REDOX TECH, LLC

"Providing Innovative In Situ Soil and Groundwater Treatment"

A CASE STUDY FOR THE APPLICATION OF OXYGEN BIOCHEM (OBC™) TO TREAT GROUNDWATER CONTAMINATED WITH GASOLINE

Remediation Summary

OBC® Pilot Test Phase I and Phase II

Timeline 2011

SITE LOCATION: NEW HAMPSHIRE

Application Method:

Redox Tech applied through DPT

Contaminants of Concern:

- **Benzene**
- **Naphthalene**
- **1,3,5-Trimethy Benzene**
- **1,2,4-Trimethy Benzene**

Phase I and II Results:

> Benzene reduced 42% to 69%

> Naphthalene reduced 35% to 93%

> 1,3,5-Trimethy Benzene reduced 30% to 62%

> 1,2,4-Trimethy Benzene reduced 20% to 99%

Current Site Status:

Phase I and II successfully reduced the COCs in the treatment area

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Product Overview: Redox Tech's product Oxygen BioChem (OBC™) is a formulated mixture of sodium persulfate and calcium peroxide that can be employed for ISCO applications. The mixture in OBC™ supports a two-fold mechanism for treating volatile and semi-volatile organic compounds. OBC™ delivers one of the strongest chemical oxidants for short term ISCO, and also provides electron acceptors (oxygen and sulfate) for longer-term biological oxidation. OBC™ has the advantages over more traditional oxygen compounds used for bioremediation in that it works on a broader range of contaminants. Persulfate has emerged recently as an important oxidant for *in situ* remediation and is the strongest oxidant within the peroxygen family. The activated persulfate provided by OBC™ can remain available in the subsurface for months providing an unrivalled combination of power and stability. The calcium peroxide in OBC™ provides several benefits including: the provision of alkalinity for persulfate activation, the addition of a slow release source of hydrogen peroxide (which provides an extended oxygen source) and calcium hydroxide (which increases the dissolved ion concentration thus reducing the likelihood of leaching metals from soil or elevated sulfate concentrations).

Project Summary: In March 2011, OBC™ was injected into the saturated zone at a site in Manchester, New Hampshire, where elevated concentrations of gasoline constituents have been reported in groundwater. Chemical oxidation, aerobic biological remediation and oxidation by sulfate reduction using OBC™ was selected as the remedial strategy due to its proven ability to treat gasoline contamination at other sites in New Hampshire. OBC™ is safer to handle than hydrogen peroxide at higher concentrations, is effective over a wide range of total iron concentrations, and does not generate large amounts of heat. It is also less affected by background groundwater chemistry than Fenton's chemistry. After two of the three scheduled OBC™ injections were completed only one well sampled after the Phase II injection event was above the cleanup standard. Several monitoring wells which were in the target treatment area during the Phase II event were destroyed during the site construction and could not be sampled after the injection event. These wells are currently being replaced so that the post injection conditions can be assessed prior to proceeding with the Phase III scope of work.

