ORC-Advanced® for Aerobic Bioremediation:

1. Daniel Nunez, Regenesis
2. A mixture of calcium Oxy-hydroxide and calcium hydroxide (Advanced Formula Oxygen Release Compound - ORC-Advanced®):
3. MSDS & Technical Data Sheet - Attached
4. Number of Field-scale Applications to Date: >1,000 sites
5. Case Studies – Attached
6. ORC Advanced® is a food-grade formulation of calcium oxyHydroxide which, upon hydration, releases oxygen and forms simple calcium hydroxide and water for a period of up to 12 months. This provides treatment of low level petroleum hydrocarbons via enhanced aerobic bioremediation process in saturated soils and groundwater. The available oxygen is 17% by weight and is released within 12 months. The uses of this product can be applied via direct push, at bottom of excavations, trenches and barriers in the source and down gradient plumes. This product has been on the market for over seven years.

Oxygen Release Compound – Advanced (ORC *Advanced*™)
MATERIAL SAFETY DATA SHEET (MSDS)

Last Revised: October 30, 2013

Section 1 - Material Identification

Supplier:

REGENESIS
1011 Calle Sombra
San Clemente, CA 92673

Phone:	**949.366.8000**
Fax:	**949.366.8090**
E-mail:	**info@regenesis.com**

Chemical Description:	A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
Chemical Family:	Inorganic Chemical
Trade Name:	Advanced Formula Oxygen Release Compound (ORC *Advanced*™)
Chemical Synonyms	Calcium Hydroxide Oxide; Calcium Oxide Peroxide; Calcium Oxy-Hydroxide; Calcium Oxyhydroxide
Product Use:	Used to remediate contaminated soil and groundwater (environmental applications)

Section 2 – Composition

CAS No.	**Chemical**
682334-66-3	**Calcium Hydroxide Oxide [$CaO(OH)_2$]**
1305-62-0	**Calcium Hydroxide [$Ca(OH)_2$]**
7758-11-4	**Dipotassium Phosphate (HK_2O_4P)**
7778-77-0	**Monopotassium Phosphate (H_2KO_4P)**

Section 3 – Physical Data

Form:	Powder
Color:	White to Pale Yellow
Odor:	Odorless
Melting Point:	527 °F (275 °C) – Decomposes
Boiling Point:	Not Applicable (NA)
Flammability/Flash Point:	NA
Auto- Flammability:	NA
Vapor Pressure:	NA
Self-Ignition Temperature:	NA
Thermal Decomposition:	527 °F (275 °C) – Decomposes
Bulk Density:	0.5 – 0.65 g/ml (Loose Method)
Solubility:	1.65 g/L @ 68° F (20° C) for calcium hydroxide.
Viscosity:	NA
pH:	11-13 (saturated solution)
Explosion Limits % by Volume:	Non-explosive
Hazardous Decomposition Products:	Oxygen, Hydrogen Peroxide, Steam, and Heat
Hazardous Reactions:	None

Section 4 – Reactivity Data

Stability:	Stable under certain conditions (see below).
Conditions to Avoid:	Heat and moisture.
Incompatibility:	Acids, bases, salts of heavy metals, reducing agents, and flammable substances.
Hazardous Polymerization:	Does not occur.

Section 5 – Regulations

TSCA Inventory List:	Listed

CERCLA Hazardous Substance (40 CFR Part 302)

Listed Substance:	No
Unlisted Substance:	Yes
Reportable Quantity (RQ):	100 pounds
Characteristic(s):	Ignitibility
RCRA Waste Number:	D001

SARA, Title III, Sections 302/303 (40 CFR Part 355 – Emergency Planning and Notification)

Extremely Hazardous Substance:	No

SARA, Title III, Sections 311/312 (40 CFR Part 370 – Hazardous Chemical Reporting: Community Right-To-Know

Hazard Category:	Immediate Health Hazard Fire Hazard
Threshold Planning Quantity:	10,000 pounds

Section 5 – Regulations (cont)

SARA, Title III, Section 313 (40 CFR Part 372 – Toxic Chemical Release Reporting: Community Right-To-Know

Extremely Hazardous Substance:	No	
WHMIS Classification:	C	Oxidizing Material Poisonous and Infectious Material
	D	Material Causing Other Toxic Effects – Eye and Skin Irritant
Canadian Domestic Substance List:	Not Listed	

Section 6 – Protective Measures, Storage and Handling

Technical Protective Measures

Storage:	Keep in tightly closed container. Store in dry area, protected from heat sources and direct sunlight.
Handling:	Clean and dry processing pipes and equipment before operation. Never return unused product to the storage container. Keep away from incompatible products. Containers and equipment used to handle this product should be used exclusively for this material. Avoid contact with water or humidity.

Section 6 – Protective Measures, Storage and Handling (cont)

Personal Protective Equipment (PPE)

Engineering Controls:	Calcium Hydroxide ACGIH® TLV® (2000) 5 mg/m^3 TWA OSHA PEL Total dust–15 mg/m^3 TWA Respirable fraction– 5 mg/m^3 TWA NIOSH REL (1994) 5 mg/m^3
Respiratory Protection:	For many conditions, no respiratory protection may be needed; however, in dusty or unknown atmospheres use a NIOSH approved dust respirator.
Hand Protection:	Impervious protective gloves made of nitrile, natural rubbber or neoprene.
Eye Protection:	Use chemical safety goggles (dust proof).
Skin Protection:	For brief contact, few precautions other than clean clothing are needed. Full body clothing impervious to this material should be used during prolonged exposure.
Other:	Safety shower and eyewash stations should be present. Consultation with an industrial hygienist or safety manager for the selection of PPE suitable for working conditions is suggested.
Industrial Hygiene:	Avoid contact with skin and eyes.
Protection Against Fire & Explosion:	NA

Section 7 – Hazards Identification

Emergency Overview:	Oxidizer – Contact with combustibles may cause a fire. This material decomposes and releases oxygen in a fire. The additional oxygen may intensify the fire.
Potential Health Effects:	Irritating to the mucous membrane and eyes. If the product splashes in ones face and eyes, treat the eyes first. Do not dry soiled clothing close to an open flame or heat source. Any

	clothing that has been contaminated with this product should be submerged in water prior to drying.
Inhalation:	High concentrations may cause slight nose and throat irritation with a cough. There is risk of sore throat and nose bleeds if one is exposed to this material for an extended period of time.
Eye Contact:	Severe eye irritation with watering and redness. There is also the risk of serious and/or permanent eye lesions.
Skin Contact:	Irritation may occur if one is exposed to this material for extended periods.
Ingestion:	Irritation of the mouth and throat with nausea and vomiting.

