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Department of Environmental Protection
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Regenesis Bioremediation Products
1011 Calle Sombra
San Clemente, California 92673

Re: Regenesis Hydrogen Release Compound (HRC)

Gentlemen:

Enclosed is the New Jersey Department of Environmental Protection's (NJDEP) Innovative Environmental Technology Certification based on the New Jersey Corporation for Advanced Technology's (NJCAT) verification of Regenesis' Hydrogen Release Compound. The NJDEP accepts the NJCAT verification of the performance claims and the net beneficial effect of HRC. The HRC has been verified through valid quality control sampling and analytical methods. The evaluation documented a net beneficial effect of the HRC to treat contaminated groundwater in an efficient and effective manner. The evaluation was documented through case studies, lab studies, and peer reviewed literature.

The NJDEP can certify that the performance claims made by Regenesis, verified by NJCAT, are sufficient for the department to determine that the technology has a demonstrated effectiveness as defined in the NJDEP's Guidance Document for the Remediation of Contaminated Soils, Jan. 1998. This documentation of the demonstrated effectiveness of HRC will eliminate the technology validation process that would normally precede an evaluation of the use of an innovative technology at a site. This provides for an immediate review of the site-specific application of HRC within an evaluation of the project design.

In addition to the demonstrated effectiveness as a site remediation technology, HRC was able to document a significant reduction in energy use over typical current proven technologies. In a typical site of 0.25 acres, the use of HRC was calculated to save between 340,000 to 660,000 kWhs of electricity when compared to currently commercial available proven technologies. This results in approximately 220 to 430 tons of avoided CO_2 emissions in the use of HRC. This reduction in the use of energy of HRC results in overall lower air emissions, less wastewater discharges and less waste generated in the use of HRC when compared to typical current proven technologies.

Increasing the use of innovative environmental technologies that have a net beneficial effect and can assist the Department in improving our state's overall environmental quality face a two prong barrier to their commercialization and deployment. One is investors and users of the environmental technology may not have access to third party validated data of the performance and the potential successes of the technology. The other is that investors and vendors of the environmental technology face a fragmented market place represented by 50 individual state approval programs. The New Jersey verification and certification process can, in part, address these barriers.

The NJCAT verification of the environmental performance of your technology, HRC, is of itself a valuable commodity. It provides a high degree of confidence to a private sector developer who is seeking to invest in or install and use new environmental technology that can go beyond compliance with regulatory permits or standards. The key to completing our response to barriers to deployment of new environmental technologies is to link the technology verification to a NJDEP certification as set forth in the recently enacted New Jersey Environmental Energy Technology Verification Act. NJSA 13:1D. The NJDEP certification adds to the reduction of the barriers to the deployment of new environmental technologies by increasing access to valid third party evaluation data. This could assist in increasing investment in and use of innovative environmental technologies that can improve New Jersey's environmental quality indicators as established in the NJDEP Strategic Plan.

In order to multiply this effect, the technology and regulatory connection needs to be further linked to an interstate reciprocity process, which has been developed through the Environmental Council of States with the ETARP program. This means that the environmental and operational data and the overall performance of the HRC process as certified by NJDEP is accessible and useable to other states as outlined in the ETARP Project Strategies Report. This will interconnect environmental technology and regulatory acceptance in a way that we, State environmental agencies, can now respond to the real or perceived barriers to environmental technology deployment.

Again, congratulations on your success. The Department through the Commerce Commission and the Department of Treasury will continue to work closely with Regenesis to provide appropriate assistance through a broad array of market applications. A market assistance program that is immediately available is through the Brownfields and Contaminated Sites Remediation Act NJSA 58:10B-6a. This Act can provide matching funding through the Hazardous Discharge Site Remediation Fund for up to 50% or $200,000 of the project cost to perform the remedial action certified by NJDEP.

Sincerely,

Robert C. Shinn
Commissioner

Enclosure

c: Bob Tudor, Deputy Commissioner
Marlen Dooley, Deputy Commissioner
Susan Boyle, Assistant Commissioner Site Remediation
Dennis Hart, Assistant Commissioner Environmental Regulation
Leslie McGeorge, Assistant Commissioner Environmental Planning and Science

1. Introduction

Regenesis, Inc. has developed a technology called Hydrogen Release Compound, HRC, which is a passive treatment alternative for in-situ anaerobic bioremediation of chlorinated compounds. HRC is a proprietary, polylactate ester formulated for the slow release of lactic acid upon hydration. The lactic acid is the source of hydrogen, which can promote reductive dechlorination in the anaerobic subsurface. The reductive dechlorination process can reduce compounds such as perchloroethylene and trichloroethylene to simple and non-toxic endpoints.