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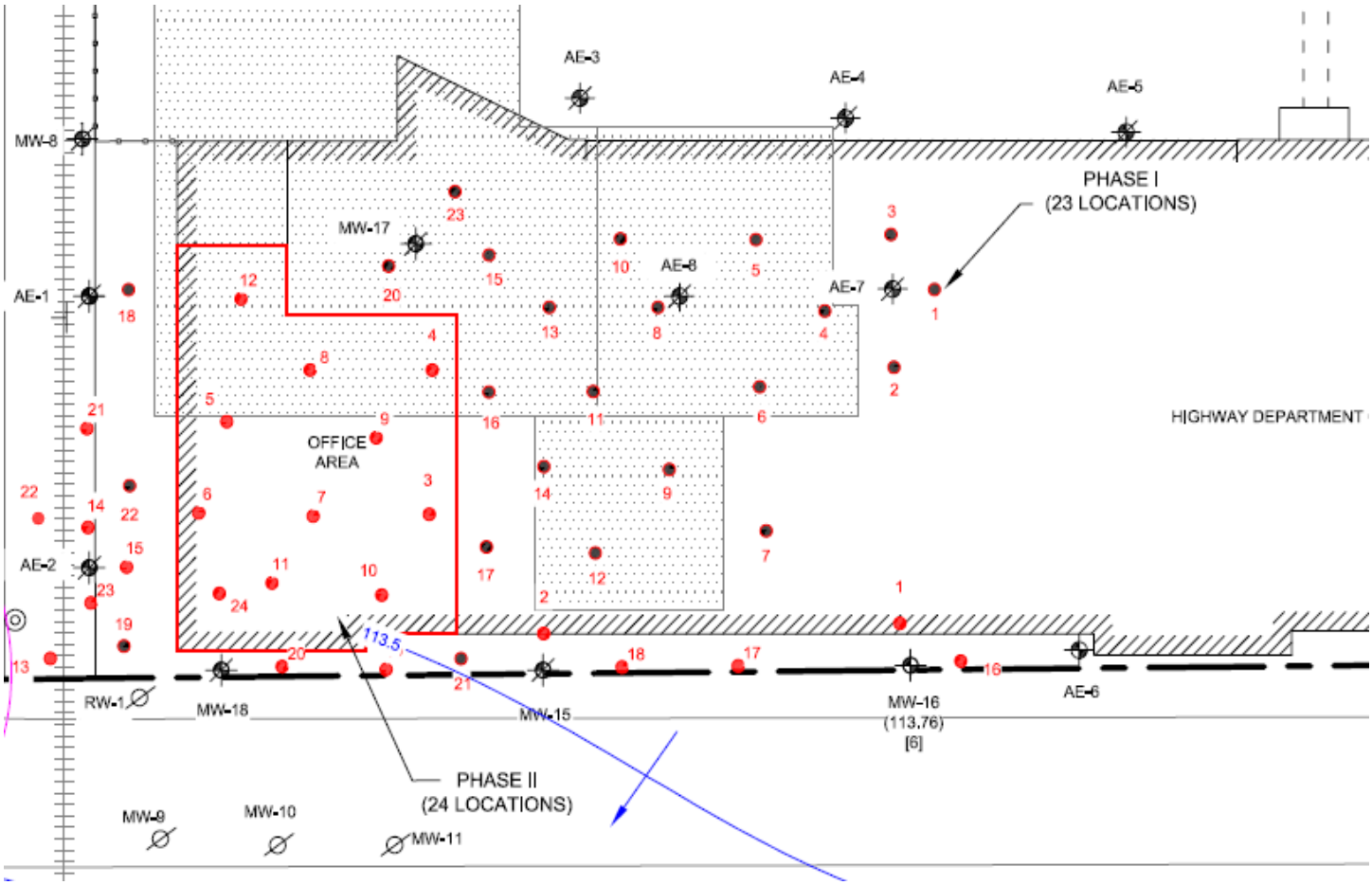
Client Reference: Aries Engineering

Project Background: In response to a 1991 gasoline underground storage tank (UST) release, the site owner retained an environmental consultant to design, operate, and maintain an emergency site soil venting and groundwater remedial systems adjacent to the northwest corner of the property. Following the abatement of gasoline vapors from an adjacent building and the recovery of approximately 16,000 gallons of gasoline, the remedial systems were decommissioned and removed from the site during 1994 and 1995.

Site groundwater quality has been monitored in monitoring wells MW-8, MW-15, MW-16, MW-17, MW-18, and MW-28 consistent with the NHDES GMP. Shallow site groundwater (which is at an approximate depth of 20 feet below grade) generally flows from the former site UST removal area towards the Maple Street and Valley Street intersection as indicated by the blue arrow in Figure 1. Historical groundwater gasoline-related constituent volatile organic compound (VOC) concentrations have been observed to generally decline over time, however, by Fall 2010 the degradation of groundwater VOC concentrations in site monitoring wells had leveled off at concentrations exceeding NHDES Ambient Groundwater Quality Standards (AGQS's), resulting in a requirement for long term monitoring.

During the spring of 2011, prior to the foundation construction for the city police station, NHDES requested a pilot in-situ chemical oxidation (ISCO) injection be completed to remediate petroleum-contaminated soil in the vicinity of the proposed building footprint and accelerate the attenuation of groundwater VOC concentrations as measured in the groundwater wells. The pilot ISCO injection was completed in two phases of work by Redox Tech using a Geoprobe® and OBC™. The March 2011 Phase I and May 2011 Phase II ISCO treatment area extended over an approximate 7,200 square-foot by 5-foot thick area over the inferred groundwater contaminant plume in the vicinity of the former office building and maintenance garage. Approximately 12,560 pounds of OBC™ were mixed with water to form a 16 percent by weight solution. Injections were conducted at twenty-three (23) temporary injection locations spaced approximately 20 to 25 feet apart to address the treatment area (**Figure 1** provided by Aries Engineering). Each injection point received 400 gallons divided between 2 depth intervals (1 and 4 feet below the groundwater table).

Figure 1
Phase 1 and 2 Injection Point Locations



Based on the preliminary May 2011 observation of increased pH, oxygen reduction potential (ORP) and dissolved oxygen (DO) levels in adjacent monitoring wells, the client and Redox Tech estimated an OBC™ injection radius of influence of 15 feet was reasonable and an additional three to six months of time may be required to understand the overall ISCO affects on the site VOC source area.

Following the Phase I ISCO injection work the NHDES requested that groundwater samples be collected from site monitoring wells MW-15, MW-16, MW-17, MW-18, AE-1, AE-2, AE-7 and AE-8 for laboratory VOC analysis. The March 31, 2011 laboratory results indicated groundwater total VOC concentrations decreased in amounts ranging from 21% in monitoring well MW-16 to 95% in monitoring well AE-7 following the Phase I ISCO injection. The groundwater sample laboratory results before and after the OBC™ injections are summarized in **Figure 2 (**provided by Aries Engineering).