Section 8 – Measures in Case of Accidents and Fire

After Spillage/Leakage/Gas Leakage:	Collect in suitable containers. Wash remainder with copious quantities of water.
Extinguishing Media:	See next.
Suitable:	Large quantities of water or water spray. In case of fire in close proximity, all means of extinguishing are acceptable.
Further Information:	Self contained breathing apparatus or approved gas mask should be worn due to small particle size. Use extinguishing media appropriate for surrounding fire. Apply cooling water to sides of transport or storage vessels that are exposed to flames until the fire is extinguished. Do not approach hot vessels that contain this product.
First Aid:	After contact with skin, wash immediately with plenty of water and soap. In case of contact with eyes, rinse immediately with plenty of water and seek medical attention. Consult an opthalmologist in all cases.

Section 8 – Measures in Case of Accidents and Fire

Eye Contact:	Flush eyes with running water for 15 minutes, while keeping the eyelids wide open. Consult with an ophthalmologist in all cases.
Inhalation:	Remove subject from dusty environment. Consult with a physician in case of respiratory symptoms.

Ingestion:	If the victim is conscious, rinse mouth and admnister fresh water. DO NOT induce vomiting. Consult a physician in all cases.
Skin Contact:	Wash affected skin with running water. Remove and clean clothing. Consult with a physician in case of persistent pain or redness.
Special Precautions:	Evacuate all non-essential personnel. Intervention should only be done by capable personnel that are trained and aware of the hazards associated with this product. When it is safe, unaffected product should be moved to safe area.
Specific Hazards:	Oxidizing substance. Oxygen released on exothermic decomposition may support combustion. Confined spaces and/or containers may be subject to increased pressure. If product comes into contact with flammables, fire or explosion may occur.

Section 9 – Accidental Release Measures

Precautions:	Observe the protection methods cited in Section 3. Avoid materials and products that are incompatible with product. Immediately notify the appropriate authorities in case of reportable discharge (> 100 lbs).
Cleanup Methods:	Collect the product with a suitable means of avoiding dust formation. All receiving equipment should be clean, vented, dry, labeled and made of material that this product is compatible with. Because of the contamination risk, the collected material should be kept in a safe isolated place. Use large quantities of water to clean the impacted area. See Section 12 for disposal methods.

Section 10 – Information on Toxicology

Toxicity Data

Acute Toxicity:	Oral Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%) Dermal Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%) Inhalation, LD_{50}, rat, > 5,000 mg/m^3 (powder 35%)
Irritation:	Rabbit (eyes), severe irritant

Sensitization:	No data
Chronic Toxicity:	In vitro, no mutagenic effect (Powder 50%)
Target Organ Effects:	Eyes and respiratory passages.

Section 11 – Information on Ecology

Ecology Data

Acute Exotoxicity:	10 mg $Ca(OH)_2$/L: pH = 9.0 100 mg $Ca(OH)_2$/L: pH = 10.6 Fishes, Cyprinus carpio, LC_{50}, 48 hrs, 160 mg/L Crustaceans, Daphnia sp., EC_{50}, 24 hours, 25.6 mg/L (Powder 16%)
Mobility:	Low Solubility and Mobility
Abiotic Degradation:	Water – Slow Hydrolysis. Degradation Products: Calcium Hydroxide Water/soil – complexation/precipitation. Carbonates/sulfates present at environmental concentrations. Degradation products: carbonates/sulfates sparingly soluble
Biotic Degradation:	NA (inorganic compound)
Potential for Bioaccumulation:	NA (ionizable inorganic compound)

Section 11 – Information on Ecology (cont)

Comments:	Observed effects are related to alkaline properties of the product. Hazard for the environment is limited due to the product properties of: • No bioaccumulation • Weak solubility and precipitation as carbonate or sulfate in an aquatic environment. Diluted product is rapidly neutralized at environmental pH.
Further Information:	NA

Section 12 – Disposal Considerations

Waste Disposal Method:	Consult current federal, state and local regulations regarding the proper disposal of this material and its emptied containers.

Section 13 – Shipping/Transport Information

D.O.T Shipping Name:	Oxidizing Solid, N.O.S [A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
UN Number:	1479
Hazard Class:	5.1
Label(s):	5.1 (Oxidizer)
Packaging Group:	II
STCC Number:	4918717

Section 14 – Other Information

HMIS® Rating	Health – 2 Flammability – 0	Reactivity – 1 PPE - Required

HMIS® is a registered trademark of the National Painting and Coating Association.

NFPA® Rating	Health – 2 Flammability – 0	Reactivity – 1 OX

NFPA® is a registered trademark of the National Fire Protection Association.

Reason for Issue: Update toxicological and ecological data

Section 15 – Further Information

The information contained in this document is the best available to the supplier at the time of writing, but is provided without warranty of any kind. Some possible hazards have been determined by analogy to similar classes of material. The items in this document are subject to change and clarification as more information become available.

ORC ADVANCED® OXYGEN RELEASE COMPOUND

Highest amount of active oxygen in a controlled-release, oxygen producing compound

PRODUCT OVERVIEW

ORC Advanced® is the state-of-the-art technology for stimulating aerobic bioremediation. It offers unparalleled, maximum oxygen release for periods up to 12 months on a single injection and is specifically designed to minimize oxygen waste while maximizing contaminated site remediation.

ORC Advanced is a formulation of calcium oxyhydroxide which, upon hydration, releases oxygen and forms simple calcium hydroxide and water.

$$CaO(OH)_2 + H_2O \longrightarrow \tfrac{1}{2}O_2 + Ca(OH)_2 + H_2O$$

PRODUCT BENEFITS

HIGHEST AVAILABLE OXYGEN CONTENT

More active oxygen (17%) plus Regenesis' patented Controlled Release Technology (CRT™) saves time and money by increasing degradation rates and improving remediation performance by providing more oxygen on a single injection. It is particularly effective at higher demand sites where oxygen may be limited and scavenged by competing carbon sources.

PATENTED CONTROLLED-RELEASE TECHNOLOGY (CRT™)

Based on the same proven technology employed in the industry standard Oxygen Release Compound (ORC®), CRT allows for an efficient, long-term release of oxygen providing the optimal conditions for sustained aerobic biodegradation. This can save time and money by reducing the potential need for multiple applications. Also, oxygen release "lock-up" is avoided – an unfortunate problem experienced with commodity chemicals.

IN-SITU APPLICATION

Remediation with ORC Advanced is typically more cost-effective than ex-situ treatments. With the use of ORC Advanced there is minimal site disturbance with no above-ground piping or mechanical equipment, no operations and maintenance costs and no hazardous materials handling or disposal.

PRODUCT BENEFITS

CRT

DEFINING THE SCIENCE BEHIND CONTROLLED-RELEASE TECHNOLOGY (CRT™)

Early on, Regenesis researchers noted that in order to optimally stimulate the natural attenuation of aerobically degradable contaminants, biologically usable oxygen was best supplied in low but constant concentrations. Big bursts of oxygen are wasteful and simply "bubble off", often generating undesirable foaming and producing unwanted preferential flow paths in the subsurface. Regenesis sought to solve this problem by controlling the rate of oxygen release from solid oxygen sources.

