FIELD RESULTS WITH AN ALKALINE IN-SITU CHEMICAL OXIDATION PROCESS

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Abstract

RegenOx™ is a proprietary (patent-applied-for) in situ chemical oxidation process using a solid oxidant complex (sodium percarbonate/catalytic formulation) and an activator complex (a composition of ferrous salt embedded in a micro-scale catalyst gel). With its highly active catalytic system, RegenOx is capable of treating a broad range of soil and groundwater contaminants including both petroleum hydrocarbons and chlorinated solvents. RegenOx uses a basic oxidizer complex and thus generates alkaline conditions (high pH) and does not rely on operating under the acidic conditions (low pH) that are required when using standard catalyzed hydrogen peroxide (Fenton's chemistry). RegenOx is safe and easy to apply to the contaminated subsurface without the health and safety concerns and lingering environmental issues that have become associated with other chemical oxidation technologies.

RegenOx has been applied at over 50 sites for both chlorinated and petroleum-based contaminants. Several successful applications are now complete. The case studies to be presented are from sites exhibiting varying lithologies, using different application methods (such as direct push injection, in-situ and ex-situ soil mixing) and within different regulatory environments. Treatment results from sites containing a variety of contaminants will be presented, including a site with a mixed chlorinated solvent and petroleum hydrocarbon plume.

Introduction

RegenOx directly oxidizes contaminants while its unique catalytic complex generates a suite of highly charged, oxidative free radicals that are responsible for the rapid destruction of contaminants. The mechanisms by which RegenOx operates are:

Surface-Mediated Oxidation:

Surface-Mediated Oxidation is responsible for the majority of RegenOx contaminant destruction. The oxidizer complex and contaminant react with the activator complex surface, destroying the contaminant.

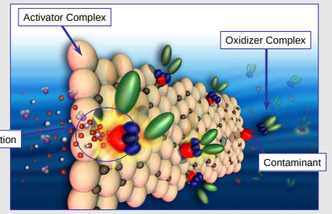
Direct Oxidation:

Contaminants can be directly oxidized by the sodium percarbonate complex.

Free Radical Oxidation:

Highly charged, oxidative free radicals are capable of rapid contaminant degradation and include the following:

- Perhydroxyl Radical (HO_2•)
- Hydroxyl Radical (OH•)
- Superoxide Radical (O_2•)
- Organic Free Radicals



Surface mediated oxidation by RegenOx

Proper Personal Protective Equipment (PPE). RegenOx is soluble in water and is often mixed with a paint mixer.

Treatable Contaminants

RegenOx has been tested in the laboratory and the field on:

- Petroleum hydrocarbons (aliphatic and aromatic)
- Polyaromatic hydrocarbons (e.g., napthalene and phenanthrene)
- Gasoline oxygenates (e.g., MTBE and TAME)
- Chlorinated hydrocarbons (e.g., PCE, TCE, TCA)

Application Methods

RegenOx can be applied in a variety of ways, with some or all of the methods being appropriate at a given site. Direct-push, excavation and soil mixing are common application methods.

Direct push injection

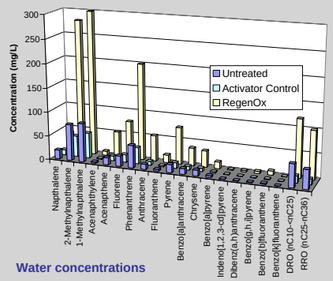
Excavation application – RegenOx is added to a loader bucket and applied to excavation area

Total Petroleum Hydrocarbon Laboratory Study

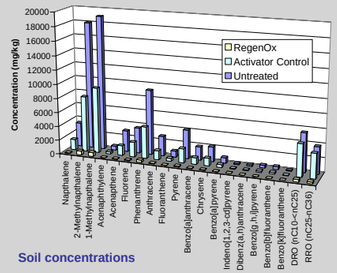
This bench-scale study evaluated the potential for TPH degradation by RegenOx from an impacted site in Alaska. The test consisted of 300 g of soil and 3 L of site water in a 1-gallon poly bottle at 8°C to simulate groundwater temperatures. Three set of samples were prepared:

1. Untreated control batch – to account for contaminant loss through other mechanisms
2. Activator Control – the activator strongly sorbs contaminants
3. RegenOx (30,000 ppm) treated batch

After 72 hours, each batch was disassembled, soil and water separated, and sent to a commercial laboratory for analysis of individual TPH constituents.



Water concentrations



Soil concentrations

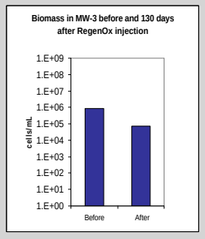
Individual contaminant mass reductions (sum of water and soil) after 72 hours

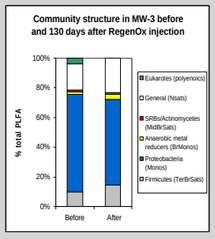
Constituent	% Reduction achieved by Activator Alone	% Reduction Achieved by RegenOx	Constituent	% Reduction achieved by Activator Alone	% Reduction Achieved by RegenOx
Napthalene	55.2	85.9	*Benzo[a]anthracene*	49.8	78.4
2-Methylnapthalene	55.5	82.1	*Chrysene*	47.3	81.6
1-Methylnaphtalene	50.4	82.0	*Benzo[a]pyrene*	45.3	79.6
Acenaphthylene	45.3	81.8	*Indeno[1,2,3-cd]pyrene*	41.8	81.8
Acenapthene	52.4	80.3	*Dibenz(a,h)anthracene*	42.0	82.0
Fluorene	40.8	76.2	*Benzo[g,h,i]pyrene*	49.6	86.3
Phenanthrene	49.9	75.9	*Benzo[b]fluoranthene*	42.8	76.1
Anthracene	52.6	78.1	*Benzo[k]fluoranthene*	42.0	92.7
Fluoranthene	50.9	79.1	*DRO (nC10-<nC25)*	20.6	74.2
Pyrene	50.4	78.7	*RRO (nC25-nC36)*	13.8	70.5

