Bioremediation Successes in Cold-Weather Climates

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Owning Challenges. Winning Trust.

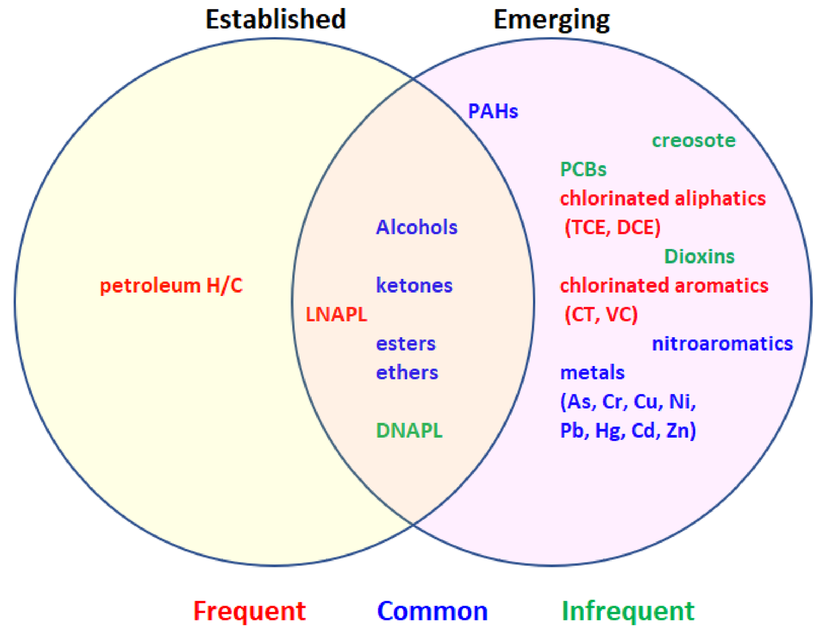
Background

Bioremediation, or the enhanced acceleration of microorganisms to facilitate the breakdown of environmental pollutants is an established and effective means for the cleanup in soil, sediment, groundwater and open water environments in cold-weather climates. Constraints imposed by low temperatures can lead to parameter limitations such as a lack, or surplus, of oxygen and/or other nutrients, and physical constraints such as freezing. Despite skepticism, bioremediation remains the most cost-efficient and sustainable solution for the destruction of environmental contaminants. The goal of implementing bioremediation programs under these conditions is the same as many cleanup projects – reduction of constituent concentration levels below a regulatory standard to obtain site closure. While biodegradation rates in cold-climates are slower than temperate regions, properly designed, executed, and monitored bioremediation projects are extremely effective in contaminant reduction and site restoration.

Challenges

A large portion of the world is considered a cold climate, due to seasonal snow cover or occurrence of permafrost. Cold-adapted microorganisms exist everywhere, capable of biodegradation in all media – soil, soil gas, sediments, and surface and groundwater. Identifying naturally occurring organisms and available microbes for bioremediation is critical early in site investigations. Application methods are diverse and unique to each project. This work outlines essential elements in identifying, investigating, sampling, testing, designing, monitoring and presenting biostimulation and bioaugmentation programs for all classes of compounds in glacial and bedrock terrains in northern-tier states and provinces, including bedrock and karst terrains in the central and midwestern states. Identifying and selecting the proper bioremediation strategy is essential for each individual cleanup project - each site is unique.

Common Contaminants Addressed



Why Bioremediation ?

- ADVANTAGES
  - Long-term protection of public health & environment
  - Cheapest remedial alternative
  - Minimal space requirements
  - No liberating hazardous material
  - Natural processes
  - Sustainable
  - Complete contaminant destruction

- PERCIEVED DISADVANTAGES
  - Perceived costs/failure meeting targets
  - Poor management/planning
  - Climate issue (cold)
  - Release of organisms to environment
  - Months to year(s) clean-up time-frames

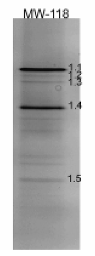
Biostimulation	Bioaugmentation	Natural Attenuation
• Have microbes	• Need microbes	• Have microbes
• Need food/nutrients	• Have food/nutrients	• Have food/nutrients

Common bioremediation field application methods:

- Ex-Situ (soil excavation/handling)
- Injection/surface applications
- Extraction/re-injection of fluids
- Introduction of nutrients and substrates