A. New Jersey Department of Environmental Protection Technology Certification Program

There is a number of technical regulatory and economic barriers that have been identified which hinder the acceptance of Innovative Environmental Technologies (IETs). Some of the principle barriers center on regulatory acceptance of IETs. In general, new technologies must overcome a two step approval process. First, they must gain the approval from risk-adverse business managers and responsible parties to specify the use of the IETs, and then they need to gain approval from risk-adverse permit writers. This barrier is then magnified when the technology attempts to gain approval in other states.

Technology acceptance can be enhanced by independent third-party review of performance data. The New Jersey Department of Environmental Protection (NJDEP) in cooperation with the New Jersey Corporation for Advanced Technology (NJCAT) has launched an effort to evaluate IETs. This verification/certification program is designed to allow technology vendors to submit information about their technologies along with specific claims regarding the performance of the technology. This information along with data to support the claims will then be reviewed and verified by NJCAT and when appropriate, certification of the technologies' performance will be issued by NJDEP.

It is anticipated that this verification/ certification process will increase both business and regulators understanding of an IET and that the technology's performance, as independently evaluated, will work as claimed.

Both NJDEP and NJCAT are working with other States and Countries on reciprocity agreements, which could interconnect state permitting agencies by recognizing standard protocols for verification of IETs performance. These protocols would assure that technologies are evaluated in a uniform manner assuring minimum standards for quality assurance and quality control (QA/QC). The certification can be viewed by states as tool to predict similar performance under similar conditions.

This certification process is not a replacement nor should it be viewed or construed in any way as advocating or supporting a reduction in current NJDEP environmental performance standards for air, water or soil end points. The certification is not a site-specific permit or a replacement for a site-specific permit; however, it is anticipated that the certification of an IET may facilitate certain permit conditions. For example, in this case, any evaluation of HRC would begin with the site-specific application, bypassing the initial review of the technology.

Finally, it must be noted that certification of an IET does not in any way endorse the manufacturer or guarantee future performance of the technology. It is a report of an independent, verified application of the technology directly related to a set of performance claims.

B. Technology Verification Report

In January 2000, Regenesis Bioremediaiton Products, 1011 Calle Sombra, San Clemente, California, submitted a formal request for participation in the NJCAT Technology Verification Program. The technology involves the controlled release of hydrogen in the subsurface to allow a passive treatment option for in-situ anaerobic bioremediation of chlorinated substances. This request was accepted and a verification report was prepared and submitted to the NJDEP.

C. Technology Description

1. Technology Status

Early 1997 marked the beginning of product development for HRC. HRC is a source of hydrogen that can function as an electron donor in an anaerobic bioremediation system. The product is designed to remediate groundwater contaminated with anaerobically degradable compounds such as perchloroethylene (PCE) and trichloroethylene (TCE). To date, the product has been applied at over 50 sites, primarily in the United States.

2. Technology Applicability

Regenesis has produced a manual guiding the use of the HRC. The manual describes the demand factors on HRC to determine how much to use and where to apply it. Site specific issues are also discussed which can contraindicate the use of HRC. The manual contents assume that the remediation designer has a background in environmental engineering with an emphasis on aquifer bioremediation, but provides the necessary detail and calculation support to assist in developing a natural attenuation/bioremediation design using ORC or HRC.

Regenesis has also created software to simplify and automate the bioremediation evaluation and design process. This software is free from Regenesis. This software is updated as new knowledge and experiences in its use are gained.

2. Applicant

Regenesis evolved from a company called Plant Research Laboratories (PRL), which made Oxygen Plus Plant Food, a fertilizer that was enhanced with oxygen. The oxygen was derived from a stabilized source of urea hydrogen peroxide. Oxygen Plus was designed to alleviate a condition known as soil anaerobiosis. When soils are subjected to flooding, oxygen is limited to the miniscule amount that is soluble in water, and this has a negative impact on plant growth. In the early 1990's the company realized the potential application of this substance in bioremediation. It was renamed Oxygen Release Compound (ORC).

Incorporated in March 1994, Regenesis was founded to extend PRL's work to develop and commercialize ORC for aerobic bioremediation. After extensive laboratory and field testing, ORC was introduced to the market in the spring of 1995. Early 1997 marked the beginning of product development for Hydrogen Release Compound, HRC.

