AEROBIC BIOREMEDIATION OF RESIDENTIAL PETROLEUM RELEASES

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ABSTRACT: Releases of no. 2 heating oil from residential storage tanks have become an increasing and costly problem in New Jersey. In many cases, common remediation technologies will cause severe disruption to homeowners and the household. Often, the source of the problem is in hard to reach locations because petroleum migration extends to beneath the residence and its foundation. The introduction of Oxygen Release Compound (ORC®) to soil and ground water is a cost effective method of remediating petroleum releases with minimal disruption to the household.

The injection of ORC to the subsurface will passively remove residual concentrations of petroleum trapped within the soil and dissolved in the ground water. Over the past two years, the ORC remediation method has been applied on four residential petroleum cases where both soil and ground water have been impacted to concentrations above the regulatory standards. After the injection of ORC into the subsurface, concentrations of volatile organic compounds (VOCs) and base/neutral extractable compounds (B/Ns) were found to decrease to within the regualtory standards. Two of the four cases have been closed by the regulatory agency and the remaining two cases are still within the review phase.

INTRODUCTION

Oxygen Release Compound (ORC®) is a mixture of magnesium oxide, magnesium hydroxide and magnesium peroxide. The introduction of these compounds into ground water cause an increase of the oxygen content to occur. The increased oxygen levels allow the indigenous petroleum-degrading bacteria to multiply. The bacteria then use the petroleum as a food source causing the dissolved petroleum concentrations to decrease.

Petroleum releases at residential sites occur from leaks in underground, aboveground and basement storage tanks. Residential tanks are commonly used for the storage of no. 2 heating oil, but may also contain gasoline and kerosene. In general, releases occur because of tank or line failures, improper filling, improper tank installation or poor maintenance.

Because the tanks are located within a residential setting, remediation efforts may often be difficult and cumbersome. In many cases, the petroleum migrates to hard to reach locations, such as beneath foundations, within drainage systems, underneath living quarters or around expensive structures such as pools. The use of excavating

methods is often impossible or highly disruptive to the household. In addition, the installation of pump-and-treat systems, to remove the petroleum and the impacted ground water, may not be physically possible or not a cost effective remedial alternative.

The introduction of ORCs into the subsurface is a cost effective and relatively non-intrusive method of remediating difficult residential petroleum releases. The ORC is injected into the subsurface in a slurry through borings. The borings may be completed by hand or with a small drilling rig, such as a direct-push Geoprobe rig. The ORC slurry is then injected with a high-pressure pump or pressure grouter. In addition, ORC may be obtained in a sock form which is hung within monitoring wells, if wells happen to be present at the site.

REGULATORY CRITERIA

The state of New Jersey is heavily dependent on ground water as a source of potable water. Many communities outside of the metroplitan areas of Newark, Paterson, Camden or Trenton do not have municipal water systems. Many municipal water systems rely on ground water for at least a portion of their supply. Private residences outside of these areas normally rely on individual potable wells for their water needs. In these same areas, private residences commonly use underground or aboveground tanks for the storage of petroleum products. Releases of petroleum from residential tanks may cause severe ground-water contamination sufficiently serious to render the wells unfit for use as a water supply. Accordingly, the New Jersey Department of Environmental Protection (NJDEP) oversees all residential cleanups to insure that ground-water supplies in these areas remain fit for consumption.

In 1994, the State of New Jersey passed regulatory criteria for contaminants in soil and ground water. Three types of cleanup standards were provided for soil: (1) a Residential Direct-Contact Soil Cleanup Criterion; (2) a Non-Residential Direct-Contact Soil Cleanup Criterion, and (3) an Impact to Ground Water Soil Cleanup Criterion. The direct-contact criteria apply to surficial soils, while the impact to ground water criteria applies to soils at deeper depths. On residential cases, the impact to ground water criteria are normally applied and they are generally the most stringent. A responsible party may petition the NJDEP for a less stringent cleanup standard. In these cases, an alternative criterion is used and a deed restriction may be placed on the property. Table 1 presents the impact to ground water soil cleanup criteria for selected petroleum compounds.

