

Enhanced Aerobic Bioremediation
Case Study using IXPER® 70C
Calcium Peroxide

IXPER® 70C Calcium Peroxide

CASE STUDY

INTRODUCTION TO ENHANCED AEROBIC BIOREMEDIATION

Enhanced aerobic bioremediation is a well-established and viable remediation technology for *in situ* degradation of a variety of petroleum hydrocarbon contaminants. One of the major obstacles to the success of this remedial approach is the lack of sufficient oxygen to promote biodegradation. Three oxygen releasing compounds that have been considered for *in situ* aerobic bioremediation applications are calcium peroxide (CaO_2), magnesium peroxide (MgO_2), and sodium percarbonate ($2Na_2CO_3 \cdot 3H_2O_2$). Calcium peroxide and magnesium peroxide are orders of magnitude less water soluble than sodium percarbonate which allows these compounds to serve as sustained sources of oxygen over prolonged periods of time. Oxygen that is released from solid peroxide products, such as calcium peroxide, will support soil and groundwater assisted natural attenuation of contaminants by maintaining aerobic conditions necessary to enhance biological activity. In the presence of water, calcium peroxide produces oxygen through the following reaction:

$$CaO_2 + 2H_2O \rightarrow Ca(OH)_2 + 2O_2 + H_2O$$

IXPER® Calcium Peroxide products provide an effective source of oxygen to promote enhanced aerobic bioremediation of petroleum hydrocarbons and are available in two particle sizes: 1) IXPER® 70C Calcium Peroxide and 2) IXPER® 75C Calcium Peroxide. IXPER 70C is a solid granulated calcium peroxide product that is used to accelerate the natural attenuation of contaminated soils in a cost-effective manner and specifically formulated to avoid dust generation during application. IXPER 75C is a high quality calcium peroxide powder that can be injected as a slurry into a contaminated aquifer to support enhanced aerobic microbial activity.

The ability of aerobic microbes to biologically degrade contaminants such as petroleum hydrocarbons can be limited by inadequate levels of oxygen. IXPER 70C ensures that adequate oxygen is present over an extended period of time for enhanced aerobic bioremediation of a wide variety of contaminants. The compounds that can be aerobically degraded include: benzene, toluene, ethylbenzene, and xylene (BTEX), methyl tertiary butyl ether (MTBE), total petroleum hydrocarbons (TPH) from light and heavy fuel oils, non-halogenated volatile solvents such as methylethylketone, methanol, ethanol, acetone, ethyl acetate, acetonitrile, tert-butyl alcohol, phenols, polycyclic aromatic hydrocarbons (PAHs), some halogenated compounds such as vinyl chloride, chlorobenzenes, and high explosives.

IXPER 70C can be applied as a reactive liner for an excavation pit prior to the deposition of clean fill soil, as an enhanced aerobic bioremediation amendment in *ex situ* soil blending applications, injected into an aquifer for *in situ* treatment of contaminated soil and groundwater, and as a reactive enhanced aerobic bioremediation barrier.

ENHANCED AEROBIC BIOREMEDIATION CASE STUDY USING IXPER® 70C CALCIUM PEROXIDE

Environmental investigations were conducted by GSI Water Solutions, Inc. at a former truck shop in central Oregon to characterize contaminated soil and groundwater. Findings from the investigations indicate that elevated concentrations of petroleum-contaminated soil were located beneath the former shop area (shop area). A work plan for site work at the former truck shop was submitted and approved by the Oregon Department of Environmental Quality (DEQ) in August 2011 summarizing the site conditions and site conceptual model as well as the cleanup goals. The proposed remediation work included, excavating fuel impacted soils, and constructing a soil treatment pile (STP). The location of the impacted area at the truck shop site is shown in Figure 1.

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Figure 1. Remediation areas: former truck shop site, Central Oregon

FORMER TRUCK SHOP SITE CONDITIONS AND CONCEPTUAL MODEL

Soil

Numerous subsurface soil borings were obtained during several site characterization investigations between 2002 and 2005. Concentrations of the following compounds were found on-site in the fueling and shop areas that exceeded Oregon DEQ risk-based concentrations (RBCs): gasoline-range total petroleum hydrocarbons (TPH-G), benzene, and ethylbenzene (Figure 2).

