Provect-OX® - *In Situ* Chemical Oxidation + Enhanced Bioremediation to Address a Comingled Plume

Active Auto Service Center: Manalapan, New Jersey
Contaminants of Interest: Petroleum Hydrocarbons and Chlorinated Solvents

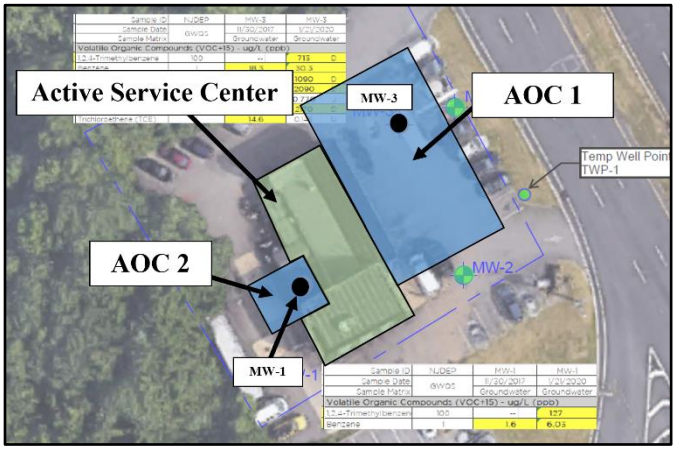
Project Summary

An active auto service center in Manalapan, New Jersey required *in situ* remediation to address a comingled petroleum hydrocarbon and chlorinated solvent plume. Historical site operations have impacted the saturated soil and groundwater with petroleum hydrocarbon volatile organic compounds (VOCs), specifically benzene, ethylbenzene, xylenes, and 1,2,4-trimethylbenzene (1,2,4-TMB). Tetrachloroethene (PCE) and trichloroethene (TCE) are also present at lower concentrations compared to the petroleum hydrocarbons. Two accessible areas of concern (AOC) were targeted to address the groundwater plume. The total treatment area was 5,625 sq ft with a 7 to 15 feet below ground surface (ft bgs) vertical target interval. The geology at the site consists of silty sand that is underlain by a clayey sand at 8 ft bgs. Average depth to groundwater is 8 ft bgs. Prior to remediation, the baseline aquifer conditions exhibited oxidizing conditions with positive ORPs (>+100) and slightly acidic pH (~6.5).

Remediation Plan

The Remedial Action Objective (RAO) was to significantly reduce the groundwater VOC concentrations within the accessible areas, which included two target monitoring wells (MW-1 and MW-3; see **Figure 1**). The remedial program was developed by Engineering & Land Planning Associates, Inc. (E&LP) and Provectus Environmental Products, Inc. (Provectus) with *in situ* implementation provided by Innovative Environmental Technologies, Inc. (IET). To achieve the RAO, ferric iron activated sodium persulfate (Provect-OX®; US Patent 9,126,245) was selected. From July 20 to July 22, 2020, a total of 13,200 lbs of Provect-OX® was applied via 28 direct push injection points within the AOCs. The injection points were spaced between 12 and 15 ft apart. The service center remained open and active during drilling and injection activities.

Figure 1: Site Map



Provect-OX® rapidly oxidizes organic contaminants present in soil and groundwater and provides long-term, sustained secondary bioremediation to manage residuals and prevent contaminant rebound. This is accomplished by using ferric iron (Fe III) as a safe and effective means of activating persulfate, which quickly yields sulfate radicals and ferrate (site-specific) for chemical oxidation treatment. The technology process enhances subsequent utilization of sulfate and iron as terminal electron

acceptors for facultative redox reactions to support secondary biodegradation of any residual contaminant mass.

Treatment Program Results

Field and geochemical data for the two target monitoring wells are presented below in **Table 1** and **Table 2**. Contaminants of interest (COI) data for the monitoring wells are presented in **Table 3** and **Table 4**. Oxidative conditions were present prior to application of the Provect-OX®; however, significant ORP increases (+502 and +438 mV) were observed following injection. The presence of sulfate and iron in groundwater confirmed that Provect-OX® was successfully distributed throughout the targeted areas. During the April 2021 sampling event, MW-3 (AOC 1) transitioned from oxidative to reducing conditions (9 months post-injection). ORPs in MW-1 (AOC 2) continued to exhibit strongly oxidizing conditions for over 20 months, with reducing conditions observed in April 2022. The residual sulfate and iron are likely facilitating the reducing conditions and providing an enhanced bioremediation environment to further address the COIs.