TABLE 1. Impact to Ground Water Soil Cleanup Criteria for Selected Petroleum Compounds

Compound	Criterion (mg/kg)	Compound	Criterion (mg/kg)
Benzene	1	Total Xylenes	10
Toluene	500	Total Organics	10,000
Ethyl benzene	100	Total Volatile Organics	1,000

In new Jersey, soil samples to be collected in response to a release of no. 2

heating oil must be analyzed for total petroleum hydrocarbons (TPHCs). If the TPHC concentration exceeds 1,000 milligrams per kilogram (mg/kg), 25% of the samples must also be analyzed for volatile organic compounds (VOCs). The results are then compared to the criteria for the individual VOCs. If the TPHC concentration exceeds 10,000 mg/kg, additional analyses are not required because the criterion for total organic contaminants has been exceeded.

In 1994, the state of New Jersey also passed ground-water quality standards. The state was essentially divided into three classes: Class I, the Pine Barren where no degradation of the ground water is allowed; Class II, the majority of the state where the promulgated ground-water quality criteria are in effect, and Class III, heavily industrialized areas or portions of the state where low-permeability formations are present, where degradation of ground-water quality may be allowed with restrictions. Table 2 presents the ground-water quality criteria for the most common petroleum compounds.

TABLE 2. Ground-Water Quality Criertia for Selected Petroleum Compounds

Compound	Criterion
Benzene	1 microgram per liter (µg/l)
Ethylbenzene	700
Toluene	1,000
Total xylenes	1,000

In Class II areas, which encompasses the majority of the state, responsible parties may petition the NJDEP for a less stringent ground-water quality criterion. In these cases, a Classification Exception Area (CEA) may be delineated. The installation of wells would be restricted within the CEA and its extent would be attached to the deed for the property.

CASE HISTORY NO. 1

In 1997, a 280-gallon underground storage tank (UST), previously containing leaded gasoline, was excavated and removed from an abandoned farm in Burlington County, New Jersey. The UST has been out of service since the mid-1950s and was found during an inspection of the property prior to its sale. Because corrosion holes were found in the base of the UST, a ground-water sample was also collected from the on-site potable well for laboratory analysis of volatile organic compounds (VOCs). The potable well was hand dug and is located within the basement of the farmhouse. The sample exhibited a slight odor of gasoline and it was subsequently submitted to a laboratory for analysis of VOCs. The laboratory analytical results revealed that targeted VOCs detected in the sample included chloroform, benzene, toluene and *o,m,p*-xylenes at concentrations of 2.5 micrograms per liter (µg/l), 1.5 µg/l, 3.1 µg/l and 3.3 µg/l, respectively. Non-targeted VOCs were detected at a total concentration of 376 µg/l.

In December 1997, five monitoring wells were installed at the farm. Gasoline

odors were detected in two of the boreholes: MW-3 and MW-4. Evidence of petroleum contamination was not present in the remaining boreholes and a product layer was not present in any of the wells. Subsequent sampling of the wells confirmed a small plume originating from the former UST location and extending to the farmhouse potable well (Table 3).

TABLE 3. Concentrations of BTEX in ground-water samples, Burlington County site

Well	Pre-ORC (7/97)	Post-ORC (7/98)
MW-1	ND	ND
MW-2	7	ND
MW-3	164	ND
MW-4	1.6	ND
MW-5	ND	ND
Potable Well	386	0.79

Remedial activities were conducted at the farm in January 1998 to insure that the shallow aquifer remains potable. A series of thirteen borings were completed with a Geoprobe rig. An ORC slurry containing 10 pounds of ORC and 3.5 gallons of water was injected into each boring at a depth interval of 10 to 20 feet bgs. A carbon treatment unit was then installed onto the existing potable well and the treated effluent from the carbon units was discharged into a wooded area behind the farmhouse. A replacement potable well was also installed at a location east of the farmhouse and within an area known to be free of gasoline contamination.

In July 1998, ground-water samples were collected from the potable well and the monitoring wells. The data reveal that a significant reduction in the concentrations of gasoline constituents in the ground water had occurred after the introduction of ORC. Accordingly, since the installation of the carbon treatment unit and the treatment of the ground water with ORC, VOC concentrations detected in all the wells have decreased to concentrations well below NJDEP criteria. The ground-water sampling data were subsequently submitted to the NJDEP with a request for case closure. The NJDEP is presently reviewing the data and case closure is expected shortly.