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Figure 2. Soil boring locations of compounds found in exceedance of Oregon DEQ cleanup criteria

Groundwater

Water level monitoring in November 2010 indicated a northwestern groundwater flow with measured groundwater levels ranging from 8 to 10 feet below the ground surface in wells near the two source areas. Groundwater sampling in November 2010 indicated that groundwater in the vicinity of the shop area continued to be impacted by contaminated soil in the source areas.

Remedial action objectives (RAOs) are general goals for protecting human health and the environment. The RAOs for the former truck shop site are:

- Remedial actions must reduce concentrations of petroleum-derived constituents in soils to below RBCs to protect human health in an industrial work setting.
- Remedial actions must reduce concentrations of petroleum-derived constituents and chlorinated volatile organic compounds (VOCs) in soils to below RBCs to be protective of groundwater.

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A summary of the key elements of the former truck shop conceptual site model follows:

- The remedial investigation (RI) found the shop area to be a likely source area at the site based on the elevated petroleum-contaminated soil in these areas and reported spills.
- The contaminants of interest were found to be petroleum-derived VOCs which were above RBCs.
- The source area soils in the shop area were found to have impacted groundwater near the source areas.
- The shallow groundwater at the site within the Locality of the Facility (LOF) was found to have no beneficial use.
- The area of impacted shallow groundwater is slowly decreasing over time.
- Modeling results indicated that migration of petroleum constituents from the shallow groundwater to the deep basalt aquifer is unlikely to occur.
- Table 1 provides a summary of the cleanup goals for the soil compounds that exceeded RBCs.

Table 1. Summary of cleanup goals for detected compounds exceeding RBCs

Oregon DEQ Risk-Based Concentrations for Soil(1)		
Exposure Pathway ==========>		**Leaching to Groundwater**
Receptor Scenario ==========>		**Occupational**
Parameter	Units	
Total Petroleum Hydrocarbons		
TPH (as gasoline)	mg/Kg	110
Volatile Organic Compounds		
Benzene	ug/Kg	53
Ethylbenzene	ug/Kg	900
Tetrachloroethene	ug/Kg	37
Semi-volatile Organic Compounds		
Naphthalene	ug/Kg	440

(1) Department of Environmental Quality (DEQ) risk-based concentrations can be found at http://www.deq.state.or.us/lq/rbdm.htm, accessed June 12, 2011.

IXPER® 70C CALCIUM PEROXIDE ENHANCED AEROBIC BIOREMEDIATION REMEDIAL ACTION PLAN

A number of remedial technologies were evaluated based on expected performance, ease of application, and cost with the overarching goal of reaching the RAOs. The general remedial approach called for reducing contaminant concentrations in the source area soils and thereby reducing the contaminant concentrations in the groundwater over time. The selected remedy at the former truck shop site called for excavation of the soils in the shop area followed by enhanced biological treatment of the soils using IXPER® 70C Calcium Peroxide until concentrations below RBCs were reached. Excavation in the shop area extended to the water table and the lateral extent of the excavations were based on field screening to confirm that the majority of the soils excavated were above RBCs. Remedial work was completed the week of July 16, 2012 under the direction of GSI Water Solutions, Inc. Each of the elements of the remedial action plan is discussed below.

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REMEDIAL ACTION

Removal of the concrete slab was completed prior to excavation of the shop area soils. The excavated soils were mixed with IXPER® 70C Calcium Peroxide then placed in the treatment pile.

- Concrete Slab. The concrete slab in the shop area was removed and stockpiled onsite before beginning the excavation.

Figure 3. Breaking up concrete floor slab in former shop area to prepare for soil excavation (June 2012)

- Treatment Pile. IXPER 70C and water were mixed with the soil as the treatment pile was being constructed. The water was added to the soil as needed so that it had adequate moisture for biological growth. The treatment pile was constructed adjacent to the shop area on an impervious liner over an area about 60 feet by 100 feet with slopes no greater than 2.5 to 1. After the treatment pile was constructed, the pile was covered with an impervious cover and anchored to prevent dislodging in the event of high winds.
- Backfilling. Samples were collected from the treatment pile every few months to monitor the progress of the biological degradation of the contaminants. After the concentrations of the contaminants were below the RBCs, the treatment pile soils were placed back into the excavation in the fueling area. Stockpiled clean overburden gravel was placed over the filled excavation to provide a clean cap over the treated soils. The excavation area was graded to drain.

