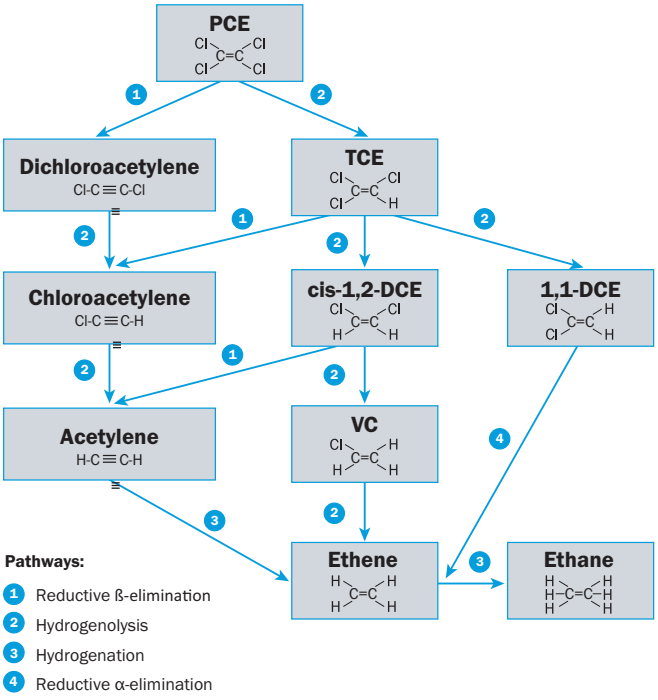
SiREMNA™ Natural Attenuation Parameter Testing



Abiotic degradation of PCE and TCE favors Reductive ß-elimination reactions through acetylene. Anaerobic biological reactions follow sequential hydrogenolysis [2].

For more information on how SiREMNA™ can help quantify important abiotic and biotic processes at your sites visit:

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Monitored natural attenuation (MNA) can be an effective and low cost approach for remediation of chlorinated volatile organic compound (cVOCs) sites. MNA includes physical, chemical and biological processes that reduce contaminant mass or concentration in soil or groundwater. The most common MNA mechanisms at cVOC contaminated sites are anaerobic biodegradation and abiotic/chemical reduction. Biodegradation involves key bacteria that are capable of degrading cVOCs to non-toxic end products. Abiotic degradation of cVOCs is mediated by naturally occurring reduced iron and sulfur minerals, and although often unrecognized, is now considered a key process in natural attenuation of these compounds [1,2].

In support of MNA remedies, SiREM is pleased to offer SiREMNA™, a comprehensive analytical package that can be customized to identify and quantify reactive minerals, dechlorinating bacteria and other indicator parameters for abiotic and biotic degradation of cVOCs. The analyses can be performed directly on aquifer materials or complement SiREM's bench-scale treatability testing services, including batch microcosm and column testing to:

- Characterize site conditions for MNA evaluation and remediation decision tools such as BioPIC [3].
- Assess the effectiveness and sustainability of biotic degradation of cVOCs.
- Determine the role of abiotic reductive dechlorination by biogenic reactive minerals that occur in naturally reducing aquifers, and include iron sulfides, green rusts, pyrite, magnetite, biotite and siderite.
- Support design and monitor performance of enhanced in-situ chemical reduction (ISCR).
- Assess the role of abiotic dechlorination by biogenic reactive minerals formed by iron and sulfate reducing bacteria (SRB) at enhanced reductive dechlorination (ERD) bioremediation applications.

The analyses offered under SiREMNA™ are provided on the reverse.

References

[1] USEPA. 2009. Identification and characterization methods for reactive minerals responsible for natural attenuation of chlorinated organic compounds in ground water, EPA600-R09/115.

[2] He, Y.T., Wilson, J.T., Su, C. and R. T. Wilkin. 2015. Review of Abiotic Degradation of Chlorinated Solvents by Reactive Iron Minerals in Aquifers. Groundwater Monitoring & Remediation 35, no. 3, pages 57–75.

