CAMBRIA

June 15, 1999

Barney Chan
Alameda County Health Care Services Agency
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

1, 2, backfill well

Re: **Letter Response**
Shell-branded Service Station
4411 Foothill Boulevard
Oakland, California
Incident #98995746
Cambria Project# 241-0897

Dear Mr. Chan:

On behalf of Equiva Services LLC (Equiva), Cambria Environmental Technology, Inc. (Cambria) is submitting this response to the Alameda County Health Care Services Agency (ACHCSA) April 30, 1999 letter to Equiva. Following is a response to specific items requested in the letter.

RESPONSE TO LETTER ITEMS

Regarding your first item of concern, Cambria has run the ORC model by adding the average concentration of TPHg, benzene and MTBE in the wells with the highest concentrations. This is an overly conservative estimate which assumes that the concentration of the entire plume is that of the highest well. To this we have added a safety factor of 4 to account for oxygen sinks and other unknowns. Attachment A presents the ORC application software spreadsheet calculations for this conservative model using both 6 inch and 4 inch well diameters. In addition, we are installing ORC socks in wells which allows us the flexibility of replacing the ORC socks as dissolved oxygen levels decrease to pre-ORC levels.

In response to your second item of concern, studies have been performed by Regenesis which demonstrate MTBE degradation using ORC. A Regenesis bulletin is included in Attachment B. The presence of BTEX inhibits initial MTBE degradation. However, once all BTEX has been degraded, MTBE consumption begins. In a talk by Jack Peabody of Regenesis, Jack explained that the most effective way to install ORC is to install ORC upgradient of the source or within the source area, allow oxygen to travel with the groundwater flow, and monitor downgradient locations. As per Cambria's March 18, 1999 Work Plan we will install ORC in well S-2 as part of our oxygen barrier and monitor ORC effectiveness using wells S-3 and proposed well S-4.

ENVIRONMENTAL
PROTECTION
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Cambria's work plan addendum serves as the feasibility study for control of MTBE at the site. According to vendor information from Regenesis, remediation of MTBE using ORC is feasible. A low technical remedial approach is warranted at this site since there are no sensitive receptors on the vicinity and there are two other responsible parties for groundwater contamination adjacent to the Shell-branded station

Cambria believes the likely source of MTBE was the dispensers. As presented in Cambria's November 30, 1999 Dispenser Soil Sampling Report, MTBE was detected beneath three of the dispensers at a maximum concentration of 13 parts per million. Secondary containment was added to the dispensers and the gasoline turbines at that time, therefore, we believe that the release has been contained.

CLOSING

We appreciate the opportunity to work with you on this project. Please call Darryk Ataide at (510) 420-3339 if you have any questions or comments.

Sincerely,
Cambria Environmental Technology, Inc

Darryk Ataide
Project Manager

Ailsa S. Le May, R.G.
Senior Geologist

Attachment: A – ORC Application Software Spreadsheet Calculations
Attachment: B – Regenesis Bulletin

cc: Karen Petryna, Equiva Services LLC, P.O. Box 6249, Carson, California 90749

Attachment A

ORC Application Software Spreadsheet Calculations

SOURCE TREATMENT - REPLACEMENT WELLS

Dissolved Hydrocarbon Level (ppm)	46
(For gasoline sites use BTEX measurements)	
Plume Width (ft)	85
Plume Velocity (ft/day)	0.22
Thickness of contamination in Saturated Zone (ft)	10
Thickness of ORC Filter Socks in Saturated Zone (ft)	10
Porosity	0.3
(sand = 0.3, silt = 0.35, clay = 0.4)	
Safety Factor for Barriers	4
(recommended value is about 2)	
Hydrocarbon Load Per Day (lbs)	0.644
Oxygen Demand per Day (lbs)	1.932
Oxygen Required (lbs)	347.8

APPLICATION COMMENTS

* Barrier Design should potentially handle constant mass flux requirements

Well Diameter (in.) ***enter 4 or 6 ONLY***	6
Number of Wells	3
Well Spacing (ft.)	28
Total Number of Socks	30
Oxygen Available (lbs)	16.5
Cost per sock	$ 37.50
Cost of ORC Socks per Charge	$ 1,125.00
Percent of O2 Available to O2 Requied	5%
Minimum number of recommended charges to complete clean up	22.00
Total Cost of ORC Socks for Cleanup	$ 24,750.00
Solute Transport Model	
Compliance Point (ft.)	35
HC Level at compliance point after one charge in ppm	21.078

or 11 yrs ?

