
oxidant dose (g oxidant / kg media)	2.0	4.0	19	3
design ROI (ft)	11	12	21	3
# of delivery events	2	2.5	3.3	4
mean duration of delivery events (days)	7	11	13	3
% performing treatability test	75			4
% performing pilot test (full-scale projects only)	50			4

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chlorobenzenes concentration in GW	8	19	22	4
% of sites w/ rebound at one or more locations in TTZ	100			2
at sites where rebound occurred, % of wells w/ rebound	53	55	58	2
total cost (1000s US $)	1,670	1,670	1,670	1
unit cost ($ / cubic yd treated)	5	5	5	1

Attainment of Site Closure

	%	n
percent attaining site closure	0	5

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	2
meet ACLs	na	0
reduce concentration / mass	100	3
evaluate effectiveness	100	1

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Scenario-Specific Commentary

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

While the range in concentration reductions among these sites is lower than chloroethene contaminated sites where DNAPL was present, it is worth noting that three of these six case studies were implemented in fractured bedrock. Some additional details on selected projects are included below.

- The Eastland Woolen Mills NPL site in Corinna, ME used persulfate to treat chlorobenzenes in both glacial till overburden and bedrock. In the overburden, 73% reductions in COC mass as a result of ISCO were calculated, though recalcitrant hot spots remained.
- The SWMU 196 project used CHP to remediate chlorobenzene and dicholorbenzene isomers. The full scale injections resulted in significant contaminant concentration reductions in groundwater. However, contaminant rebound was observed post-ISCO. Enhanced bioremediation was used as a polishing technology at this site.
- One of the permanganate projects was designed primarily to remediate chloroethenes. The second was a pilot study evaluated the use of permanganate to treat monochlorobenzene and 1,2-dichlorobenzene in a situation in which DNAPL was presumed to be present. Bench scale testing indicated that permanganate was capable of degrading these COCs. The case study source documents indicated that permanganate was successfully distributed through the treatment zone. However, most monitoring locations did not show sustained decreases in COC concentrations. The project team suggested using a higher concentration of permanganate, citing the fact that the reaction between the oxidant and COCs is second order overall, and would therefore react more quickly if the permanganate concentration was higher.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & chlorobenzenes COCs with DNAPL)

- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & chlorobenzenes COCs without DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	3
performed pilot test (full-scale projects only)	100	2
ISCO coupled w/ other technologies	100	2
any coupled technology before ISCO	100	2
excavation before ISCO	100	2
any coupled technology during ISCO	0	2
any coupled technology after ISCO	50	2
MNA after ISCO	50	2
enhanced bioremediation after ISCO	50	2
program modified during implementation	100	2

Delivery Method

	# Sites
injection wells	2
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	2
ozone	0
persulfate	1
peroxone	0
percarbonate	0

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

3 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of all geology groups & chlorobenzenes COCs without DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	124	124	1
# of pore volumes delivered	0.051	0.067	0.084	2
oxidant dose (g oxidant / kg media)	0.74	0.74	0.74	1
design ROI (ft)	23	23	23	1
# of delivery events	2.8	3.5	4.3	2
mean duration of delivery events (days)	4	4	4	2
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	100			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of all geology groups & chlorobenzenes COCs without DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of all geology groups & chlorobenzenes COCs without DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total chlorobenzenes concentration in GW	54	63	71	2
% of sites w/ rebound at one or more locations in TTZ	no data			
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	1
evaluate effectiveness	100	1

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Scenario-Specific Commentary

(for query of all geology groups & chlorobenzenes COCs without DNAPL)

The groundwater concentration reductions reported among these three sites containing chlorobenzenes without DNAPL are greater than those sites that treated chlorobenzenes when DNAPL was present and also greater than those that treated chloroethenes when DNAPL was not present. Each of these three sites treated heterogeneous, permeable geologic media. One of the case studies included in these results was a portion of the Eastland Woolen Mills NPL site in Corinna, ME.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & chlorobenzenes COCs without DNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Chlorobenzenes have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur. ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.
- Chlorobenzenes are not as reactive with permanganate as they are with the free radical based oxidants.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary | **return to query page**