[3] ESTCP Project ER-201129. 2015. Development and validation of a quantitative framework and management expectation tool for the selection of bioremediation approaches at chlorinated ethene sites.

SiREMNA™ Methods for Evaluation of Abiotic and Biotic Natural Attenuation Processes For Chlorinated Volatile Organic Compounds

Medium	Type of Analyses	Relevance to Natural Attenuation	Methodology
Groundwater	Total and Dissolved Iron Ferrous Iron	Dissolved iron speciation, confirmation of redox state, indication of reductive processes mediated by dissolved iron Fe(II)	EPA Method 6020A HACH Method 8146
	Sulfate Sulfide	Dissolved sulfur speciation, confirmation of redox state and indication of potential formation of reduced sulfide minerals	EPA Method 9056A EPA Method 9030B
	Total Organic Carbon/ Volatile Fatty Acids	Presence of electron donors for microbially mediated mineral transformations and reductive dechlorination reactions	EPA Method 9060A
	Ethene, Ethane, Acetylene, Methane	Biotic and abiotic degradation products for cVOCs. Methane is an important indicator of redox state	EPA Method RSK 175
	Dissolved Hydrogen	Direct electron donor for reductive dechlorination	Customized evaluation
	Compound Specific Isotope Analysis	To determine if degradation is occurring, and if so, to distinguish between abiotic and biotic processes	Customized evaluation
Aquifer Material (Solids)	Total Iron	Amount of ferric and ferrous iron available for forming reduced minerals	EPA Method 6010B
	Ferrous Iron	Total amount of reduced iron, indication of amount of available iron to form iron sulfides or other reduced iron minerals	EPA Methods 3050b extraction + 6020A
	Bioavailable Iron	Total amount of reduced bioavailable iron, indication of the amount of iron available to form iron sulfides or other reduced iron minerals	New Horizons Bioavailable Ferric Iron Assay
	Total Sulfur	Total amount of oxidized and reduced sulfur, indication of amount of sulfur available to form reduced sulfide minerals	EPA Method 6010B
	Total Sulfide	Total amount of reduced sulfur, indication of amount of sulfide available to form reduced sulfide minerals	EPA Method 9030B, SM-4500S2-AD
	Acid Volatile Sulfide	Detects ferrous sulfide (FeS) mineral phases, indication of the presence and amount of FeS available for abiotic reactions with cVOCs	EPA-121-R91-100
	Chromium Reducible Sulfide	Detects pyrite (FeS_2) mineral phases, indication of the presence and amount of FeS2 available for abiotic reactions with cVOCs	Customized evaluation
	Organic Carbon Content	Presence of energy source for microbially mediated mineral transformations	EPA Method 9060B (TOC)
	Potentially bioavailable organic carbon (PBOC)	Estimates organic carbon potentially available for biotic reactions with cVOCs to assess long-term sustainability of biotic degradation	Customized evaluation
	Magnetic Susceptibility	Total amount of magnetic fraction, mainly magnetite, indication of the presence and amount of magnetite available for abiotic reactions with cVOCs	See EPA, 2009 (EPA 600/R-09/115)
	Scanning Electron Microscopy and EDX	Qualitative confirmation of iron and sulfur phases present in soil matrix to identify the potential for abiotic degradation	Customized evaluation
Microbial Analyses	Iron-Reducing Bacteria (IRB, *Geobacter*)	IRB required to create and regenerate the reduced iron minerals	Gene-Trac® Geo
	Sulfate-Reducing Bacteria (SRB)	SRB required to create and regenerate the reduced iron sulfide minerals	Gene-Trac® SRB
	Next Generation Sequencing	Provides overall microbial community composition for detailed assessment of MNA potential and progress	Customized evaluation
	Dechlorinating Bacteria	Bacteria/functional genes for dechlorination of chlorinated solvents by anaerobic and aerobic pathways	Gene-Trac® *Dhc, vcrA, tceA, bvcA, Dhb, cfrA* and *Dhg* (reductive dechlorination) Gene-Trac® *Polaromonas* and *etn*-cDCE/ VC (aerobic pathways)