Table 1. Field and Geochemical Data for MW-3

MW-3									
Sampling Date	**07/20 (Baseline)**	**9/20**	**1/21**	**4/21**	**7/21**	**9/21**	**1/22**	**4/22**	**7/22**
pH	6.53	6.55	4.96	6.11	6.49	6.39	6.59	6.66	6.51
ORP (mV)	+120	+438	+212	-22	-101	-89	-105	-167	-165
Sulfate (mg/L)	ND	-	1,140,000	520,000	895,000	1,040,000	487,000	185,000	161,000
Iron (mg/L)	51,600	-	175,000	146,000	208,000	202,000	182,000	167,000	183,000

Table 2. Field and Geochemical Data for MW-1

MW-1								
Sampling Date	**07/20 (Baseline)**	**9/20**	**1/21**	**4/21**	**7/21**	**9/21**	**1/22**	**4/22***
pH	6.52	3.97	2.96	3.28	4.58	4.70	4.94	5.60
ORP (mV)	+136	+502	+426	+321	+290	+148	+72	-98
Sulfate (mg/L)	ND	-	6,420,000	3,350,000	1,600,000	1,940,000	1,580,000	2,490,000
Iron (mg/L)	36,600	-	500,000	521,000	368,000	324,000	298,000	482,000

**Groundwater VOC results below NJDEP Standards during 9/2021 & 1/2022 sample event; See Table 4.*
**Geochemical data still collected during 4/2022 field sample event.*

Following the Provect-OX® application, petroleum hydrocarbon and chlorinated solvent groundwater concentrations have significantly decreased (**Table 3** and **Table 4**). The VOC reductions in MW-3 are promising with an average reduction of >77% for all target VOCs, including significant reductions in total xylenes (e.g., 3,980 ug/L to ND) and 1,2,4-TMB (e.g., 1,400 ug/L to 104 ug/L). MW-1 exhibited average groundwater reductions of >90% for all target VOCs. MW-1 reached the New Jersey Groundwater Quality Standards (NJ GWQS) approximately 1 year after injection. Additional contaminant concentration decreases in MW-3 are anticipated due to the iron and sulfate enhanced bioremediation processes.

Table 3. VOC Data for MW-3

MW-3									
Sample Date	**7/20 Baseline**	**10/20**	**1/21**	**4/21**	**7/21**	**9/21**	**1/22**	**7/22**	**Reductions**
1,2,4-TMB (100 ug/L)	1,400	0.16	841	695	151	211	105	104	93%
Benzene (1 ug/L)	51.6	1.14	36.2	33.3	31.7	32.8	18	22.1	57%
Ethylbenzene (700 ug/L)	2,020	0.244	1,380	1,580	1,710	1,020	300	921	54%
PCE (1 ug/L)	7.67	2.33	1.86	0	1.57	4.09	5.84	1.46	81%
Total Xylenes (1,000 ug/L)	3,980	0.244	1,640	1,330	544	91	31.2	ND	100%
TCE (1 ug/L)	3.37	0.146	0.146	0.146	0.146	1.27	1.52	0.721	79%

ND: Non-Detect; Shaded indicates compound detected above NJDEP GWQS (standards in parentheses).

Table 4. VOC Data for MW-1

MW-1								
Sample Date	**7/20 Baseline**	**10/20**	**1/21**	**4/21**	**7/21**	**9/21***	**1/22***	**Reductions**
1,2,4-TMB (100 ug/L)	119.00	7.88	31.70	67.3	40.1	29.5	23.2	81%
Benzene (1 ug/L)	3.36	ND	2.32	3.64	1.36	0.984	ND	100%
Ethylbenzene (700 ug/L)	15.20	0.94	4.13	10.7	4.26	3.76	2.33	85%
PCE (1 ug/L)	0.80	ND	0.55	0.706	ND	0.562	ND	100%
Total Xylenes (1,000 ug/L)	79.9	4.6	17.0	36.0	20.2	16.1	11.2	86%

**Groundwater results below NJDEP GWQS at 9/2021 & 1/2022 sample events. Additional VOC sampling not conducted.*
ND: Non-Detect; Shaded indicates compound detected above NJDEP GWQC (standards in parentheses).

Please contact our office at (815) 650-2230 or via email at info@provectusenv.com for additional information regarding this project or our technologies.