Design Conditions

(for query of all geology groups & PAH COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	100	8
performed pilot test (full-scale projects only)	40	5
ISCO coupled w/ other technologies	50	6
any coupled technology before ISCO	67	3
excavation before ISCO	33	3
any coupled technology during ISCO	33	3
P&T during ISCO	33	3
any coupled technology after ISCO	67	3
P&T after ISCO	67	3
program modified during implementation	25	4

Delivery Method

	# Sites
injection wells	6
direct push	1
sparge points	2
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	1

Oxidant Selected

	# Sites
permanganate	2
CHP	4
ozone	2
persulfate	0
peroxone	0
percarbonate	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

10 of the 242 DISCO case studies match this query

(Continued on following page)

Design Conditions

(for query of all geology groups & PAH COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	13	17	20	2
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)	4.5	4.5	4.5	1
design ROI (ft)	15	15	15	1
# of delivery events	3	4	5	2
mean duration of delivery events (days)	1	1	1	1
% performing treatability test	100			2
% performing pilot test (full-scale projects only)	0			1

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	175	393	595	4
# of pore volumes delivered	0.18	0.32	0.46	2
oxidant dose (g oxidant / kg media)	0.42	0.78	1.1	2
design ROI (ft)	10	10	20	3
# of delivery events	1	1	1.8	4
mean duration of delivery events (days)	33	60	121	4
% performing treatability test	100			4
% performing pilot test (full-scale projects only)	67			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & PAH COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	365	365	365	1
design ROI (ft)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	0			1

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & PAH COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total PAH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)	558	929	1,299	2
unit cost ($ / cubic yd treated)	130	260	380	2

Attainment of Site Closure

	%	n
percent attaining site closure	0	6

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	1
meet ACLs	na	0
reduce concentration / mass	100	3
evaluate effectiveness	100	3

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & PAH COCs with NAPL)

The ten sites treating PAHs with NAPL present showed a relatively wide range of approaches, as four different oxidants were selected. The two projects that used permanganate attempted to both oxidize the COCs and encapsulate the unoxidized residuals in the manganese dioxide precipitate that is formed. Project documents indicated that this approach did reduce mass flux of COCs to groundwater. These projects included five former manufactured gas plants and two wood treatment facilities. All projects except for one were performed in permeable, unconsolidated geologic media.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

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- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & PAH COCs with NAPL)

- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating NAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & PAH COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	no data	
performed pilot test (full-scale projects only)		
ISCO coupled w/ other technologies	100	1
any coupled technology before ISCO	0	1
any coupled technology during ISCO	100	1
SVE during ISCO	100	1
any coupled technology after ISCO	100	1
program modified during implementation	100	1

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

2 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	1
direct push	0
sparge points	1
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	0
CHP	1
ozone	1
persulfate	0
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & PAH COCs without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	na			
# of pore volumes delivered				
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	595	595	595	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)				
# of delivery events				
mean duration of delivery events (days)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med.** is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & PAH COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	56	56	56	1
design ROI (ft)	no data			
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & PAH COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total PAH concentration in GW	no data			
% of sites w/ rebound at one or more locations in TTZ				
at sites where rebound occurred, % of wells w/ rebound				
total cost (1000s US $)	151	151	151	1
unit cost ($ / cubic yd treated)	25	25	25	1

Attainment of Site Closure

	%	n
percent attaining site closure	100	1

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	no data	
meet ACLs		
reduce concentration / mass		
evaluate effectiveness		

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & PAH COCs without NAPL)

