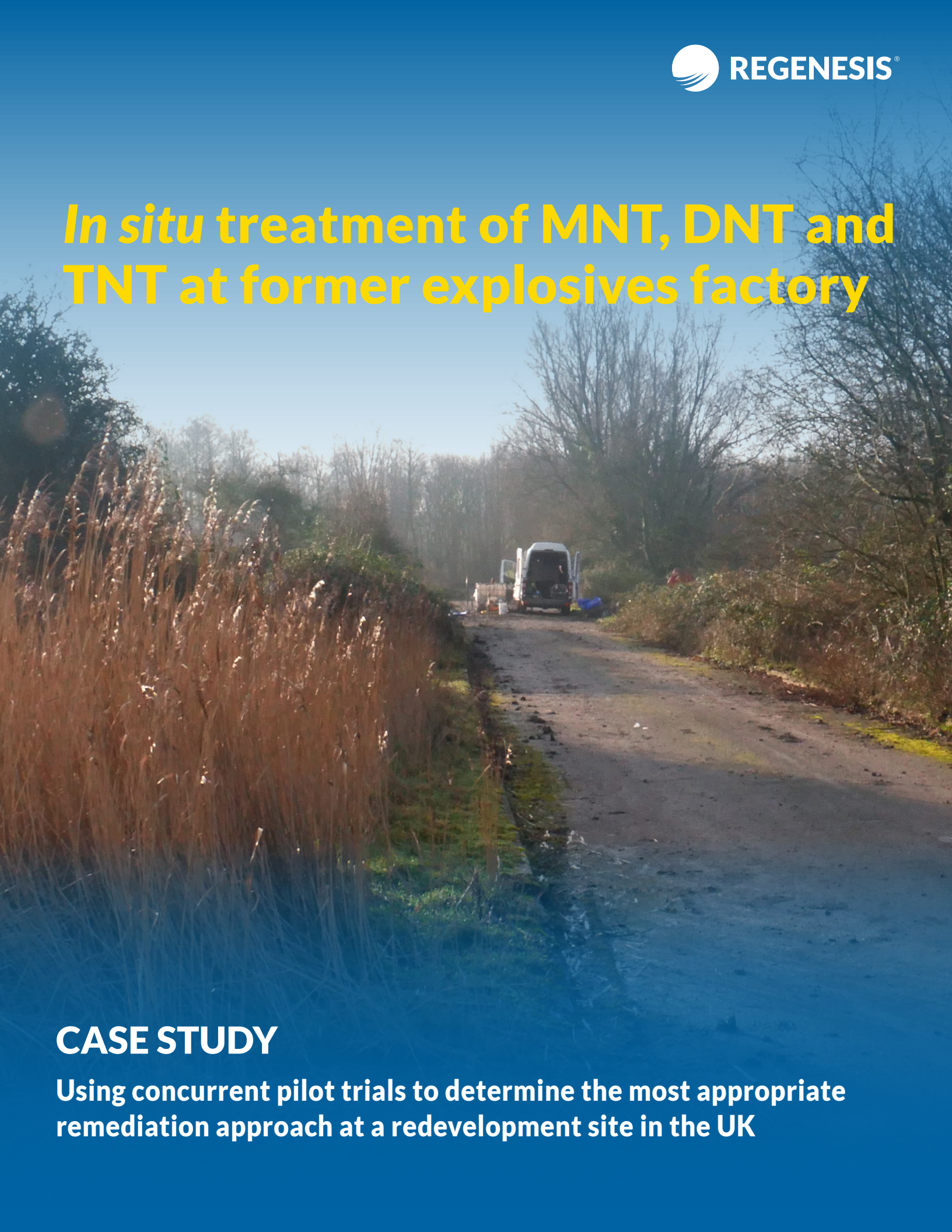
REGENESIS®

In situ treatment of MNT, DNT and TNT at former explosives factory



CASE STUDY

Using concurrent pilot trials to determine the most appropriate remediation approach at a redevelopment site in the UK

SUMMARY

REGENESIS was asked to provide a remedial solution for groundwater contamination relating to a former explosives manufacturing facility in the UK, featuring complex geology. A fixed deadline had been set for the handover of the site to new ownership prior to redevelopment, and the timeframe for remediation was therefore limited.

Fig. 1 Site Overview

The main objective of the treatment was overall betterment of the site condition via mass reduction of the dissolved phase propellant contamination. However, due to the unusual contaminant mix reported on the site, multiple pilot trials were undertaken to investigate the optimum degradation pathway of a co-mingled TNT, DNT, MNT plume.