TPH contaminant reduction ranging from 70-92% was observed in the soil and water system. Some contaminant concentrations increased in the water phase of RegenOx-treated samples, indicating that RegenOx is effective in removing contaminant mass from the soil. The activator control results show that the RegenOx activator sorbs contaminant mass. Once in place on the activator, more contaminant is oxidized due to increased probability of contacting the oxidant in solution and producing a surface-catalyzed oxidation.

RegenOx Followed by Bioremediation

- RegenOx can be followed by low-cost bioremediation as part of a treatment train approach
- Leaves behind very little residue, limited primarily to the innocuous carbonate and bicarbonate ions
- Does not interfere with efficient natural attenuation or enhanced bioremediation
- Does not detrimentally impact the quality of the groundwater treated





After a RegenOx™ application, the biomass concentrations and microbial diversity were determined. Biomass and community structure, as measured by phospholipid fatty acid analysis (PLFA), did not significantly change after treatment, or rebounded rapidly.

Case Study 1 – RegenOx Treats Mixed Chlorinated Solvent and Hydrocarbon Plume

Site Layout

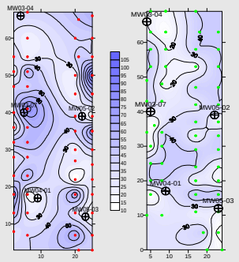
Remediation Objective: Reduce concentrations of toluene, ethyl benzene, xylenes, PCE, VC, cis-DCE, toluene and methyl isobutyl ketone (MIBK) at a chemical distribution facility

RegenOx Application

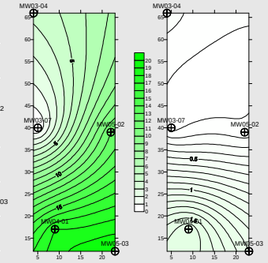
Application Type: Injection point grid application
Product: RegenOx
Quantity Applied:
1st application (Aug. 2005): 1890 lbs. RegenOx
2nd application (Sept. 2005): 1500 lbs. RegenOx
Application Rate: 20-30 lbs./ft.
Injection Spacing: 6 ft. on-center

Hydrogeology

Treatment Area: 2500 ft.[2]
Soil Type: Clay
Groundwater Velocity: ~ 0 ft./day
Depth to Groundwater: 5 ft.



RegenOx product distribution based on injection volume (gal): 1st injection (left) and 2nd injection (right). Some areas of the clay formation were able to accept more RegenOx (shown in dark blue) than other areas (shown in white).



Vinyl chloride concentrations (mg/L) pre-injection July 2005 (left) and post-injection Oct 2005 (right)

Contaminant reductions in MW05-03

Analyte (mg/L)	Pre-RegenOx	Post-RegenOx	% Reduction
Toluene	87	44	**50**
Ethyl Benzene	2.7	0.91	**66**
Xylenes	15	5.8	**61**
Vinyl Chloride	20	1.2	**90**
Cis 1,2-dichloroethene	25	9.2	**63**
Tetrachloroethene	.054	.013	**24**
Methyl Isobutyl Ketone	240	53	**78**

Conclusions

In the most contaminated well, MW05-03, contaminant reductions ranged from 24-90% after the first application round. RegenOx application to an expanded treatment area is planned. Over a short period of 3 months, RegenOx effectively degraded a mixed plume containing chlorinated solvents, BTEX contaminants and MIBK.

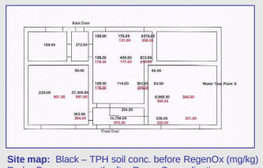
Case Study 2 – High TPH Concentrations

Remediation Objective: Reduce concentrations of TPH underneath a cottage. TPH contamination resulted from a heating oil spill. Excavation was not an option due to the nature of the building structure.

RegenOx Application

Application Type: Hand-dug trench application
Product: RegenOx
Quantity Applied: 4200 lbs. RegenOx

Cottage with heating oil spill



Site map: Black – TPH soil conc. before RegenOx (mg/kg)
Red – Conc. one month after RegenOx application

Geology

Treatment Area: 540 ft.[2]
Soil Type: Alluvium (silty-sand and gravel)

Conclusions

- Overall, an average TPH reduction of 92% was measured. Upon entering the building for the post application sampling, field personnel noted that for the first time there was no strong smell of heating oil.
- Following this treatment, the regulators have required no further remedial action.
- RegenOx proved to be an inexpensive, effective remediation strategy and required no special equipment.

Results before and 4 weeks after RegenOx treatment

Sample	*Pre-RegenOx (mg/kg)*	*Post-RegenOx (mg/kg)*	*Reduction*
B001	5,376	568	89%
B002	176	161	9%
B004	833	474	43%
B005	409	177	57%
B006	159	175	-10%
B007	903	596	34%
B009	189	178	6%
B011	**14,700**	**570**	**96%**
B016	**27,300**	**981**	**96%**
B017	362	284	22%
B019	536	330	38%
B021	**6,950**	**360**	**95%**
Average	**4,824**	**405**	**92%**