The case that attained closure was the "Former Fuel Oil Distribution Terminal" in Ilion, NY reported in ITRC (2005). Attempts made by DISCO's creator to gather further information from site contacts were unsuccessful.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & PAH COCs without NAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- PAHs generally have a lower solubility and are more highly sorptive to soil than chloroethenes, and hence these COCs are less available for oxidation reactions which generally occur in the aqueous phase. This may require use of greater injection durations to allow desorption to occur.
- ISCO applications that generate surfactants (e.g. superoxide free radical generated during CHP) may be beneficial with low solubility COCs.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & methylene chloride COCs with DNAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	75	4
performed pilot test (full-scale projects only)	50	2
ISCO coupled w/ other technologies	75	4
any coupled technology before ISCO	67	3
P&T before ISCO	67	3
any coupled technology during ISCO	0	3
any coupled technology after ISCO	33	3
MNA after ISCO	33	3
program modified during implementation	50	2

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

4 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	3
direct push	1
sparge points	0
infiltration gallery / trench	0
recirculation	0
fracturing	0
soil mixing	0
horizontal wells	0

Oxidant Selected

	# Sites
permanganate	1
CHP	2
ozone	0
persulfate	1
peroxone	0
percarbonate	0

(Continued on following page)

Design Conditions

(for query of all geology groups & methylene chloride COCs with DNAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	31	31	31	1
# of pore volumes delivered	no data			
oxidant dose (g oxidant / kg media)				
design ROI (ft)	40	40	40	1
# of delivery events	1	1	1	1
mean duration of delivery events (days)	no data			
% performing treatability test	100			1
% performing pilot test (full-scale projects only)	no data			

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	309	405	500	2
# of pore volumes delivered	0.085	0.13	0.18	2
oxidant dose (g oxidant / kg media)	5.1	5.3	5.4	2
design ROI (ft)	7.5	10	13	2
# of delivery events	1.3	1.5	1.8	2
mean duration of delivery events (days)	14	14	14	1
% performing treatability test	50			2
% performing pilot test (full-scale projects only)	50			2

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & methylene chloride COCs with DNAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	na			
design ROI (ft)				
% performing treatability test				
% performing pilot test (full-scale projects only)				

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & methylene chloride COCs with DNAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum methylene chloride concentration in GW	45	45	45	1
% of sites w/ rebound at one or more locations in TTZ	67			3
at sites where rebound occurred, % of wells w/ rebound	no data			
total cost (1000s US $)				
unit cost ($ / cubic yd treated)				

Attainment of Site Closure

	%	n
percent attaining site closure	0	3

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	na	0
meet ACLs	0	1
reduce concentration / mass	50	2
evaluate effectiveness	100	2

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & methylene chloride COCs with DNAPL)

The four case studies returned by this query include three where methylene chloride was a co-contaminant along with chloroethenes, and one where methylene chloride was a primary contaminant being treated. Three of the sites treated heterogeneous unconsolidated materials, and one treated fractured rock.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & methylene chloride COCs with DNAPL)

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary

return to query page

Scenario-Specific Commentary

(for query of all geology groups & methylene chloride COCs without DNAPL)

There are no case studies in DISCO that match these query criteria. Users are encouraged to perform another query for all COCs without NAPL (keeping in mind that the vast majority of projects treated chloroethenes) and a specific type of geology. Also note the general considerations for ISCO below and on the following page, particularly with respect to how methylene chloride's physical properties differ from chloroethenes, and how this might impact ISCO performance.

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous (K_{max}/K_{min} < 1000) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.

(Continued on following page)

Scenario-Specific Commentary (cont.)

(for query of all geology groups & methylene chloride COCs without DNAPL)

- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.
- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
- Methylene chloride has a higher solubility and is less highly sorptive to soil than chloroethenes. These properties may make methylene chloride more available for oxidation in the aqueous phase relative to other commonly treated COCs (e.g. chloroethenes).
- Methylene chloride is not reactive with permanganate.