348/16.5 = 21

SOURCE TREATMENT - REPLACEMENT WELLS

Dissolved Hydrocarbon Level (ppm)	46	Well Diameter (in.) ***enter 4 or 6 ONLY***	4
(For gasoline sites use BTEX measurements)		Number of Wells	3
Plume Width (ft)	85	Well Spacing (ft.)	28
Plume Velocity (ft/day)	0.22	Total Number of Socks	30
Thickness of contamination in Saturated Zone (ft)	10	Oxygen Available (lbs)	11.25
Thickness of ORC Filter Socks in Saturated Zone (ft)	10	Cost per sock	$ 37.50
Porosity	0.3	Cost of ORC Socks per Charge	$ 1,125.00
(sand = 0.3, silt = 0.35, clay = 0.4)		Percent of O2 Available to O2 Requied	3%
Safety Factor for Barriers	4		
(recommended value is about 2)		Minimum number of recommended charges to complete clean up	31.00
Hydrocarbon Load Per Day (lbs)	0.644		
Oxygen Demand per Day (lbs)	1.932	Total Cost of ORC Socks for Cleanup	$ 34,875.00
Oxygen Required (lbs)	347.8		

Solute Transport Model

Compliance Point (ft.)	35
HC Level at compliance point after one charge in ppm	21.412

APPLICATION COMMENTS

* Barrier Design should potentially handle constant mass flux requirements

If slurry is 10% by wt.
you'll need 3478 # of ORC slurry
if slurry is 20% by wt
you'll need ~ 1650 #s of ORC slurry.

Attachment B

Regenesis Bulletin

Enhanced Aerobic Bioremediation of MTBE With ORC®

MTBE: A Problem In Groundwater Contamination

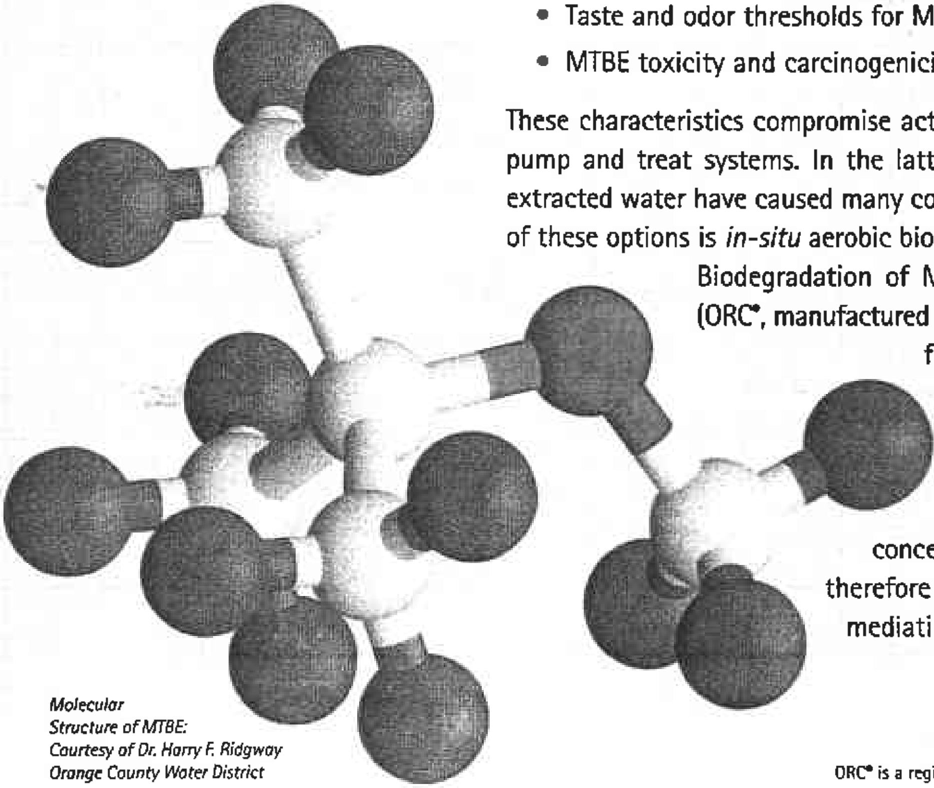
Methyl tertiary butyl ether (MTBE) is a synthetic chemical used as a gasoline oxygenate that reduces carbon monoxide emissions by promoting more complete fuel combustion. Regulatory concern over air quality has prompted increased use of MTBE in gasoline over the last several years. Consequently, MTBE is detected more frequently in groundwater and surface waters across the U.S.

