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In Situ Enhanced Bioremediation of TCE Impacted Groundwater in Aerobic Aquifer

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Introduction

Industrial activities extensive use of chlorinated solvents and inadequate disposal have led to widespread groundwater contamination worldwide. Trichloroethylene (TCE) is a common groundwater contaminant of toxic and carcinogenic concern. The study site is located in South Australia, Australia.

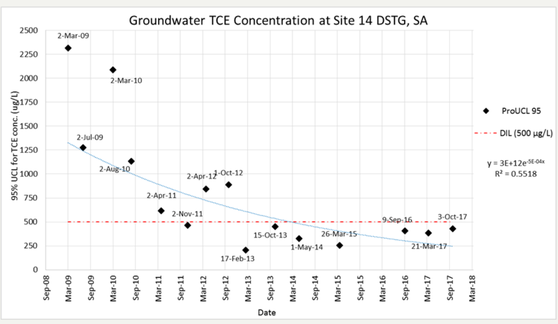
- Reductive dechlorination under anaerobic conditions are the predominant pathways for TCE biotransformation under reducing aquifer system. Hydrogeochemical factors for biodegradation include REDOX conditions and nutrient deficiency.
- In the real environment, sites are often polluted in the aerobic system, consequently, turning the aerobic system to anaerobic condition involves pumping of large carbon source.
- The incomplete anaerobic degradation of TCE, and possible accumulation of known carcinogen of vinyl chloride (VC) is a main limitation on its application. Hence, there has been much interest in developing aerobic *in-situ* biotransformation processes for complete TCE degradation.

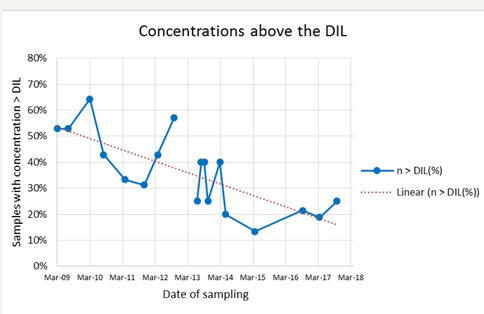
Methods

- Implementation to degrade TCE under aerobic condition by co-metabolic degradation using molasses as growth substrates *in situ* enhanced bioremediation of TCE impacted groundwater in aerobic aquifer.
  - *Supplement nutrient injection near source plume.*
  - *Accelerated delivery technique using systematic installation of pumping-and-extraction wells using groundwater transport modelling.*

Results

Shrinking plume: The primary line of evidence evaluates contaminant spatial distribution and decreasing concentration trends over time (USEPA, 2011).





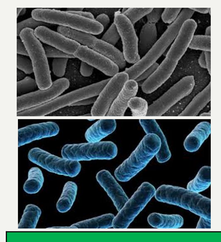
- The TCE plumes of 500 µg/L (Dutch Intervention Level (DIL)) is achieved that has reduced the TCE concentration levels from site maximum concentration of 4,956 µg/L.
- The result shows that the TCE groundwater plume is shrinking significantly with 95% confidence level and P-value <0.002.

Figure 1 Groundwater TCE Plume before RAP and progress to current monitoring, (a) October 2012 (b) March 2017

Biogeochemical Indicators of bioremediation: The secondary line of evidence evaluates geochemical conditions to ensure they are supportive of natural attenuation (USEPA, 2011).

- ✓ *Monitoring of elevated levels of groundwater chloride concentration from the background level is used as indicative of co-metabolic biodegradation activities.*

Microbial activity and biodegradation: The tertiary line of evidence involves microbiological studies.



Microcosm studies showed that Nocardioides sp. can utilize TCE and Rhodococcus sp. can degrade TCE to chloral hydrate that can be utilized by Arthrobactor sp. (CRC CARE 2014). Other TCE degrading bacteria reported in literature are also present in the groundwater of the site (Table).

TCE degrading bacteria	Reference	% relative abundance presents in groundwater at Site 14	
		Range	Average
Geothrix sp.	Kuan-hsun et al. 2011, Tsai et al. 2014	0.00–0.03	0.001
Rhodococcus sp.	CRC CARE 2014	0.00–0.0775	0.0208
Nocardioides sp.	CRC CARE 2014	0.00–0.015	0.0053
Clostridium sp.	Kuan-hsun et al. 2011, Tsai et al. 2014	0.03–0.63	0.23
Burkholderiales	Kuan-hsun et al. 2011	0.55–7.71	2.38
Pseudomonas sp.	Kuan-hsun et al. 2011; Kao et al. 2016	0.14–43.94	9.07
Geobacter sp.	Kuan-hsun et al. 2011	0.00–0.69	0.14
Hydrogenophilaceae	Kuan-hsun et al. 2011	0.01–36.71	6.14

Conclusion

- ✓ After enhancing microbial activities at the site, higher rates of natural attenuation were observed. The estimated rates of decay of TCE in MW005 and MW011 are 0.148 and 0.180 per year, which require 8.4 and 7.8 years, respectively to attain a concentration of 500 µg/L
- ✓ All line of evidence of biodegradation confirmed that attenuation of hydrocarbons in groundwater is occurring at the sites. General decreasing trend of TCE concentration. UCL 95 under DIL threshold.
- ✓ The source concentration is continuously released to groundwater by leaching and which will ultimately exhaust the sources and lead to the contraction of the plume.

References

USEPA 2011. An Approach for Evaluating the Progress of Natural Attenuation in Groundwater. Office of Research and Development. National Risk Management Laboratory. Ada, OK. EPA 600/R-11/204. December 2011.

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