To accelerate aerobic biodegradation, 3,300 pounds of IXPER 70C was mixed to a depth of 6-inches with soils in the floor of the excavation. The soil treatment pile (STP) was constructed in a single cell with a height of about 5 feet. The STP was located to the east of the former shop area and placed on a reinforced polyethylene liner to provide a relatively impervious bottom. The excavated soil was first placed on a concrete pad immediately east of the excavation area. IXPER 70C and a small amount of water was mixed with the soil and then placed in the STP. A total of 8,700 pounds of IXPER 70C was added to the STP resulting in an estimated 0.5 percent concentration by weight and applied at a rate of 1 pound per 5,000 pounds of soil. After completion of the STP, the area was lightly sprayed with water to provide moisture and covered with polyethylene sheeting. The cover was then anchored with clean soil. Figures 4 through 8 illustrate the process of excavation and treatment pile construction as well as IXPER 70C emplacement and the well-blended IXPER-amended soil in the STP.

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Figure 4. Completed excavation in former shop area (July 2012)

Figure 5. IXPER® 70C Calcium Peroxide placed in the bottom of the completed former shop area excavation (July 2012)

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Figure 6. IXPER® 70C Calcium Peroxide being added to the soil treatment pile (July 2012)

Figure 7. Construction of IXPER 70C enhanced aerobic bioremediation soil treatment pile on liner (July 2012)

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Figure 8. IXPER® 70C Calcium Peroxide blended into treatment pile soil

EXCAVATION SAMPLING RESULTS

To track treatment progress of the soil treatment piles using IXPER® 70C Calcium Peroxide, soil samples were obtained along the perimeter of the soil treatment pile and analyzed for remaining contamination. The results of these soil samples demonstrated that remediation using IXPER 70C was successful and that all contaminants dropped below regulated cleanup goals following the 8-month treatment period. A selection of these results can be seen in Figure 9.

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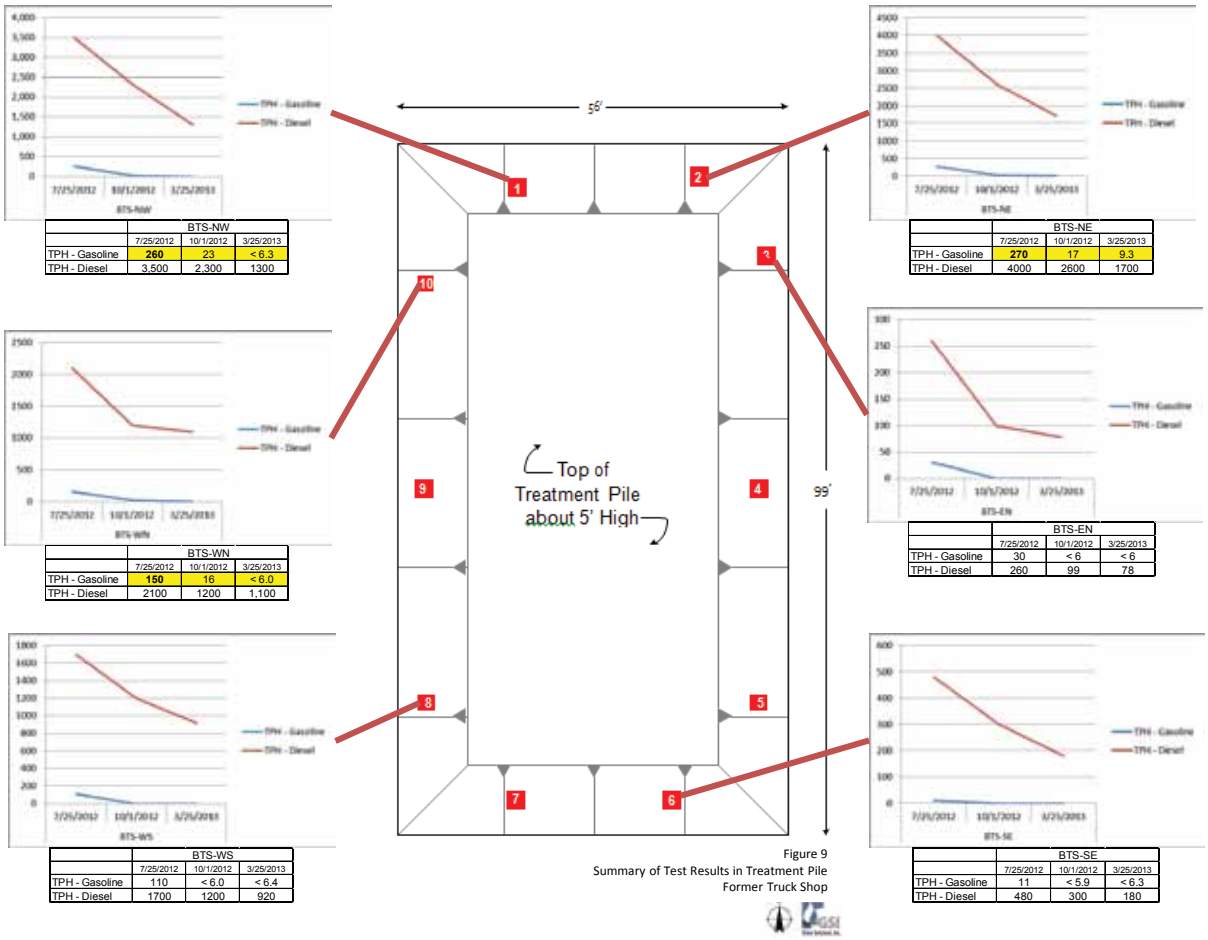