MTBE complicates remediation and closure of properties contaminated with BTEX and other conventional fuel hydrocarbon components. Regulators and oil companies are becoming increasingly concerned about the environmental impact of MTBE. Several factors responsible for the heightened level of concern include the following:

- MTBE tends to degrade very slowly.
- Due to the dipole nature of its ether bond, it is highly soluble in water and does not easily sorb onto the aquifer matrix; retardation of MTBE is therefore minimal.
- Due to its Henry's Law constant, MTBE is slow to volatilize out of ground water.
- Taste and odor thresholds for MTBE are very low – approximately 35 ppb.
- MTBE toxicity and carcinogenicity profiles are largely undetermined.

These characteristics compromise active remediation methods such as air sparging and pump and treat systems. In the latter case, stripping inefficiencies encountered with extracted water have caused many consultants to evaluate other treatment options. One of these options is *in-situ* aerobic bioremediation of the compound.

Biodegradation of MTBE is enhanced by Oxygen Release Compound (ORC®, manufactured by REGENESIS Bioremediation Products), a patented formulation of magnesium peroxide capable of slow and sustained release of oxygen when hydrated. Typically, ORC will release oxygen for about six months to one year. Unlike sparged air, ORC provides pure oxygen and has raised dissolved oxygen concentrations to levels over 30 ppm in the field. ORC is therefore an ideal innovation for supporting aerobic bioremediation in the oxygen-limited contaminated subsurface.



Molecular Structure of MTBE: Courtesy of Dr. Harry F. Ridgway Orange County Water District

ORC® is a registered trademark of REGENESIS Bioremediation Products

Evidence for Aerobic Biodegradation of MTBE

Several years ago, REGENESIS noticed that MTBE concentrations decreased at an unusually high rate in monitoring wells containing ORC filter socks. Though data were sparse, as MTBE was rarely measured and reported, an intriguing trend was emerging. In some cases the rate of MTBE reduction, presumed to be a function of biological degradation, was extremely high. An early REGENESIS data set from 11 wells across three diverse sites in California, Michigan, and New Jersey, measured high MTBE degradation rate constants (k). While the literature reports MTBE degradation rate constants ranging from .0231 to .0038 (half-life = 30-180 days), average values measured in ORC wells show rate constant values ranging from .1447-.0112 (half-life = 5-61 days).[1]

Subsequent laboratory experiments by REGENESIS indicated that ORC does not directly absorb or chemically oxidize MTBE. Furthermore, since ORC releases oxygen at a slow, steady rate and by virtue of the Henry's Law constant for MTBE, it is unlikely that MTBE was being volatilized out of the aquifer. These observations led to the hypothesis that ORC may facilitate the aerobic bioremediation of MTBE.