The answer was provided by the development of CRT. The CRT process involves intercalating (embedding) phosphates into the crystal structure of solid peroxygen molecules. This patented feature, now available in the ORC Advanced® formulation, slows the reaction that yields oxygen within the crystal, minimizing "bubble off" which can waste the majority of oxygen available in common solid peroxygen chemicals.

CRT provides "balance" – it slows down the rate of oxygen release while at the same time preventing "lock-up". Commodity solid peroxygen chemicals, when in contact with water, will produce an initial rapid and uncontrolled-release of oxygen. Then, as hydroxides form, a significant portion of the oxygen deeper in the crystal is made unavailable or becomes "locked-up." This undesirable effect is inefficient and costly. CRT prevents lock-up and controls the rate of oxygen release, representing the state-of-the-art technology in passive oxygen delivery.

FIGURE 1:
FILLING A PUMP WITH ORC ADVANCED SLURRY

REGENESIS / 1011 Calle Sombra / San Clemente / CA 92673-6244 / USA / T: 949.366.8000 / F: 949.366.8090 / www.regenesis.com

ORC TECHNICAL BULLETIN #2.3.5

Oxygen Release Compound, ORC®

Uses in Odor Control

ORC can be used to inhibit and neutralize odors associated with chemically reduced environments. For example, hydrogen sulfide (H_2S) is generated by microorganisms that thrive in anaerobic, reducing conditions. Other reduced forms of sulfur, such as mercaptan, as well as reduced forms of nitrogen are also sources of noxious odors.

The redox potential is a measure of the state of reduction of oxidation in the system; highly reduced environments as those described have a low redox potential. ***Incorporation of ORC into the impacted environment raises the redox potential to levels that are inhibitory to the organisms that generate the odorous compounds.*** Also, there is potential for the direct neutralization of hydrogen sulfide by a reaction with the ORC.

A study conducted IT Corporation, which was presented at the Annual Meeting of the American Chemical Society in 1992, showed that ORC could be used to reduce sulfide odors in large open lagoon areas in the San Francisco Bay region. In this study, the sulfide content was reduced from 7000 ppm to 1400 ppm with the use of an ORC suspension of only 1.4 g/L.

In another study by Schrader and Associates, sulfides were significantly reduced with the application of .4% wt./wt. to sewage treatment sludge, at the municipal facility in Mt. View, CA. ORC had an advantage over higher pH treatments, by limiting ammonia release and carbonate precipitation.

One possible application of Regenesis' ORC filter socks is in preventative maintenance for sewer lines. When hung in the line, the ORC filter socks can inhibit the corrosion in regions of the pipe which are exposed to acidic gases generated by sulfides.

Technical Bulletin Index||Regenesis Home Page

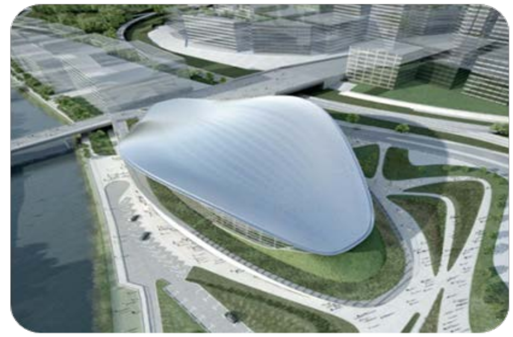
2012 Olympics

REGENESIS

1994 – 2012

18 Years of Excellence

18,000 Sites Worldwide



London Olympic Park Environmental Cleanup Uses Bioremediation Technology ORC Advanced® to Treat Hydrocarbons and Expedite Construction

The multi-billion dollar development of the 500 acre London 2012 Olympic Games Park has been one of the largest Brownfields regeneration projects in recent years. Located in Stratford in East London, the site was formerly an industrial estate with uses including: chemical, fertilizer, engineering works, landfills and depots leaving a legacy of soil and groundwater contamination.

The Olympic Delivery Authority (ODA) set strict deadlines for the Olympic facility construction projects. The development included the construction and refurbishment of 16 new major stadia and sports facilities. More specifically, the subsurface foundations for the London Aquatic Centre (LAC) were to be completed by the 27th July 2009 (exactly three years before the London 2012 Olympic Games Opening Ceremony).

The LAC site was contaminated with petroleum hydrocarbons from lubricating oil as a result of historic operations. The first stage of remediation began in November 2007 using dual-phase vacuum extraction (DPVE) to remove the LNAPL, however due to the strict ODA deadlines and integration with construction programmes (starting in April 2008) prolonged use of DPVE was not practical to remediate the dissolved phase hydrocarbon plume. An *in situ* solution became the only viable option.

In Situ Enhanced Bioremediation, a widely accepted and well understood natural biodegradation process was chosen to cleanup this portion of the site. This approach utilizes indigenous microbes to aerobically biodegrade petroleum hydrocarbons in-place. The actual process is facilitated using an injectable, Advanced Oxygen Release Compound (ORC Advanced®). Upon hydration and injection, this powder-like material accelerates aerobic bioremediation by releasing molecular dissolved oxygen for periods up to 12 months on a single application. Without this valuable oxygen supply, the required aerobic bioremediation processes either cease or proceed at very slow rates.

Continued on the Back

The London Aquatic Centre (LAC) Key Facts:

Designed by internationally acclaimed and Prizker Prize winning architect Zaha Hadid, the Concept of the LAC is inspired by the fluid geometry of water in motion, the undulating roof sweeps up from the ground as a wave.

The walls and floor are constructed from exposed precast concrete. The eye-catching roof has a steel outer roof and an aluminium ceiling built with over 30,000 sections of Red Lauro Timber.

The Centre Features two 50 metre (160 foot) pools and a 25 metre (82 foot) diving pool. The LAC houses a total Water Volume of 10 million litres (2.6 million gallons).

Venue Capacity: 17,500

Total Development Cost: £242 million (US $376 million)

The LAC will be a lasting Legacy of the 2012 Olympic Games adding to Great Britain's sporting heritage and inspiring athletes for years to come. It will replace the Crystal Palace National Sports Centre in South London as the city's leading facility for aquatic sports.

The patented Controlled-Release Technology (CRT™) in ORC Advanced allows for an efficient, long-term release of oxygen which provides optimal conditions for sustained aerobic biodegradation. CRT also saves time and money during implementation by eliminating the need for multiple oxygen release compound applications.

Additionally, ORC Advanced® was applied at the LAC site using direct-push injection. This application approach is highly efficient as it requires no permanent well installation, above-ground piping or mechanical equipment and after application, no operational costs or further site disturbance. Remedial objectives or the Olympic Games Aquatic Centre were satisfied and redevelopment of the site was unhindered by the ongoing *in situ* remedial work. More importantly, the construction-phase was completed according to the ODA set deadlines.