SITE TYPE

Former manufacturing site (explosives factory)

GEOLOGY

Made ground and clay over bedrock

CONTAMINANTS

TNT 3,590 µg/L,
DNT 9,520 µg/L,
MNT 18,900 µg/L

PROJECT DRIVER

Site Redevelopment

TREATMENT

In-situ Chemical Oxidation,
Enhanced Anaerobic Biodegradation,
Enhanced Aerobic Degradation

TECHNOLOGIES

RegenOx®, 3DME®,
ORC Advanced®

PILOT TRAILS

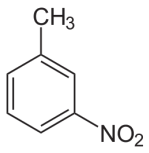
The nature of the site provided REGENESIS with the opportunity to demonstrate the versatility of the technology range available to our clients. A joint literature review by BAE Systems and REGENESIS, concluded that no common degradation pathway was available to address the explosive contaminants *in situ* (see table 1). Anaerobic biodegradation of nitroaromatic compounds typically results in the reduction of the nitro group to an amino group **(1)**, with the potential exception of MNT. Under aerobic conditions however, MNT isomers have been shown to undergo complete mineralisation in both lab and field-based investigations **(2) & (3)**. Therefore, an aerobic biological degradation pilot test was proposed using **ORC Advanced**. In another area where higher concentrations were observed, in situ chemical oxidation (ISCO) was also trialled using **RegenOx**.

Enhanced anaerobic biodegradation of nitroaromatic compounds through amendment with carbon has been demonstrated in the lab and field (4),(5). The nitro substituents of the nitroaromatic compounds are highly electro-negative and therefore compete for available electrons. These are typically reduced to amino substituents, forming compounds from TNT such as 2-A-4,6-DNT and 4-A-2,6-DNT.

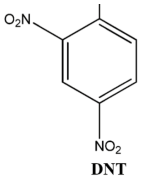
Table 1. CoC concentrations and proposed trials

Target Well	BH23A		BH31		BH38a
Installs (mBGL)	9 to 12		12 to 16		6 to 9
Geology	Lias		Lias		Lias
Area Name	Tank farm		Plume 1		Plume 2
Year	2013	2017	2013	2017	2018
2-MNT*	47	15	0.15	4	66
3-MNT*	9.7	3.3	0.05	1.1	19
4-MNT*	N/A	N/A	N/A	N/A	2
2,6-DNT**	0.2	0.01	BDL	BDL	3
2,4-DNT**	0.5	0.26	BDL	BDL	7
TNT**	BDL	BDL	BDL	BDL	1
2018 Trial	3-D MICROEMULSION		ORC OXYGEN RELEASE COMPOUND		REGEN Ox
	Chosen due to combination of degradation pathways		Chosen due to combination of degradation pathways		Chosen due to combination of degradation pathways

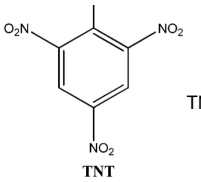
Predominant degradation pathway key: *Aerobically [3][4][2] , **Anaerobically [1][5][6]



MNT molecular structure



DNT molecular structure



TNT molecular structure

Fig. 2 Molecular structures of the Contaminants of Concern (CoC)

Also formed is 2,4,6-triaminotoluene (TAT) as a product of the complete reduction of TNT. TAT and amino-DNT compounds are irreversibly bound to the soil matrix and therefore removed from the groundwater.

This occurs through sequestration of the daughter products to soil minerals and humic substances through several processes including adsorption, polymerisation and humification (4). It was therefore also suggested that an enhanced anaerobic biological degradation pilot test be completed using 3-D Microemulsion (3DME).

Fig. 3 3DME prior to mixing and injection

PILOT RESULTS

The five-month post-application groundwater monitoring results from the 3DME area showed that all contaminant concentrations including daughter products were below the laboratory detection limit. In the other areas, RegenOx was successful at chemically oxidising all explosive contaminants *in situ*. However, without a follow-on application of ORC Advanced or 3DME, contaminant concentrations rebounded within 3 months. The ORC Advanced pilot successfully reduced MNT levels below detection limits.

TREATMENT

The pilot results and lessons learned during the treatment allowed REGENESIS to design a full-scale treatment. The remediation would be based on the application of 3DME. This was due to: (1) the natural aquifer conditions being strongly anaerobic, (2) the efficacy of 3DME shown during the pilot, (3) the wide injection spacing that could be utilized with 3DME. This spacing significantly reduced the cost and time spent onsite completing the application. The full-scale design targeted the two source areas with a grid-based 3DME injection pattern in and immediately down-gradient of each tank farm.