Site monitoring wells AE-1, AE-2, AE-7, AE-8, MW-8, MW-15, MW-17 and MW-18 were removed and site construction work prevented the installation of replacement monitoring wells prior to the December 2011 sampling round. The NHDES requested that groundwater samples be collected from the remaining monitoring wells (MW-16, MW-28 and MW-29) in the vicinity of the Maple Street and Valley Street intersection during the sampling round.

Figure 2
Groundwater VOC Analytical Results
(sampling after Phase I - 03/2011 and sampling after Phase II - 12/2011)

Volatile Organic Compound		Benzene	Toluene	Ethylbenzene	Xylene	MTBE	Naphthalene	Isopropyl-benzene	n-Propyl-benzene	1,3,5-Trimethyl benzene	1,2,4-Trimethy-benzene	sec-Butyl-benzene	p-Isopropyl-toluene	Total VOC's	% VOC Change
NHDES AGQS (µg/l)		5	1,000	700	10,000	13	20	280	260	330	330	260	260	NA	NA
NHDES GW-2 Standard (µg/l)		2,000	50,000	50,000	30,000	10,000	2,000	NA	NA	1,000	3,000	NA	NA	NA	NA
Location	Date														
MW-15															
Pre Injection	11/30/2010	45	76	230	280	<2	51	29	42	36	450	5.6	8.6	1,233	
Post Injection	3/31/2011	26	65	220	280	<4	61	25	36	79	450	<10	<10	1,242	1%
MW-16															
Pre Injection	11/30/2010	<4	48	290	630	<4	65	20	49	77	420	<10	<10	1,599	
Post Injection	3/31/2011	<12	36	230	650	<2	43	13	25	31	240	<5	<5	1,268	-21%
Post Injection	12/5/2011	<2	<5	<5	<5	<2	<10	<5	<5	<5	5.6	<5	<5	6	-99.6%
MW-17															
Pre Injection	11/30/2010	<4	<10	120	175	<4	22	14	23	15	380	<10	<10	749	
Post Injection	3/31/2011	<1.6	<4	40	142	<1.6	14	4.8	7.4	29	160	<4	<4	397	-47%
MW-18															
Pre Injection	11/30/2010	<4	29	260	2,020	<4	91	32	54	340	1100	<10	<10	3,926	
Post Injection	3/31/2011	<8	<20	180	1,310	<8	57	<20	25	160	590	<20	<20	2,322	-41%
AE-1															
Pre Injection	11/30/2010	<4	14	150	147	<0.8	32	21	29	130	330	3.5	4.9	861	
Post Injection	3/31/2011	<0.8	<2	14	20	<0.8	4.5	3.4	4.9	14	59	<2	<2	120	-86%
AE-2															
Pre Injection	11/30/2010	<4	53	500	2,710	<4	200	77	150	460	1,500	14.0	13	5,677	
Post Injection	3/31/2011	<8	20	340	1,630	<8	130	56	97	320	1,200	<20	<20	3,793	-33%
AE-7															
Pre Injection	7/1/2010	9.7	87	27	174.0	<4	29	<10	22	70	200	<10	<10	619	
Post Injection	3/31/2011	3.0	19	2.2	8.6	<0.8	<4	<2	<2	<2	<2	<2	<2	33	-95%
AE-8															
Pre Injection	11/30/2010	<8	<20	160	<40	<8	<40	43	130	200	560	20.0	<20	1,113	
Post Injection	3/31/2011	<1.6	<4	72	<8	<1.6	<8	17	45	54	180	5.7	4.4	378	-66%
MW-28															
Pre Injection	11/30/2010	<4	33	530	2,620	<4	120	62	120	370	1,300	11.0	10	5,176	
Post Injection	12/5/2011	<4	92	160	590	<4	38	24	46	140	640	<10	<10	1,730	-67%
MW-29															
Pre Injection	7/1/2010	<0.8	<2	30	<2	<0.8	<4	5	9	<2	9	<2	<2	53	
Post Injection	12/5/2011	<0.8	<2	<2	<2	<0.8	<4	<2	<2	<2	<2	<2	<2	0	-100%

Note: MW-28 was not in the treatment area and is part of the Phase III injection area, which was postponed due to the success of Phases I and II.

OBC™ Application Results: Phase I of the OBC™ application successfully reduced the COC concentrations in all wells within the treatment area (MW-17, AE-8 and AE-7) to below the target cleanup standard. After Phase I, four wells outside the Phase I treatment area remain above the standard: MW15, MW-16, MW18, and MW-28. Phase II addressed the contamination in these area, however due to the destruction of monitoring wells during the site building construction only MW-16 and MW-28 could be sampled after the completion of Phase II. The need for any additional treatment, including the Phase III treatment near MW-28 will be evaluated after destroyed monitoring wells are completed.