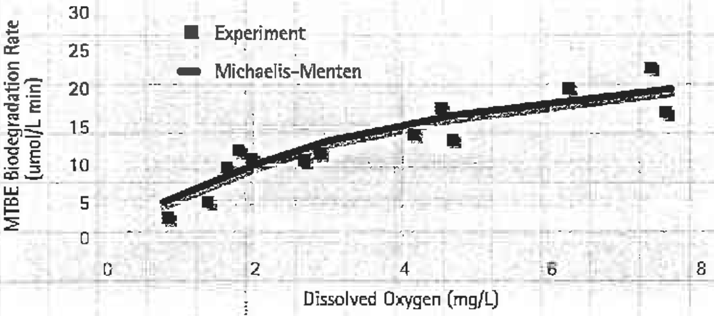


Figure 1: *MTBE Biodegradation Rate as a Function of Initial DO*

An independent study conducted by Fortin and Deshusses, at the University of California, Riverside, and supported by REGENESIS investigated MTBE biodegradation by respirometry.[2] The study demonstrates that the rate of MTBE biodegradation is proportional to dissolved oxygen concentration in water; in fact, MTBE uptake followed Michaelis-Menten kinetics with respect to dissolved oxygen. As depicted in Figure 1, higher dissolved oxygen concentrations resulted in higher MTBE degradation rates. Other laboratory and field studies also conclude that MTBE biodegrades aerobically, some of which include the following:

- Scientists at Shell Oil isolated a strain of aerobic bacteria capable of biodegrading MTBE.[3]
- According to a study investigating the effects of dissolved oxygen on MTBE degradation, "the biodegradation rate of MTBE is highly dependent on...available dissolved oxygen concentration."[4]
- An Amoco Oil field study found MTBE degraded in the aerated portion of an air sparged plume.[5]
- Pure oxygen injections on a site in New York correlated decreasing MTBE concentrations with higher dissolved oxygen levels.[6]

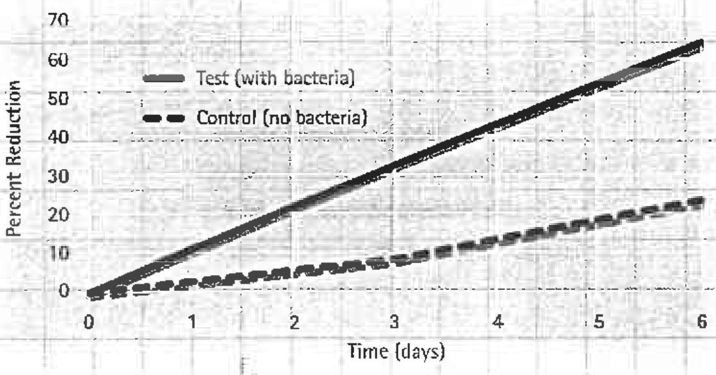


Figure 2: *"In-Vitro Biodegradation of MTBE"*

Laboratory studies conducted by REGENESIS also demonstrate *in-vitro* aerobic degradation of MTBE.[7] In one experiment, MTBE was added to petri dishes containing two sets of media: one that contained aerobic bacteria and another that contained no bacteria. As presented in Figure 2, MTBE degradation was high in the presence of aerobic bacteria.

MTBE Bioremediation with ORC

Laboratory and field studies indicate that elevated dissolved oxygen levels accelerate the rate of MTBE biodegradation. Application of ORC in this process presents several important advantages:

- ORC treatment does not rely on volatilization of MTBE. Since MTBE is difficult to volatilize, pump and treat and air sparging techniques may not be cost-effective solutions.
- ORC delivers higher concentrations of useable oxygen to the contaminated subsurface more efficiently than air sparging techniques.
- Typically, passive remediation with ORC is substantially less costly than active remediation systems.

Field Results Show ORC Enhances MTBE Bioremediation

Commercial application of ORC has had a positive impact on remediation of MTBE contamination in groundwater. The following case studies illustrate ORC's ability to enhance bioremediation of MTBE.

1. A service station in Lake Geneva, Wisconsin was contaminated with high levels of MTBE and BTEX due to a leaking underground storage tank (UST). Measurements indicated MTBE and BTEX concentrations reached levels up to 800 ppb and 14,000 ppb, respectively. Though project engineers removed the UST and excavated the contaminated soil, MTBE and BTEX still persisted in the groundwater.