(This is the end of your query. Please start over with the link below.)

open DISCO Glossary **return to query page**

Design Conditions

(for query of all geology groups & all COCs with NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	78	67
performed pilot test (full-scale projects only)	58	52
ISCO coupled w/ other technologies	76	75
any coupled technology before ISCO	77	57
excavation before ISCO	46	57
P&T before ISCO	26	57
any coupled technology during ISCO	28	57
P&T during ISCO	12	57
SVE during ISCO	7	57
any coupled technology after ISCO	47	57
MNA after ISCO	26	57
enhanced bioremediation after ISCO	12	57
program modified during implementation	59	46

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

110 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	49
direct push	54
sparge points	8
infiltration gallery / trench	9
recirculation	10
fracturing	6
soil mixing	2
horizontal wells	1

Oxidant Selected

	# Sites
permanganate	48
CHP	44
ozone	10
persulfate	7
peroxone	1
percarbonate	3

(Continued on following page)

Design Conditions

(for query of all geology groups & all COCs with NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	14	28	43	39
# of pore volumes delivered	0.021	0.34	1.7	21
oxidant dose (g oxidant / kg media)	0.15	0.85	3.4	24
design ROI (ft)	6.5	12	23	20
# of delivery events	1	2	4	43
mean duration of delivery events (days)	2	4	10	32
% performing treatability test	76			34
% performing pilot test (full-scale projects only)	54			26

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	214	595	27
# of pore volumes delivered	0.040	0.073	0.23	18
oxidant dose (g oxidant / kg media)	1.0	1.8	5.1	16
design ROI (ft)	10	12	15	20
# of delivery events	1.5	2	4	35
mean duration of delivery events (days)	4	7	14	26
% performing treatability test	79			29
% performing pilot test (full-scale projects only)	64			25

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Design Conditions

(for query of all geology groups & all COCs with NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	225	303	389	4
design ROI (ft)	no data			
% performing treatability test	50			2
% performing pilot test (full-scale projects only)	33			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

(Continued on following page)

Performance Results

(for query of all geology groups & all COCs with NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	17	50	77	44
% of sites w/ rebound at one or more locations in TTZ	70			40
at sites where rebound occurred, % of wells w/ rebound	34	47	72	18
total cost (1000s US $)	170	235	579	27
unit cost ($ / cubic yd treated)	72	160	240	17

Attainment of Site Closure

	%	n
percent attaining site closure	13	72

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	0	16
meet ACLs	36	22
reduce concentration / mass	71	28
evaluate effectiveness	96	24

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & all COCs with NAPL)

The following trends in these data should be noted.

- The preceding data show that permanganate and CHP have been the most commonly applied oxidants to treat NAPL, and that injection wells and direct push points are the most common delivery approaches. However, other oxidants and delivery methods have been used as well.
- None of these case studies met and maintained MCLs, while one third of the sites that attempted to meet ACLs were successful in doing so.
- The range of groundwater COC reduction percentage is relatively wide, and reductions were not as great as those reported at the case studies in DISCO where NAPL was not present.
- Contaminant rebound occurred at a majority of sites.
- Both concentration reduction and rebound occurrence are dependent upon the geologic media being treated.
- Nearly half of these sites treated heterogeneous, permeable geologic media, one quarter homogeneous, permeable geologic media, and the remaining one quarter heterogeneous, impermeable or fractured rock.
- The majority of these sites treated chloroethenes.

Because of the impact of geology on ISCO performance, users are encouraged to run queries for a specific type of geologic media, particularly if they are using DISCO because they are considering using ISCO in the future at a particular project site. Some general considerations regarding these query criteria are presented on the following pages.

(Continued on following page)

Scenario-Specific Commentary

(for query of all geology groups & all COCs with NAPL)

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

- Homogeneous media are the easiest type of geology to treat, all else equal.
- Sites that are classified as homogeneous ($K_{max}/K_{min} < 1000$) in DISCO, or that appear largely homogeneous in the field, may still have heterogeneities that impact reagent flow.
- Heterogeneous materials present a challenge to remediation technologies that rely on the delivery of fluid reagents due to preferential flow through the higher K strata.
- Back diffusion of COCs from low permeability strata after ISCO may lead to COC rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Permeable geologic materials are more suited to ISCO than impermeable ones, all else equal.
- Low permeability media may preclude advective delivery of oxidants.
- Soil mixing or fracturing may be valuable tools that enhance contact between oxidant and COCs when treating impermeable geologic media.
- Diffusive transport may be a possible oxidant transport mechanism through low permeability media or the fractured rock matrix, though oxidant persistence and the required travel distance must be considered.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & all COCs with NAPL)