REGENESIS is proud to have supported environmental consultants, remediation contractors and regulators in successfully delivering the multi-billion dollar, award winning, remediation for The London 2012 Olympic Games

For Further Information Regarding this Project:

Gareth Leonard/ District Manager / UK & Scandinavia
+44 (0) 1833 630 411
gleonard@regenesis.com

Performance-Based Contract Remediation Team Utilizes Innovative Oxygen Release Technology to Achieve Rapid Closure of BTEX/MTBE Site

Andrews Air Force Base

Project Background

Figure 1. Air Force One

- **Andrews Air Force Base (AAFB) Description:**
  - 4,300 acre facility located 10 miles southeast of Washington, DC in Prince Georges County, Maryland
- **AAFB is part of the Air Force District of Washington**
  - Primary mission: Transport the President and other high-ranking personnel (home of Air Force One)
- **Subject Site Location**
  - Located in the northeast portion of the base at an active motor vehicle fueling facility
- **UST Removal: 1992 and 1993**
  - Five USTs removed – gasoline, heating oil, and used oil; a concrete anchor slab was left in place
  - Evidence of subsurface release observed (staining, free product, etc.)
  - Residual and free phase hydrocarbons present within tank excavation area
  - Dissolved-phase hydrocarbons documented migrating southwest of excavation

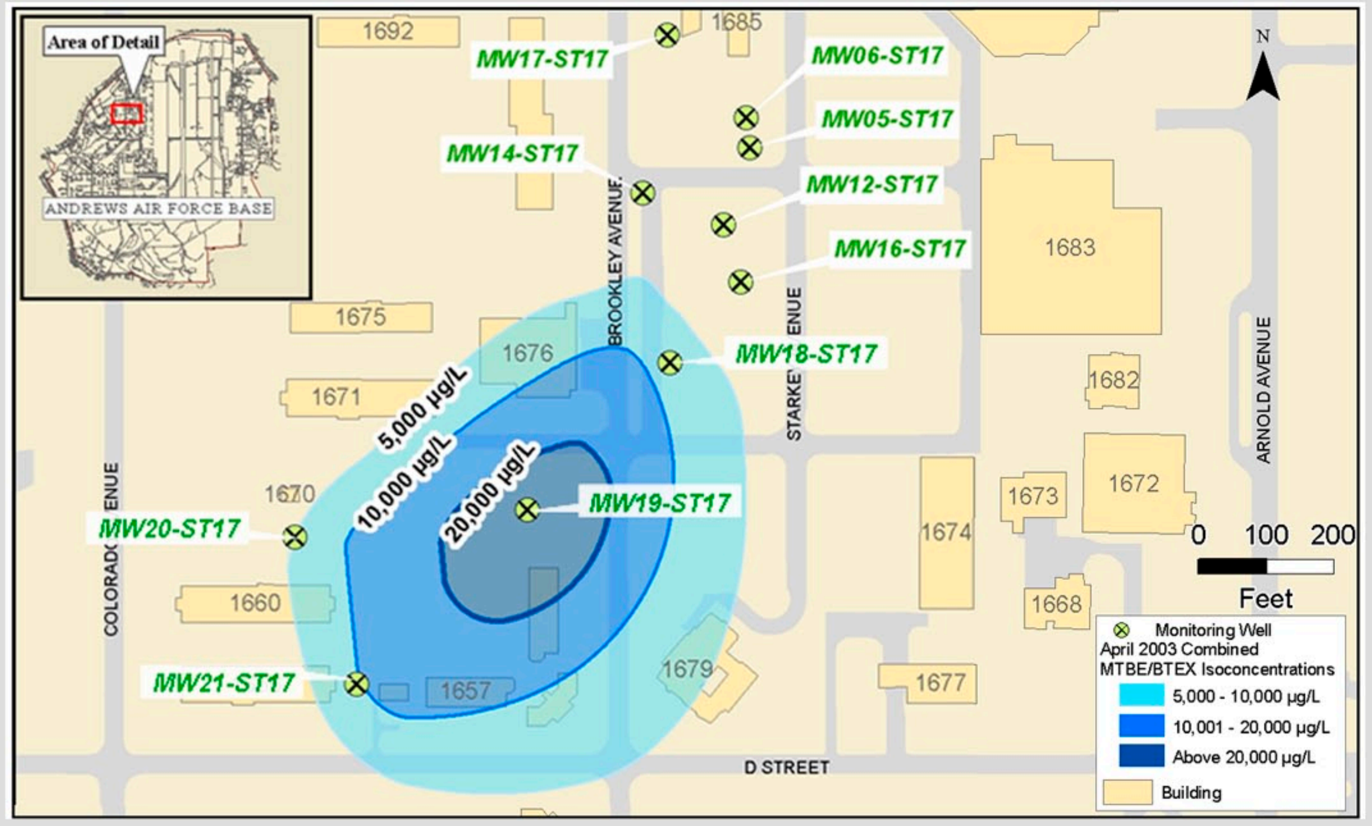


Figure 2. Pre-Remediation Combined MTBE/BTEX Isoconcentrations, April 2003

- **Average Groundwater Velocity**
  - 42.8 feet per year
- **Contaminants of Concern**
  - Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)
  - Methyl Tert-Butyl Ether (MTBE)
- **Average Depth to Groundwater**
  - 10 feet
- **Treatment Area**
  - Size: 210,000 ft^2
  - Subsurface Soil
    - Clays and Gravels – 7 feet bgs
    - Sands and Gravels – 7 to 27 feet bgs

Previous Assessment and Remedial Activities

- Groundwater Well and Soil Boring Installation and Monitoring
- Passive Recovery of Free-Phase Hydrocarbons
- Installation and Operation of SVE System (2 years)
- Application of Fenton's Reagent within Former Tank Excavation

Site Closure Requirements

- MDE required "reducing trend" in contaminant levels
  - Particular interest paid to MW-19 (highest MTBE concentration)
- Appropriate evaluation of risk and documentation of such using Maryland Environmental Assessment Technology for Leaking Underground Storage Tanks

  Risk Factors:
  - Presence of LPH
  - Current and Future Use of Impacted Groundwater
  - Contaminant Migration
  - Human and Environmental Ecological Exposure
  - Impact to Utilities or other Sensitive Receptors
- No numeric contaminant remedial goals established for site

Performance Based Contracting

Performance-Based Contracting (PBC) is a contracting style that establishes a project goal and milestones but does not prescribe how consultants will reach goals and milestones. It provides flexibility to explore various remedial techniques and make adjustments as necessary to optimize results. For this project, the PBC mechanism was crucial in allowing the BEM/MACTEC team to mitigate unexpected conditions and increase performance efficiency.

In-Situ Treatment Technology

In-situ treatment was selected to minimize infrastructure installation, alleviate operation and maintenance requirements, and reduce project wastes. Injection of ORC Advanced® provided additional oxygen within the subsurface, stimulating and supporting microbial degradation activities. ORC Advanced is an oxyhydroxide-based peroxygen product with Controlled-Release Technology (CRT™) that yields a slow oxygen release into the subsurface, lasting up to 12 months following a single application.