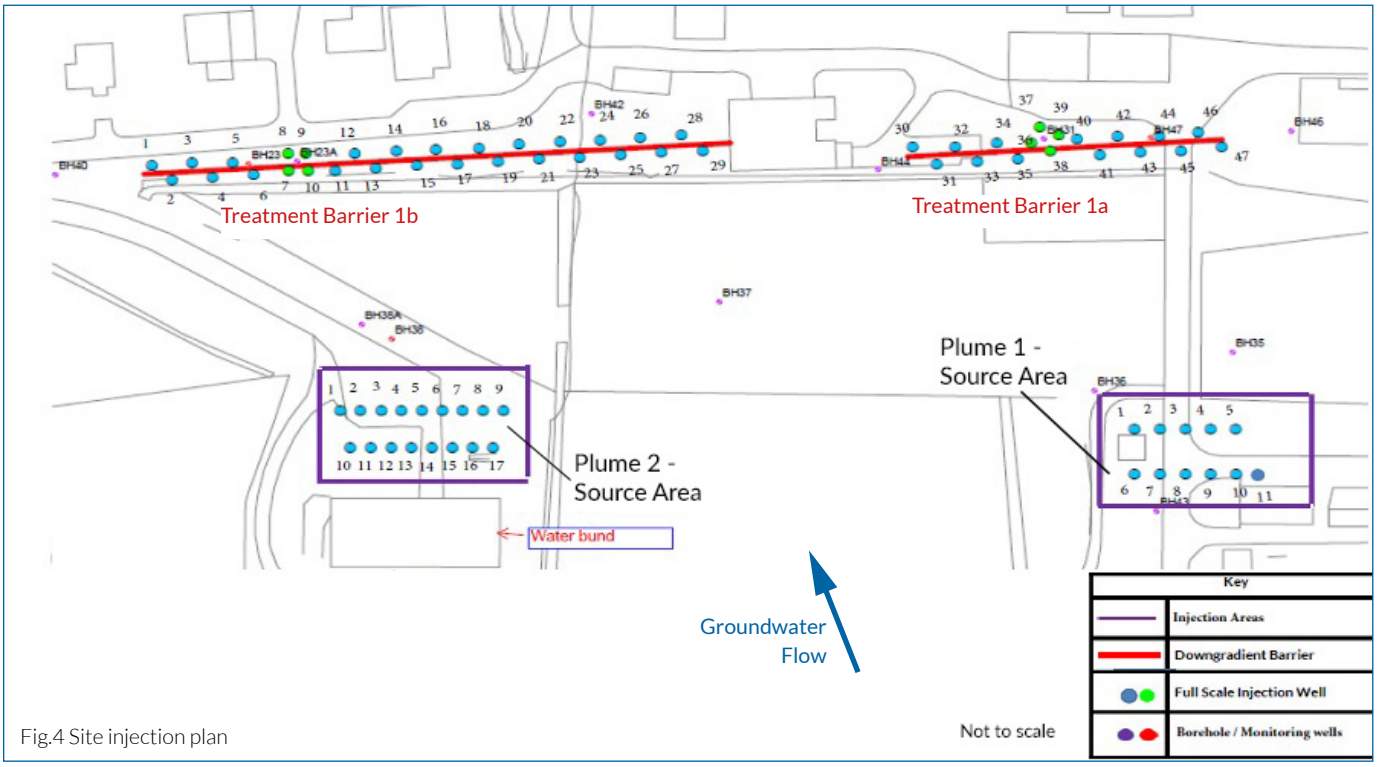


Fig.4 Site injection plan

Further down-gradient, a row of 3DME injections provided a barrier to the leading-edge of the dissolved phase plumes emanating from the two source areas, allowing groundwater flow, whilst degrading the contamination within the treatment zone that the injection creates. Injections were completed by drilling and completing an array of injection wells. Hydraulic packers were then used to connect to the wells and the requisite doses were applied to each location.

TREATMENT AREA:
2,600m² total (3 areas)

COST:
£215,000 (approx. €245k)

Fig.5 Full-scale treatment: Grid injection in source area 1

FULL-SCALE RESULTS

Where pilot applications had been completed, the remediation achieved non-detect results. The full-scale application extended the treatment and post-application monitoring showed that low concentrations were maintained, with no rebound occurring. Following collection of the validation monitoring, the site received regulatory close-out and will be redeveloped for commercial and industrial use.