- Fluid flow through fractured media is difficult to predict or control, making delivery of ISCO reagents to the target COCs difficult.
- A considerable fraction of the COC mass may be contained within the rock matrix as opposed to the fractures themselves. The fraction in the matrix is likely proportional to both the matrix porosity and the age of the spill.
- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- DNAPL is often difficult to locate in the subsurface.
- DNAPL dissolution is a kinetically rate limited (i.e. potentially slow) process. While ISCO reagents do react with DNAPL directly when there is contact between the oxidant and DNAPL itself, most oxidation of COCs likely will occur in the aqueous phase.
- It is possible that DNAPL will remain after the initial ISCO delivery event. As the COCs re-equilibrate in the subsurface (i.e. move from DNAPL to aqueous phase) COC concentrations may rebound. The location of COC rebound and duration of time required for its manifestation may both be used to refine the Conceptual Site Model and subsequent remediation efforts.
- Due to the preceding two considerations, multiple ISCO delivery events are likely required when treating DNAPL.
- There have not been any documented case studies (either using ISCO or any other treatment technology) where MCLs have been reached in a DNAPL source zone, to the knowledge of the creators of DISCO. However, many DNAPL sites in DISCO were able to meet ACLs and/or achieve COC mass reduction.
- The vast majority of DISCO case studies treated chloroethenes, hence the data presented on the previous pages are largely driven by projects treating chloroethenes.

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Design Conditions

(for query of all geology groups & all COCs without NAPL)

Pre-Design Testing and ISCO Approach

	% yes	n
performed treatability test	76	37
performed pilot test (full-scale projects only)	67	24
ISCO coupled w/ other technologies	73	40
any coupled technology before ISCO	73	30
excavation before ISCO	57	30
SVE before ISCO	23	30
any coupled technology during ISCO	23	30
SVE during ISCO	10	30
P&T during ISCO	7	30
any coupled technology after ISCO	20	30
MNA after ISCO	10	30
enhanced bioremediation after ISCO	10	30
program modified during implementation	70	23

Notes: The top two most frequently used couples are included in this table. Further details on other coupled technologies are available in the TPM Part III and Krembs (2008). MNA was only entered as a coupling technology when project documents specifically stated it would be used. **n** refers to the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

54 of the 242 DISCO case studies match this query

Delivery Method

	# Sites
injection wells	18
direct push	10
sparge points	12
infiltration gallery / trench	5
recirculation	1
fracturing	4
soil mixing	0
horizontal wells	1

Oxidant Selected

	# Sites
permanganate	25
CHP	16
ozone	11
persulfate	2
peroxone	3
percarbonate	0

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Design Conditions

(for query of all geology groups & all COCs without NAPL)

Design Parameters: Permanganate

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	8.5	24	71	18
# of pore volumes delivered	0.010	0.073	0.15	12
oxidant dose (g oxidant / kg media)	0.11	0.25	0.30	10
design ROI (ft)	14	20	33	11
# of delivery events	1	1	3	21
mean duration of delivery events (days)	2	8	15	13
% performing treatability test	89			18
% performing pilot test (full-scale projects only)	85			13

Design Parameters: CHP

	Q1	Med.	Q3	n
injected oxidant concentration (g/L)	124	135	445	8
# of pore volumes delivered	0.031	0.050	0.38	7
oxidant dose (g oxidant / kg media)	0.56	0.92	1.1	4
design ROI (ft)	10	20	24	11
# of delivery events	1	2	2	15
mean duration of delivery events (days)	2	4.5	6.5	12
% performing treatability test	85			13
% performing pilot test (full-scale projects only)	33			6

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Design Conditions

(for query of all geology groups & all COCs without NAPL)

Design Parameters: Ozone

	Q1	Med.	Q3	n
duration of oxidant delivery (days)	127	251	555	8
design ROI (ft)	24	28	35	4
% performing treatability test	40			5
% performing pilot test (full-scale projects only)	67			3