Biostimulation

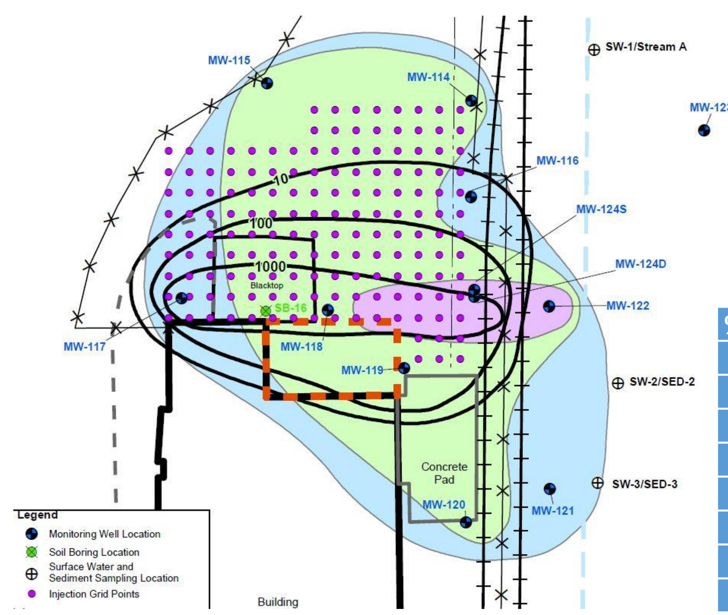
Involves modifying subsurface environment to stimulate existing bacteria /microbes capable of bioremediation – usually by addition of various forms of rate limiting nutrients and electron acceptors, such as phosphorus, nitrogen, oxygen, or carbon.



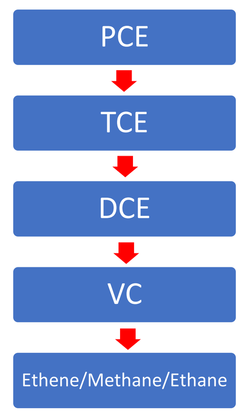
Groundwater DGGE profile of amplified DNA of 16s rRNA gene. Dechlorinating microbes require two (2) things to complete ERD reactions: 1) electron donors ("something to eat"); and, 2) electron acceptors ("something to breathe").

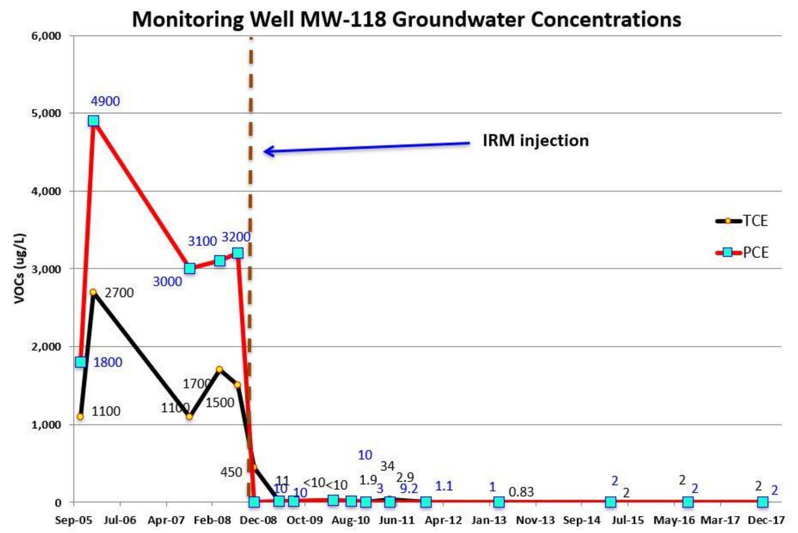
Varve clays & outwash 106 points (4 - 14' bgs)

- 2,640 gallons EVO in 23,361 gallons H_2O
- 95 gallons of nano-structured zero valent iron (nZVI) in 1,135 gallons H_2O
- Hydraulic conductivity $3x10^{-5}$ cm/sec (0.11 ft/day)



% Change	MW-118	MW-122	MW-124s
TVOCs	99%	97%	69%
PCE	100%	86%	100%
TCE	100%	94%	100%
111TCA	100%	99%	100%
11DCA	95%	91%	98%
cDCE	100%	99%	61%
VC	99%	100%	85%
11DCE	100%	97%	100%

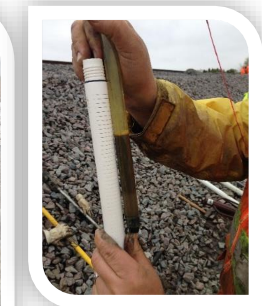




Bioaugmentation

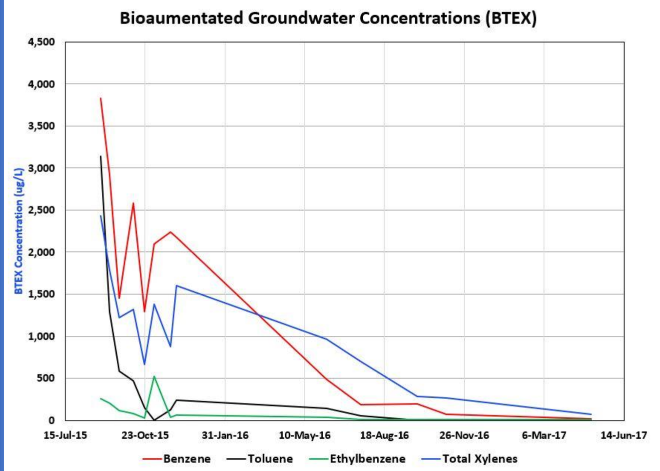
Addition of archaea, microbes, fungi, yeast, or bacterial cultures required to speed up the rate of degradation of contaminants. Bioaugmentation usually requires studying the indigenous varieties present in the location to determine if biostimulation is possible, and if not, the environment is enhanced by introduction of the appropriate biological communities.