Project Goals and Results

- **Project Goal**

  Achieve site regulatory closure under Maryland Department of Environment (MDE) criteria by the contracted date of October 2006. Closure requirements include:
  - Demonstrating a reducing trend of dissolved-phase contamination
  - Demonstrating low or minimal relative risk to human health or the environment
- **Project Result**

  Site regulatory closure attained in June 2005 (16-months ahead of required schedule). Closure granted based on regulatory review of site data and risk evaluation that demonstrated:
  - Dissolved-phase contaminant concentration reduction of approximately 23%
  - No significant risk to human health or the environment identified during risk evaluations

Table 1. Targeted Treatment Well MW-19 Petroleum Hydrocarbon Reduction (ug/L)

	Pre-ORC Advanced	Post-ORC Advanced	ORC Advanced Reduction
BTEX	<2,700	<54	98%*
MTBE	28,000	20,800	23%

BALANCED ENVIRONMENTAL MANAGEMENT

BEM SYSTEMS

MACTEC, Inc.

REGENESIS

Remedial Activities

- **Source Removal** (December 2003- addressing residual-phase contaminants)
  - Excavation removed 2,180 tons of petroleum-impacted soil
  - Backfill included 500 pounds of ORC Advanced to facilitate bioremediation of remaining residual-phase contamination
- **In-Situ Enhanced Aerobic Bioremediation** (February 2004 – addressing dissolved-phase contaminants)
  - Tight grid design around highly impacted well MW-19
  - Injection of 23,700 pounds of ORC Advanced through 415 injection points at 20-ft spacing
  - Groundwater monitoring performed as 5 events between March and December 2004

Remedial Evaluation

- **Analytical results for post-excavation soil samples below MDE non-residential standards**
- **DO (dissolved oxygen) and ORP (oxidation reduction potential) increased significantly and remained elevated**
- **Evaluation of MDE risk criteria indicated:**
  - LPH not observed following remedial activities (excavation and injection)
  - No identified current or future use of groundwater
  - Fate and Transport modeling indicated plume would attenuate before reaching AAFB boundary
  - Combined carcinogenic human health risks for on-site exposure to groundwater and volatilization of groundwater in an enclosed space were below acceptable range
  - Calculated health index for non-carcinogenic effects for groundwater volatilization <1
  - Calculated health index for non-carcinogenic effects for groundwater direct contact >1 (indicating potential risk)
  - No identified utilities at groundwater depths; no identified sensitive receptors

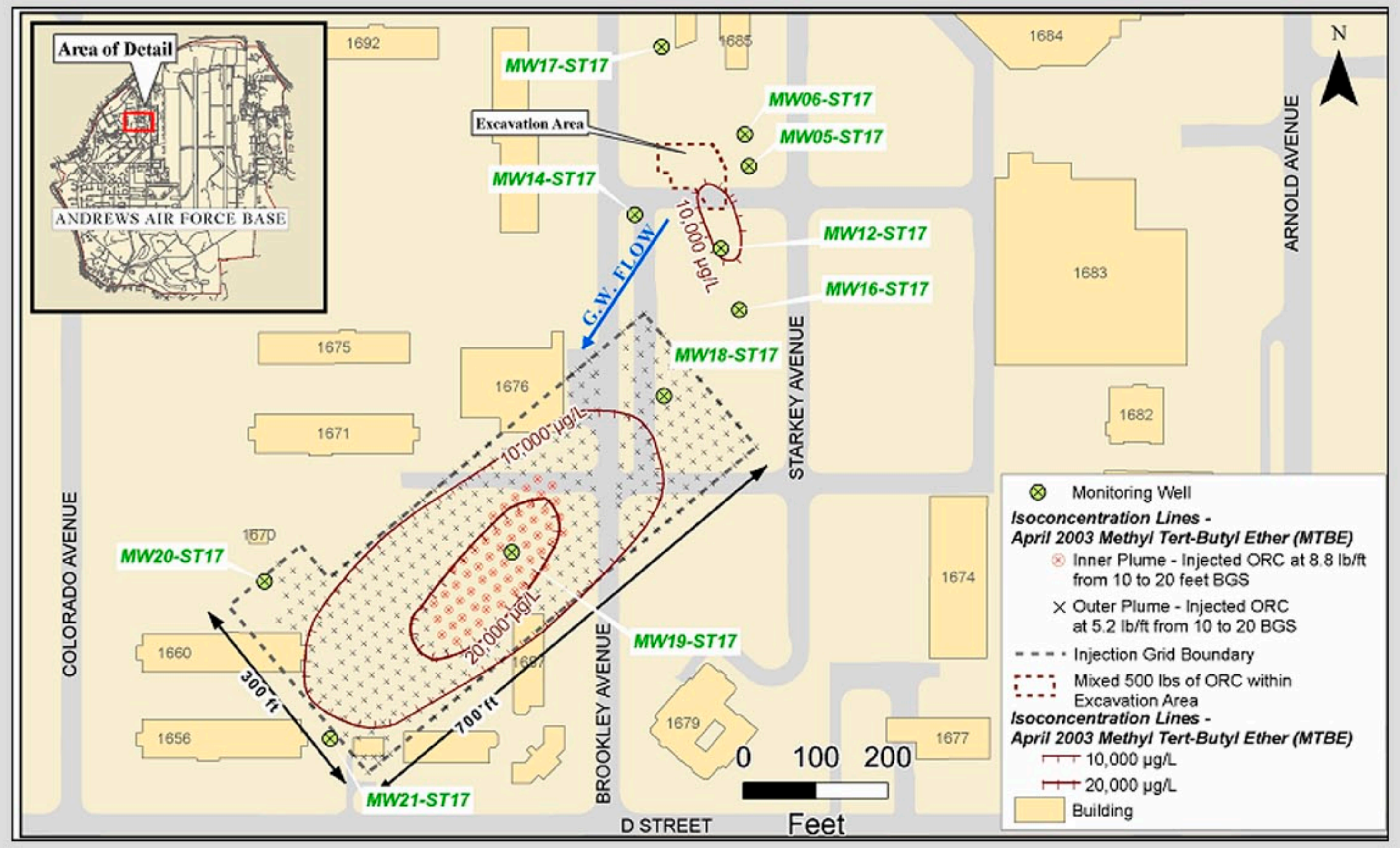


Figure 3. Outlined Excavated Area and ORC Advanced Injection Grid Design

Figure 4. ORC Advanced Injection

Figure 5. Former Tank Basin Excavation

ACCELERATED BIOREMEDIATION WITH OXYGEN RELEASE COMPOUND-ADVANCED (ORC-ADVANCED™): EVOLUTION OF TIME-RELEASE ELECTRON ACCEPTORS

Stephen S. Koenigsberg and Pat Randall • Regenesis, San Clemente, CA • 949.366.8000 • www.regenesis.com

REGENESIS

INTRODUCTION

ORC-Advanced™ is a unique, patented formulation of calcium oxyhydroxide that releases oxygen slowly upon hydration and forms simple calcium hydroxide and water.

$$CaO(OH)_2 + H_2O \longrightarrow \tfrac{1}{2}\,O_2 + Ca(OH)_2 + H_2O$$

ORC-Advanced is a new and improved time-release electron acceptor. ORC-Advanced releases a minimum of 17% oxygen by weight into the groundwater, as compared with 10% oxygen provided by the original Oxygen Release Compound (ORC®).