Notes: Due to the more recent development of peroxone persulfate and percarbonate as oxidants, they are not included in these tables due to the small sample size in DISCO. Please refer to the TPM Part I for information on theoretical considerations, and TPM Part III (or Krembs 2008) for case study data for these oxidants. **Q1** is the 25th percentile, the value that is greater than 25% of the data points and less than 75%. **Med**. is the median, or 50th percentile. **Q3** is the 75th percentile, the value greater than 75% of the data points. Half of the data points are between Q1 and Q3. **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

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Performance Results

(for query of all geology groups & all COCs without NAPL)

Quantitative Measures of Success

	Q1	Median	Q3	n
% reduction in maximum total VOC concentration in GW	45	61	79	18
% of sites w/ rebound at one or more locations in TTZ	57			23
at sites where rebound occurred, % of wells w/ rebound	29	33	42	7
total cost (1000s US $)	137	177	299	20
unit cost ($ / cubic yd treated)	26	42	220	14

Attainment of Site Closure

	%	n
percent attaining site closure	30	27

Notes: **n** is the sample size (number of sites that match the query and had data for that parameter). **na** is not applicable.

Treatment Goals and Success

Goal Attempted	% Meeting Goal	n
meet MCLs	25	20
meet ACLs	40	5
reduce concentration / mass	100	7
evaluate effectiveness	89	9

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Scenario-Specific Commentary

(for query of all geology groups & all COCs without NAPL)

The following data presented on the previous pages are worth noting.

- Permanganate and CHP are the most commonly used oxidants, while ozone and peroxone are used with a relatively greater frequency at sites where NAPL is not present compared to those where NAPL is present.
- Injection wells, direct push points, and sparge points are the most commonly used delivery methods.
- The use of treatability testing, pilot testing, and coupling of ISCO with other remediation technologies appears to be consistent among sites with NAPL and sites without.
- When considering attainment of remediation goals and site closure, percentage reduction in COC concentrations in groundwater, and elimination or minimization of rebound, sites without NAPL showed more successful performance results when compared to sites with NAPL.
- Five sites that did not contain NAPL met and maintained MCLs, a fact that was confirmed with site regulators by the creators of DISCO. These included three choroethene sites with pre-ISCO maximum groundwater concentrations between 6 and 70 ug/L, and two MTBE sites with pre-ISCO concentrations ranging between 100 and 1000 ug/L. Four of these projects (both MTBE projects and two chloroethene projects) used ozone or peroxone sparge systems, while one used CHP applied through an injection well.
- On a unit cost basis ($ / cubic yd treated), treatment of sites where NAPL is not present is less costly than treating sites with NAPL. However, for small volume treatment zone, unit costs may be relatively high regardless of the COCs present.

Because of the impact of geology on ISCO performance, users are encouraged to run queries for a specific type of geologic media, particularly if they are using DISCO because they are considering using ISCO in the future at a particular project site. Some general considerations regarding these query criteria are presented on the following pages.

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Scenario-Specific Commentary

(for query of all geology groups & all COCs without NAPL)

The success of ISCO depends on achieving contact between the oxidant and target COCs. This contact is in turn dependent to a large degree upon the geologic media in which the COCs reside. When using DISCO to assess the range of results that may be seen in the future at a particular field site, DISCO users are encouraged to perform queries that are specific to the type of geology present at the site where they are considering ISCO. Several general considerations relating to geology and COCs being treated are presented below and on the following page.

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Scenario-Specific Commentary (cont.)

(for query of all geology groups & all COCs without NAPL)

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- Highly and regularly fractured rock is more amenable to ISCO relative to more competent or irregularly fractured rock, all else equal.
- Reduced minerals in bedrock may constitute a significant oxidant demand.
- Sites without NAPL (nearly exclusively aqueous phase COCs) generally have a lower mass density of COCs present relative to LNAPL or DNAPL sites. Low mass density sites can pose a challenge to ISCO in that the COCs are more dispersed, and hence oxidants are more likely to be nonproductively consumed by non-target compounds (i.e. NOD) relative to sites with NAPL.
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