CASE HISTORY NO. 2

In 1996, a 550-gallon UST was excavated and removed from a residential site in Middlesex County, New Jersey. The UST was located immediately adjacent to the foundation of the residence and additional excavating beyond the removal of the UST could not be performed. The excavation was subsequently backfilled to prevent undermining of the residence's foundation. Because the water table was within 4 feet of the ground surface, impacted soil was not of concern. However, petroleum concentrations in excess of 6,000 µg/l were detected in the ground water. Hand auger borings were completed at locations surrounding the residence and it was determined that the plume was localized

to the vicinity of the former UST excavation.

In late February 1997, three hand auger borings were completed at locations surrounding the excavation and adjacent to the foundation. A two-inch diameter PVC screen with a well point was manually driven into each borehole to a depth of approximately 8 feet. A slurry of ORC was then injected into each well with a pressure grouter. The slurry for each well contained 20 pounds of ORC with 10 gallons of water. After the injection of the ORC, each PVC screen was removed.

In July 1997, a temporary monitoring well was installed and a ground-water samples collected for analysis of VOCs and B/Ns. The sample analytical results revealed that neither targeted nor non-targeted VOCs and B/Ns were present in the sample. A second confirmation sample was collected with the same results. The ground-water sampling data were subsequently forwarded to the NJDEP and the case was closed.

TABLE 4. Concentrations of VOCs and B/Ns in ground-water samples, Middlesex County site

Well	Pre-ORC VOCs (2/97)	Pre-ORC B/Ns (2/97)	Post-ORC VOCs (7/97)	Post-ORC B/Ns (7/97)
TW-1	191	6,605	ND	ND

CASE HISTORY NO. 3

In January 1997, a 275-gallon UST was abandoned in place within a condominium complex in Monmouth County, New Jersey. The UST was abandoned and not removed because it was located between a foundation and a retaining wall. Its removal would have undermined both structures and would have prevented entrance through the only door to the condominium for an extended period of time. The UST was taken out of service because petroleum product was found to be seeping into the basement of the condominium.

During the abandonment process, numerous holes were detected in the base of the UST and it was apparent that a significant discharge of petroleum had occurred. Three borings were completed through the base of the UST and an ORC slurry was injected into the underlying soils. In addition, ORC injections were conducted at 7 additional locations surrounding the abandoned UST.

In February 1997, six monitoring wells were installed at locations surrounding the abandoned UST. Two wells were installed with a Geoprobe rig within the garage, while two additional wells were placed within the driveway. A fifth well was installed immediately adjacent to the abandoned UST, while the sixth well is hydraulically downgradient of the site. Since 1997, ORC socks have been placed in the wells to enhance the removal of dissolved petroleum.

Since February 1997, ground-water samples have been collected from the six monitoring wells on four occasions and analyzed for TPHCs (Table 5). In general, TPHC concentrations have decreased significantly. However, beads of petroleum

product continue to recharge wells MW-3 and MW-4 and it is apparent that soils underlying the abandoned UST have not been adequately remediated. It is likely that a residual saturation of petroleum is present in the soil beneath the abandoned UST. Additional injections of ORC are proposed for this location and additional monitoring will be conducted.

TABLE 5. Concentrations of Total Petroleum Hydrocarbons (mg/l) in Ground-Water Samples, Monmouth County site

Well	2/2/97	8/15/97	11/20/97	6/16/98
MP-1	106	5	12	1.93
MP-2	122	3	3	7.79
MP-3	442	915	170	5.87*
MP-4	304	2	41	4.09*
MP-5	NA	NA	NA	1.18
MP-6	NA	5	ND	1.82

CONCLUSIONS

The injection of ORC into the subsurface is a cost effective and relatively non-intrusive method of reducing residual petroleum concentrations in ground water. It is often a preferred remedial alternative for residential cases because it alleviates the need for excavating or the use of expensive pump-and-treat systems. However, it should be noted that the use of ORC may have little or no effect when large quantities of petroleum product are present. Therefore, for the optimum use of this technology, the source of the contamination must be removed. After the source has been removed, ORC may be applied to the ground water through injections or as socks in monitoring wells.