   Project geologists injected 1,700 pounds of ORC slurry (via direct-push technology) to enhance aerobic degradation in the saturated zone. Over nine months following ORC injection, results from two downgradient monitoring wells indicate that MTBE and BTEX concentrations degraded to less than two ppb. These results are depicted in Figure 3. The site has since been submitted for closure to the state of Wisconsin.

Figure 3: *ORC Treatment in Lake Geneva, WI MTBE Reduction at 2 Wells*

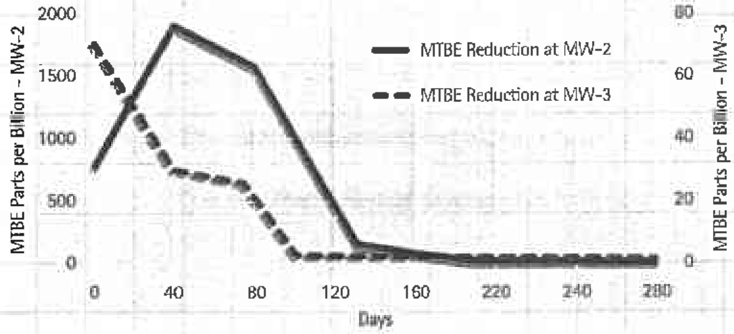


Table 1: *Cost of ORC vs. Air Sparging with Vapor Extraction for Lake Geneva, WI Site*

Remediation Alternative	Estimated Cost	Total Estimated Project Costs
Air Sparging with SVE		$422,000
Tank Excavation and Backfill plus ORC Slurry Injection:		
• ORC Product	$17,000	
• ORC Installation/O&M	$118,000	
• Soil Excavation	$156,000	
TOTAL:		$291,000

Project engineers estimated costs for two remediation alternatives: (1) tank excavation to remediate soil plus ORC injection to remediate groundwater, versus (2) soil vapor extraction and air sparging to treat both soil and groundwater. These values are compared in Table 1. Soil excavation plus enhanced bioremediation with ORC was two thirds the cost of an air sparging/SVE system which represents a 31% savings for the state of Wisconsin.

2. A leaking UST at a site in Allenton, Wisconsin resulted in high levels of MTBE and BTEX contamination. Project engineers considered several remedial options, including pump and treat and air sparging with vapor extraction, and concluded that ORC treatment presented the most cost-effective approach.

   A total of 2,000 pounds of ORC were applied (1) as a backfill amendment for remediation of the source and (2) as a slurry injected in the areas surrounding the source to contain plume migration. As shown in Figure 4, over approximately 14 months, MTBE concentrations were reduced 78%.

   In evaluating remedial alternatives, the state requested that the lowest cost remedial approach be selected. According to project engineers, "based on investigative and analytical results, [excavation with ORC treatment] is the most cost-effective means of site remediation." Table 2 presents a cost analysis of remediation options prepared by the consultants.

Figure 4: *ORC Treatment in Allenton, WI MTBE Reduction at MW-1*

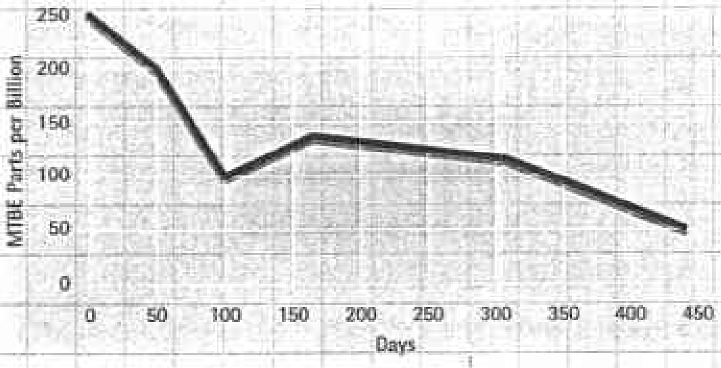


Table 2: *Cost Analysis of Treatment Alternatives Considered for Allenton, WI Site*