Fig. 6 Niroaromatic contaminant concentrations over time - Downgradient of barrier 1b

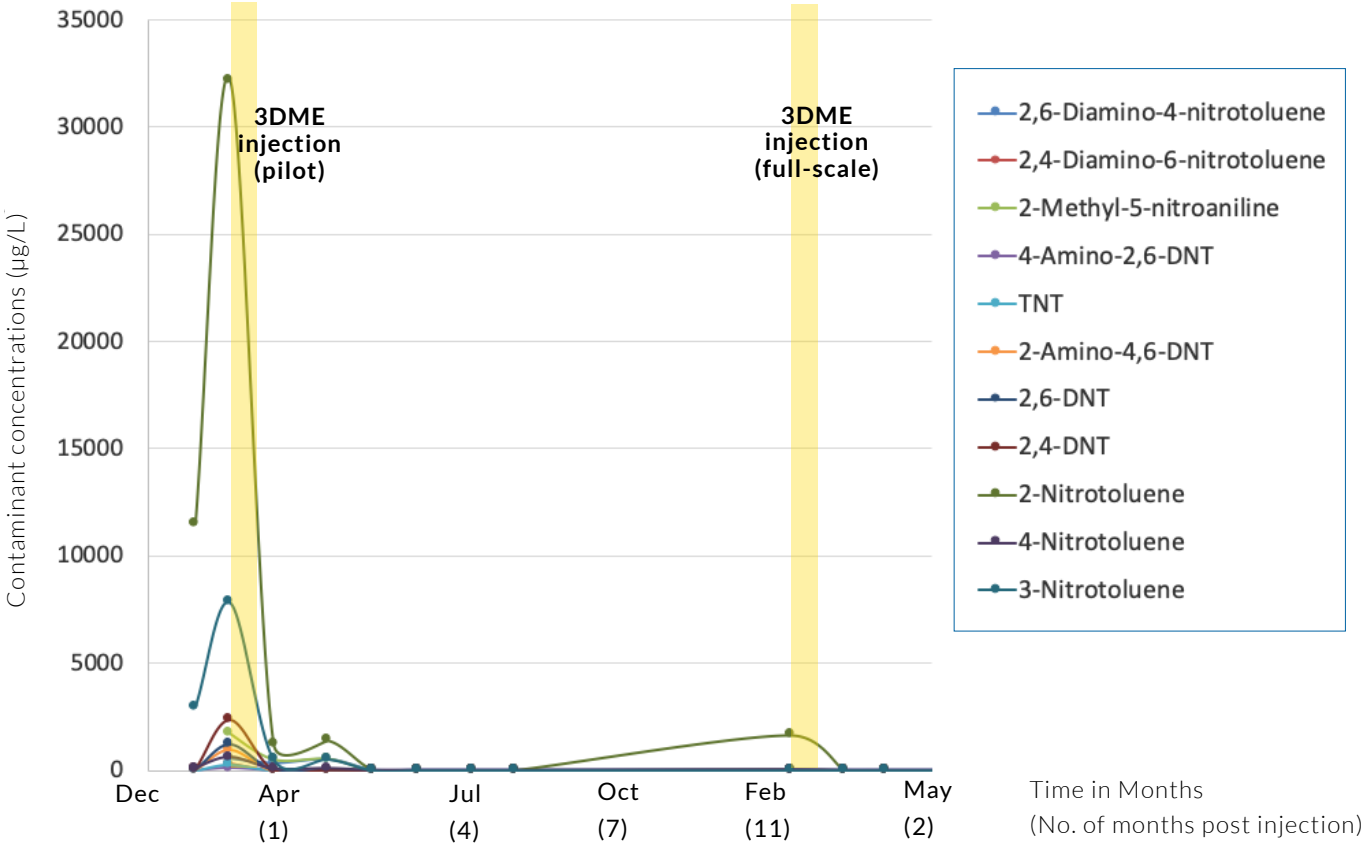


Fig. 7 Injection into wells

CONCLUSION

- A wide range of nitroaromatic contaminants were treated effectively using a combined *in situ* remediation approach.
- Substantial reductions in contaminant concentrations were achieved both in source and plume areas.
- By completing a pilot study using a range of different REGENESIS products, a range of remediation pathways were assessed.
- This allowed the optimal remedial approach – anaerobic biological degradation using 3DME – to be selected and applied at full-scale.

TECHNOLOGIES APPLIED

3-D Microemulsion® – A wide-area distribution, staged-release, electron donor emulsion for the optimized enhanced anaerobic biodegradation of chlorinated compounds

ORC Advanced® – Accelerated aerobic biodegradation of hydrocarbons for up to a year from a single application.

RegenOx® – Powerful and safe ISCO, compatible with underground structures and services.

For more information, please get in touch or visit our website.

3-D MICROEMULSION

ORC ADVANCED OXYGEN RELEASE COMPOUND

REGEN Ox

References:
(1) McCormick NG et al; Appl Environ Microb 31: 949-58 (1976)
(2) Paca J et al; Soil Sediment Contam 14: 262-279 (2005)
(3) Struijs J, Stoltenkamp J; Sci Total Environ 57: 161-70 (1986)
(4) Rieger P, Knackmuss H; Environmental Science Research, Ed J C Spain: Vol 49 (1995)
(5) Barnes et al; Proceedings from the 6th International In Situ and on-Site Bioremediation Symposium, San Diego, California, June (2001)

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