The oxygen released by ORC-Advanced facilitates the aerobic bioremediation of a wide range of environmental contaminants. Oxygen is typically the limiting substrate for microbes capable of aerobically biodegrading contaminants, such as petroleum hydrocarbons and fuel oxygenates such as MTBE. Without adequate oxygen, contaminant degradation will either cease or proceed at a much slower rate.

ORC-Advanced is the newest product in Regenesis' line of slow release compounds and offers many of the same benefits as the well established ORC. ORC and ORC-Advanced are both "low intensity" approaches to site remediation, providing a simple, passive, low-cost and long-term acceleration of aerobic natural attenuation. Remediation experts, looking for a long-lasting oxygen source without incurring the cost of installing mechanical oxygen injection systems or multiple reinjections of other oxidizing chemicals, turn to ORC-Advanced. ORC-Advanced has now been applied at over 200 sites.

TREATABLE CONTAMINANTS

ORC-Advanced can be used for bioremediation of any aerobically biodegradable contaminant. Examples of contaminants treated by ORC-Advanced:

- Benzene, toluene, ethylbenzene, and xylenes (BTEX) and other light petroleum hydrocarbons
- Heating oil, diesel, jet fuel, and polycyclic aromatic hydrocarbons (PAHs)
- Petroleum oxygenates and additives like metyl *tert*-butyl ether (MTBE) and ethanol
- Chlorinated aromatics like chlorobenzene and chloroanaline
- Chlorinated ethenes and ethanes like dichloroethene (DCE), vinyl chloride (VC), dichloroethane (DCA) and chloroethane (CA)
- Chlorinated methanes like methylene chloride and chloromethane
- Herbicides like atrazine, alachlor, metolachlor and acetochlor

CONTROLLED RELEASE TECHNOLOGY (CRT™)

In calcium peroxide compounds, often sold as "slow release," the rate of oxygen formation is simply dependent upon the rate of hydration. When placed into water, this results in a rapid, uncontrolled formation and release of oxygen from the crystalline matrix. Then, as hydroxides form, a significant portion of the oxygen deeper in the crystal is made unavailable or becomes "locked up," as shown in Figure 1.

ORC-Advanced is not simply calcium peroxide, but rather a patented formulation of calcium oxyhydroxide intercalated with food-grade phosphate (Figure 2). The term intercalation refers to the permeation of phosphate ions through the calcium oxyhydroxide crystal, partially inhibiting the transmission of water into the structure. Controlling the rate of hydration of the crystal produces a "timed" oxygen release. Intercalation also increases shelf life stability; ORC-Advanced can be stored for several years without risking significant product degradation.

The patented intercalation process, also known as Controlled Release Technology (CRT™), provides "balance" – it slows down the rate of oxygen release white at the same time preventing "lock-up".

Figure 1.
Intercalated vs. Unintercalated Peroxygens

- Unintercalated peroxygen is subject to "oxygen lock-up:"

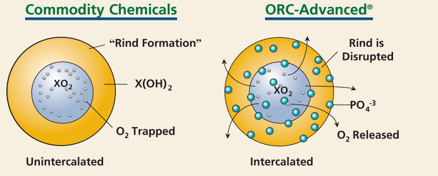
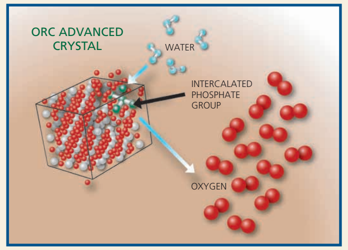


Figure 2.
Intercalated phosphate ions



CRT Specifics

Uniformly embedded within the crystalline structure of the peroxygen are phosphate ions. These ions do two important things:

1. They slow the rate of hydration that liberates oxygen thereby creating the CRT effect and
2. They form exit pathways for the oxygen in an otherwise tightly packed crystal that can become even more "locked-up" when hydroxides begin to form as a reaction by-product following oxygen liberation.

OXYGEN RELEASE CHARACTERISTICS TO OPTIMIZE BIOREMEDIATION

In the stimulation of aerobic bioremediation, the rate of oxygen release is a critical factor. If oxygen is released in excess of saturation, the oxygen will be simply wasted as it bubbles out of solution. By controlling the rate of oxygen release with CRT technology, the rapid release rates observed with calcium peroxide are avoided.

Figure 3a depicts oxygen release rate data for both ORC-Advanced and a calcium peroxide-type product often sold as being "slow release." Note the excessive oxygen released by the calcium peroxide product in the first 60 day period compared to the controlled oxygen release by ORC Advanced. In most contaminated groundwater settings, this excessive amount of oxygen would exceed the "physical holding capacity" and "microbial demand" of the aquifer and would be wasted.

Additionally, calcium peroxide compounds become exhausted in their release rates in the very period of highest aerobic microbial oxygen demand-when the microbial population is optimized and efficiently degrading contaminants. This is clearly seen in the data in Figure 3a, where the calcium peroxide compound drops off in its rate of oxygen release after about 180 days. ORC-Advanced continuously releases oxygen for approximately one year in the field.

Figure 3a
ORC Advanced vs. Commodity Calcium Peroxide

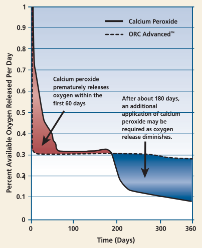
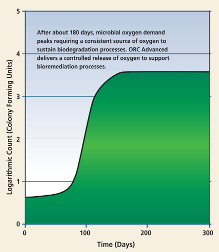


Figure 3b
Generalized Aerobic Microbial Growth Curve for Contaminated Aquifer Settings



ORC-Advanced validates its patented CRT profile optimizing the long-term, steady concentration of available oxygen at amounts between 0.3 and 0.4 percent per day. Calcium peroxide exhibits a quick initial oxygen overload in the early months following injection, losing a significant portion of its available oxygen. After 180 days calcium peroxide exhibits a sub-optimal oxygen release profile (just when microbial oxygen demand typically reaches its upper limits - Figure 3b) and is diminished in its ability to stimulate bioremediation.

BENEFITS OF ORC-ADVANCED

"Rapid" Site Closure

- Accelerates natural attenuation by 10X to 1,000X — reducing time to site closure

Cost-Effective

- No capital costs for systems
- No operation & maintenance costs
- Reduced installation costs
- Typically 30 – 50% less expensive than mechanical systems

ORC-ADVANCED APPLICATION STRATEGIES

Combined ORC-Advanced application strategies are shown in the diagram below (Figure 4). ORC-Advanced can be applied in a variety of ways, with some or all of the methods being appropriate at a given site.