Remedial Option for Soil and Groundwater Cleanup	Total Project Cost
Air Sparging/SVE plus Pump and Treat	$590,000
Excavation and Bio-Treatment of Soil plus Groundwater Pump and Disposal	$867,000
Limited Excavation and Bio-Teatment of Soil plus Pump and Treat	$593,500
Limited Excavations and ORC Soil and Groundwater Remediation	$221,750

Competitive Inhibition:
A Possible Mechanism In MTBE Biodegradation

Competitive inhibition is a biological term used to describe enzymatic activity in which two or more different substrates compete for the same enzyme. One indication that competitive inhibition may be occurring is when the degradation of one substrate is repressed in the presence of another substrate(s).

Field observations suggest that background hydrocarbons may repress MTBE degradation. As presented in Figure 5, samples from a site in Michigan show that in the presence of ORC, MTBE degradation occurs *after* BTEX concentrations subside.

Figure 5: *MTBE Reduction in an ORC Well—Michigan Site*

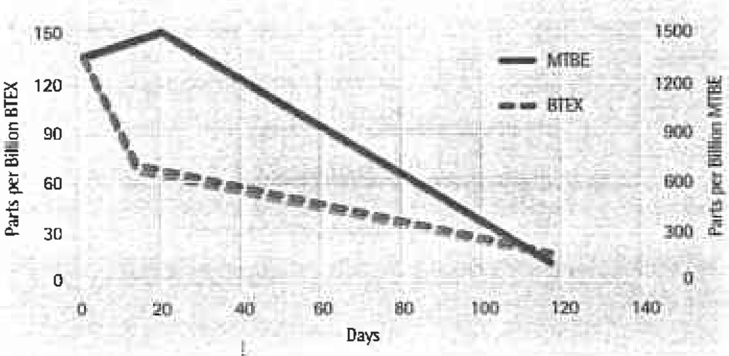
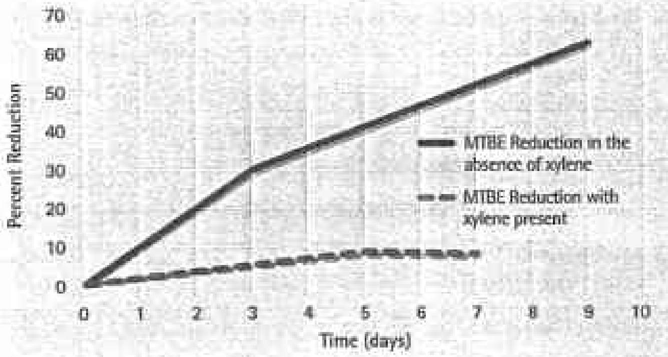


Figure 6: *Suppression of MTBE Degradation in the Presence of Xylene*



Prompted by such field results, REGENESIS conducted a series of experiments to test whether background hydrocarbons interfere with MTBE degradation. In an *in-vitro* experiment with aerobic bacteria (known to be capable of degrading MTBE and BTEX), results suggest that MTBE metabolism is inhibited by background hydrocarbons.[7] MTBE degradation was measured in the presence of (1) MTBE only and (2) MTBE and xylene (which was chosen to represent the behavior of other contaminants such as benzene, toluene and ethylene). As shown in Figure 6, results indicate that xylene inhibits MTBE degradation.

Another experiment conducted for REGENESIS used bacterial cultures known to be capable of degrading both BTEX and MTBE.[8] The study correlated increasing BTEX concentrations with a reduced rate of MTBE degradation. However, another study reports evidence of the opposite effect in which excess MTBE concentrations were shown to inhibit biodegradation of other hydrocarbons.[4] These findings support the possibility that MTBE and other hydrocarbons may be competing for the same enzyme.

Given that biodegradation of MTBE may be inhibited by background hydrocarbons, any protocol designed to bioremediate this compound must also address remediation of other hydrocarbons. Enhanced aerobic bioremediation with ORC is a cost-effective approach that may facilitate remediation of *both* MTBE and other aerobically degradable hydrocarbons, including BTEX compounds.

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References:

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