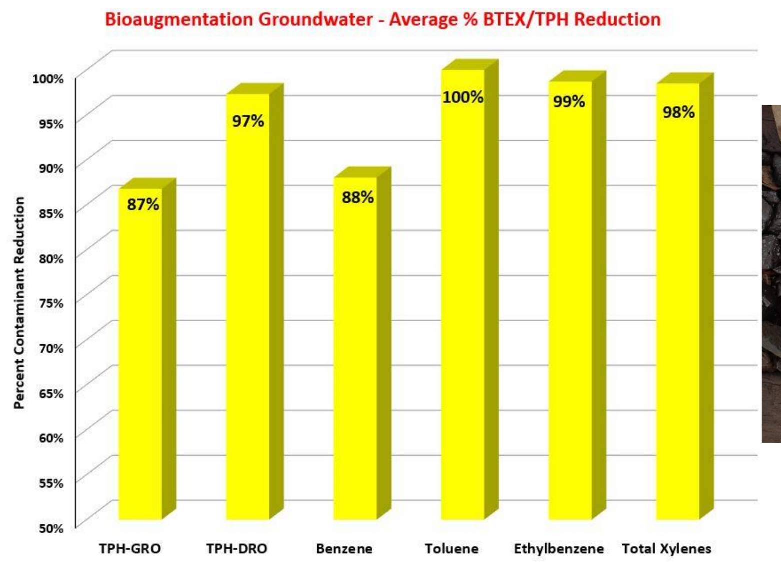
Release of Bakken crude to soil, groundwater, and surface water



September 2015 - May 2017

	Bioamendment (lbs)	Amendment Water (gallons)	Bioapplication Concentration (lbs/gal)
Bioapplication #1	1,775	4,000	0.4
Bioapplication #2	1,400	1,650	0.8
Bioapplication #3	1,600	1,800	0.9
	4,775	7,450	0.7





Common Applications

Project Description	Contaminant Type and Location	Method of Application	Result
Weaver, MN (February – August 2014)	Fresh and weathered Bakken crude oil. Up to 12,000 gallons released.	Archaea + nutrients injected to subsurface through ballast. ~275 lbs. mixed in 450 gal water	99-day pilot study reduced 90-98% BTEX and TPH-GRO 76% TPH-DRO and 65% MOR compounds
Charles City, IA (May-August 2013)	Spent locomotive engine oil and dyed diesel fuel. Oil on floodwater between 0.5 - 4" thick.	Archaea applied to oil pools manually thru backpack sprayers	Eliminated all visible oil and sheen in ~2 months (multiple treatments)
St. Cloud, MN (April - July 2015)	Unknown volume petroleum/solvents and dyed diesel fuel.	Archaea + nutrients applied manually by backpack sprayers, tilling\raking, hand spreading	Closed site with non-detect soil samples in 6 months
Heimdal, ND (May 2015 – Sept 2016)	>60K gallons Bakken crude oil saturated track ballast, wetlands, soil, and groundwater.	2,000 lbs Archaea + nutrients and 4K gallons water injected amendments to subsurface	3 bioapplications on ballast resulted in complete biodegradation of oil in soil and groundwater across application area.
Geneva, NY (October 2008)	Source DNAPLs creating SVI risk, impacted surface water, and 10-acre plume	106 Geoprobe injection points for the direct introduction of biostimulants to subsurface	99.8% soil VOC reduction from 10,000 mg/Kg to ND 98% groundwater VOC reduction to < 5 ppb SVI risks eliminated
Byron, NY (September 2007 October 2009 May 2012)	Chlorinated VOC plumes in soil, groundwater and surface water	Subsurface biodegradation program from multi-injection program through 35 injection points	Complete reduction of VOCs in soil, groundwater, and surface water to ND conditions (ppb)
Confidential Client (June 2003 –2007 February 2018-present)	>3-mile VOC plume from LNAPL\DNAPL chlorinated solvents at multiple SWMUs	Multiple direct injection programs in wells 21- 160 feet deep	Source area VOCs in soil, karst bedrock and groundwater reduced to ND concentration (ppb)

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