Figure 4.
Methods of ORC Application

ORC-Advanced powder can be made into a slurry that is backfilled or injected into the saturated zone, or it can be dispersed as the dry powder into the contaminated area. Applications of ORC-Advanced, by slurry or powder, provide oxygen at a timed rate that is generally consistent with demand. This allows the site to be passively managed.

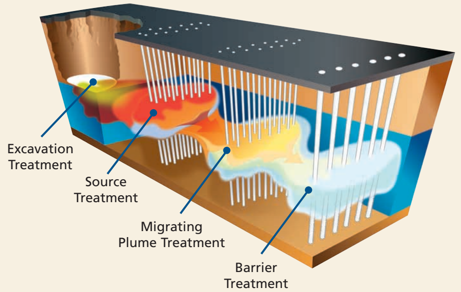
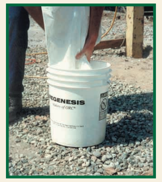


Figure 5.
ORC-Advanced Slurry Injection



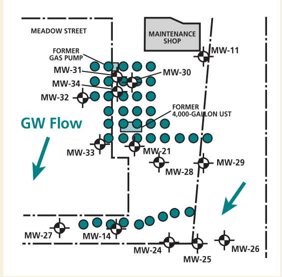
ORC powder is mixed with water to form a slurry

ORC slurry is poured into the hopper of a slurry injection pump

Direct-push injection of slurry

Figure 6.
ORC-Advanced Excavation Application

CASE HISTORY 1 – ORC-ADVANCED APPLICATION IN CONNECTICUT



Application Details

Soil type: silty sand
1,000 lbs ORC-Advanced applied in March 2004

Two areas of application:
1) source area
2) downgradient edge of plume

Source area: 32 injection points in a grid formation

Downgradient cut-off barrier: 9 injection points

Treatment thickness: 10 ft (from 8 to 18 ft bgs)

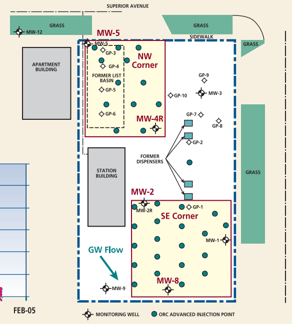
Results

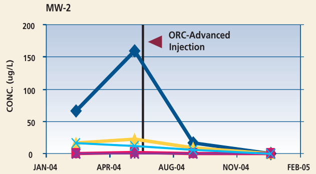
TREATED WELLS			
Location	% Change	Initial Conc. BTEX (mg/L)	Conc. BTEX (mg/L) after 3 months
In grid	53% ▼ decrease	20.4	9.5
Downgradient edge	47% ▼ decrease	1.9	1.0
Downgradient barrier	30% ▼ decrease	1.0	0.7

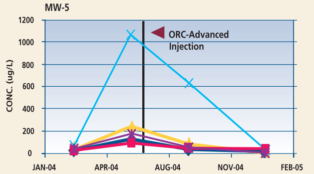
UNTREATED WELLS			
Location	% Change	Initial Conc. BTEX (mg/L)	Conc. BTEX (mg/L) after 3 months
20-25 ft Downgradient	67% ▲ increase	.03	.05
Wells lateral to grid	54% ▲ increase	1.3	2.0

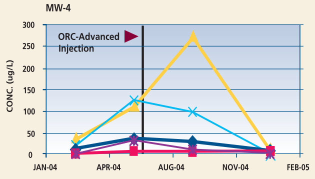
CASE HISTORY 2 – SERVICE STATION IN SHEBOYGAN, WI

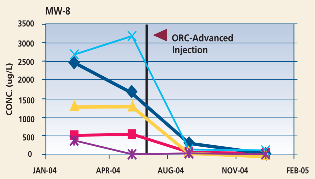
Elevated levels of petroleum hydrocarbons were discovered near the former dispenser island at a service station in Sheboygan, WI. After soil excavation, residual contamination continued to affect the groundwater. *In situ* bioremediation using ORC-Advanced was chosen to reduce BTEX and naphthalene. In the northwest corner of the site, the location of the former UST basin, a total of 480 pounds of ORC-Advanced was injected. In the southeast corner, the area of highest contamination, a total of 2,370 pounds of ORC-Advanced was injected.

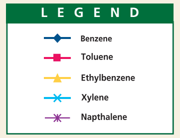












On average, concentrations continued to increase up until the ORC-Advanced application and significant decreases of all contaminants were seen shortly after ORC-Advanced injection. In well MW-2, total BTEX was reduced to non-detect. Total BTEX concentrations were reduced to 8 and 18 ug/L in wells MW-4 and MW-5, respectively. In well MW-8, total BTEX was reduced from 1745 ug/L to 42.2 ug/L, a 97% reduction. Monitoring is on-going as concentrations continue to decrease toward MCLs.

ORC ADVANCED™
OXYGEN RELEASE COMPOUND

Case History A-4

REGENESIS

Advanced Technologies for Groundwater Resources

ORC ADVANCED OXYGEN RELEASE COMPOUND

Replacement of P&T with ORC Advanced® Reduces Cost to Closure

CASE SUMMARY

Service Station, Mears, MI

Two leaking underground storage tanks (USTs) resulted in soil and groundwater contamination at a service station in Michigan. Naphthalene, trimethylbenzene (TMB) and benzene, toluene, ethylbenzene, and xylenes (BTEX) contamination were discovered in the subsurface prompting the need for remedial cleanup. Michigan DEQ began remediation via UST removal and soil excavation. A total of 4,000 cubic yards of contaminated soil was removed. A pump and treat (P&T) system was installed and operated for 8 years through November 2003. The system removed 1,575 pounds of BTEX and significantly lowered contaminant concentrations. However, the P&T system reached asymptotic conditions and would not be effective in achieving site closure goals. Regulators began looking into new ways of accelerating the remediation process and reducing the overall cost of cleanup. Enhanced aerobic bioremediation using ORC Advanced® was deployed to replace the P&T system and degrade the remaining contamination.

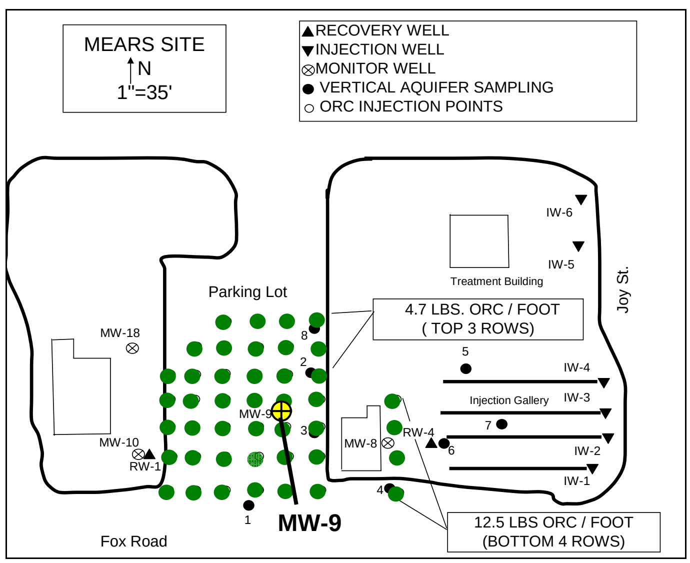
REMEDIATION APPROACH

The remediation objective was to continue the reduction of petroleum hydrocarbons in the subsurface and reduce the cost to closure. Three months after the P&T was shutdown an ORC Advanced application took place. The ORC Advanced injection included 43 injection points in a grid design within the contaminated area surrounding well MW-9 (Figure 1).