BTS-NW	7/25/2012	10/1/2012	3/25/2013
TPH - Gasoline	260	23	< 6.3
TPH - Diesel	3,500	2,300	1300

BTS-NE	7/25/2012	10/1/2012	3/25/2013
TPH - Gasoline	270	17	9.3
TPH - Diesel	4000	2600	1700

BTS-WN	7/25/2012	10/1/2012	3/25/2013
TPH - Gasoline	150	16	< 6.0
TPH - Diesel	2100	1200	1,100

BTS-EN	7/25/2012	10/1/2012	3/25/2013
TPH - Gasoline	30	< 6	< 6
TPH - Diesel	260	99	78

BTS-WS	7/25/2012	10/1/2012	3/25/2013
TPH - Gasoline	110	< 6.0	< 6.4
TPH - Diesel	1700	1200	920

BTS-SE	7/25/2012	10/1/2012	3/25/2013
TPH - Gasoline	11	< 5.9	< 6.3
TPH - Diesel	480	300	180

Figure 9
Summary of Test Results in Treatment Pile
Former Truck Shop

Figure 9. Summary of test results in the soil treatment pile (July 2012 through March 2013, 8 months post treatment). Data highlighted in yellow represents concentrations that exceed the cleanup goal during the 07/25/12 sampling event.

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At each sampling location, the concentration of gas-range TPH quickly drops from an average of 108 mg/kg to below the detection limit of approximately 6 mg/kg. This represents an average of 94% reduction in gas-range TPH over the 8-month treatment period. Concurrently, the concentration of diesel-range TPH drops considerably from an average of 1,471 mg/kg to an average of 718 mg/kg. This represents an average of 51% reduction in diesel-range TPC over the 8-month treatment period. All sample locations were below the required DEQ Risk Based Concentration requirements, so the next steps of the remedial plan was initiated.

2013 ACTIVITIES

The selected remedy of utilizing IXPER® 70C Calcium Peroxide for enhanced bioremediation of soil treatment piles at the former shop area has been successful. The final remaining task, to backfill the treated soil pile into the excavated area and cover with fresh soil and vegetation, was completed in August 2013. An additional 1,000 pounds of IXPER 70C was added to the bottom of the excavation prior to backfilling to ensure continued treatment of these areas following backfill operations. Stockpiled clean overburden gravel was placed over the filled excavation to provide a clean cap over the treated soils. The excavation area was graded to drain (Figure 10).

Figure 10. Backfilling nearly completed in the excavation area (August 2013)

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