Table 1. Concentrations Post-P&T / Pre-ORC Advanced Injection and Cleanup Goals

Contaminant	Post-P&T/Pre-ORC Advanced	Cleanup Goal
Benzene	<1	5
Toluene	29	790
Ethylbenzene	110	74
Xylenes	322	280
Naphthalene	760	520
1,3,5-TMB	650	72
1,2,4-TMB	2800	63
2-Methylnaphthalene	220	260

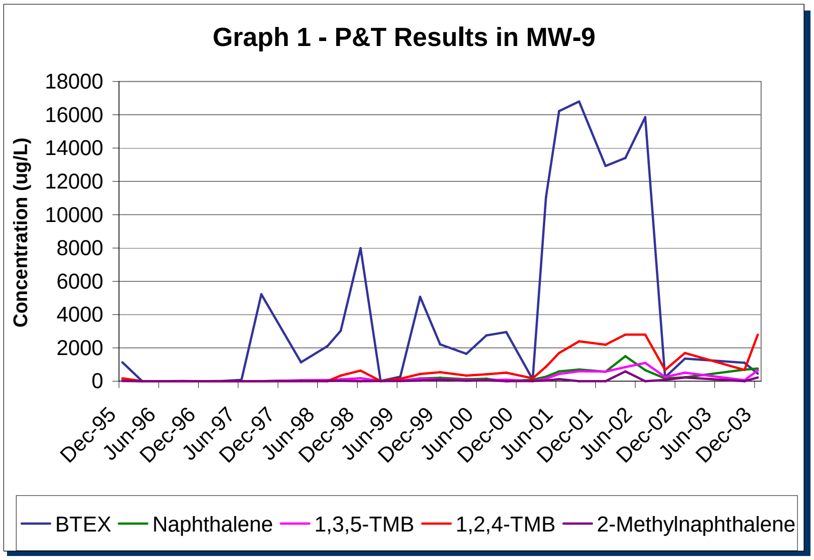
Figure 1. ORC Advanced Injection Grid Location



- **Product:** ORC Advanced®
- **Application Rate:** 5 lbs/ft
- **Injection Spacing:** 10 ft
- **Quantity Applied:** 2,325 lbs
- **Product Cost:** $20,343
- **Application Type:** Grid Injection
- **Treatment Area:** 4,200 ft^2
- **Soil Type:** Sand
- **Groundwater Velocity:** 0.5 ft/day
- **Depth to Groundwater:** 25 ft

RESULTS

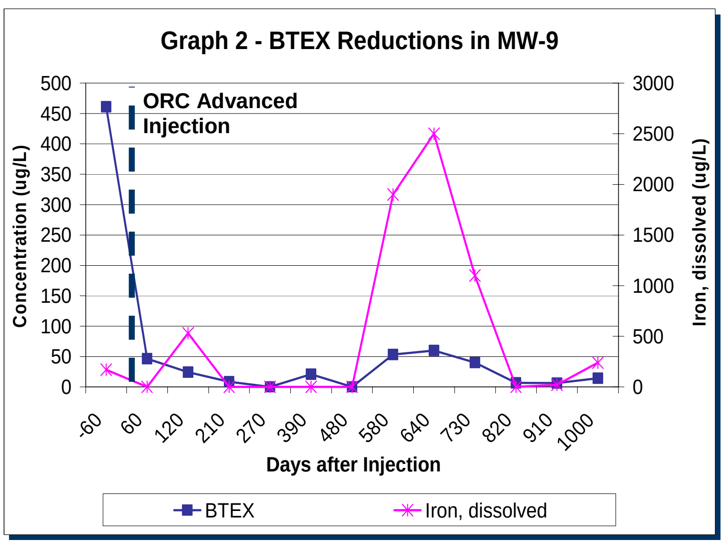
Pump & Treat Results

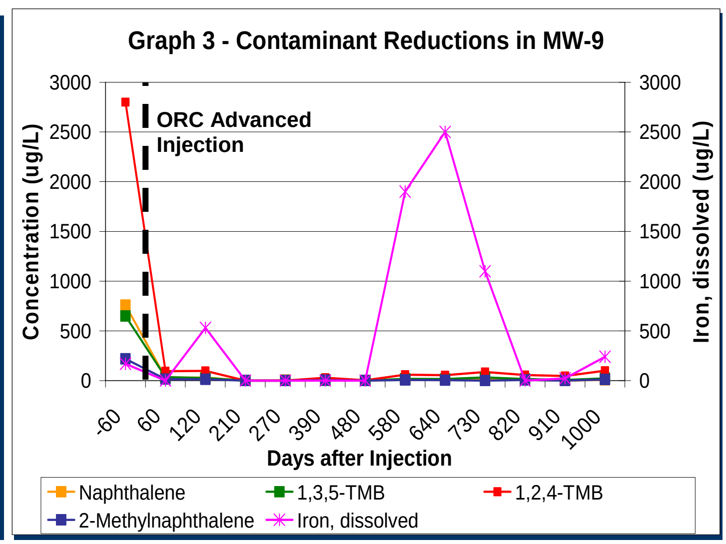


An increase in rainfall during certain parts of the remedial period contributed to some of the increases observed in Graph 1. During wet periods, an increase in concentrations resulted from the mobilization of contaminants within the capillary fringe smear zone. An infiltration gallery was installed to flush the contamination into the dissolved-phase where it was available for P&T removal.

Prior to shutdown in November 2003, O&M costs were increasing and low-level dissolved-phase concentrations were still elevated indicating the system was not effective at reaching the required low cleanup levels.

ORC Advanced Injection Results





Within 60 days of the ORC Advanced application, low-level concentrations were significantly reduced below post-P&T levels. Reduction continued throughout the monitoring period and a 99% mass reduction was achieved approximately 13 months after the initial injection. In well MW-9, concentrations in all contaminants were reduced to below the cleanup goals.

The ORC Advanced application eliminated increasing O&M costs of an aging P&T system and allowed the site to be closed years ahead of projections.

CONTACT

Barry Poling
Regenesis
Central US Regional Manager
812-923-7999 | bpoling@regenesis.com

Consultant contact information available upon request. Please contact the Regenesis representative listed above.