3. Treatment System Description

The natural biodegradation of chlorinated compounds is far more complex than that of petroleum hydrocarbons, and because the densities of most chlorinated compounds are greater than the density of water, their distribution in aquifers is typically far more complex. Biodegradation of many chlorinated ethenes and ethanes does not occur or is quite slow under aerobic conditions. Other chlorinated compounds do degrade under aerobic conditions whereby the chlorinated compound serves as a substrate or as a co-metabolite. Under anaerobic conditions most chlorinated solvents undergo reductive dechlorination. Reductive dechlorination results in the sequential removal of chlorine atoms, generating a series of intermediate degradation products. Depending upon the geochemical conditions and specific microorganisms responsible for degradation, the process may proceed to completely dechlorinate compounds or terminate after removal of only some of the chlorine atoms. Some partially dechlorinated compounds may be degraded under aerobic or iron reducing conditions.

The reductive dechlorination processes in which the chlorinated compounds serve as electron acceptors require the presence of electron donors. HRC is a source of hydrogen and hydrogen is an electron donor. The electron acceptor is the contaminant itself-most commonly a higher-order chlorinated hydrocarbon such as perchloroethylene (PCE) or trichloroethylene (TCE). HRC promotes the microbially mediated, sequential destruction of chlorinated compounds under anaerobic conditions. This essentially translates to the removal, under anaerobic conditions, of various numbers of chlorine atoms from the molecule until it is rendered either benign or aerobically degradable, whichever comes first. In a common example of this reaction sequence, one begins with perchloroethylene (PCE), which has four chlorine atoms. Under the influence of HRC, and under the right chemical and biological conditions, PCE is reduced to TCE (three chlorine's), then to dichloroethylene (DCE) (two chlorine's), and then to vinyl chloride (VC) (one chlorine). The VC is toxic and must then be reduced to the chlorine-free ethene skeleton that was originally filled with the four chlorines. The reactions from DCE on down can occur under both anaerobic and aerobic conditions. Usually the HRC application is enough, but sometimes a switch to aerobic conditions is warranted.

Reductive dechlorination describes the anaerobic phase of the mechanism just described and can often bring the molecule to its fully dechlorinated form. In reductive dechlorination, anaerobic microbes substitute hydrogen for the chlorine in the molecule using both the hydrogen and electrons that result from the breakdown of HRC. Therefore, HRC offers a physically passive treatment option for *in-situ* anaerobic bioremediation of chlorinated compounds.

HRC is a proprietary, environmentally safe, food quality, polylactate ester formulated for the slow release of lactic acid upon hydration. The lactic acid is important because it produces hydrogen. Many organic substances can serve as sources of hydrogen through fermentation reactions; however, lactic acid and related volatile fatty acids are some of the best substrates for this task as it pertains to reductive dechlorination.

There are several site-specific parameters that can affect the performance of HRC:

1. It is important to assess that there are microbes in the aquifer soil capable of dechlorination. The sulfate reducing bacteria (SRB) content should be determined. The rationale is that SRBs thrive at a redox potential that is close to the optimum for dechlorination. Although the dechlorinators are not necessarily SRBs, the presence of SRB indicates that aquifer conditions may be suitable for reductive declorination. One must be aware, however, that a high SRB count also indicates a high level of competition for hydrogen so that more HRC will be required.

2. In natural systems, including contaminated aquifers, most H_2 becomes available to hydrogenotrophic microorganisms through the fermentation of more complex substrates by other members of the microbial consortium. The dechlorinators must then compete

with other organisms, such as methanogens and sulfate-reducing bacteria, for the evolved H_2.

3. The concentrations of Competing Electron Acceptors (CEAs) such as dissolved oxygen, nitrate, ferric iron, and sulfate have an effect on the amount of HRC required for enhancing *in-situ* bioremediation. Hydrogen from the HRC is used to reduce these CEAs to create redox conditions that are conducive to reductive dechlorination processes. As a result, the CEA demand for hydrogen (and consequently HRC) must be considered in the specification of the amount of HRC required for a project. Groundwater data indicating the actual site values for these parameters are important in determining an accurate final design for HRC application.

Regenesis has a patent pending in the United States for HRC.

4. Technical Performance Claims

Claim 1 – Pilot and full-scale field demonstrations have shown, depending on site conditions and the formulation of the product, that HRC remains for four months to a year, releasing lactic acid.

Claim 2 – Lactic acid released from HRC, in the presence of indigenous anaerobic microbes, can be fermented to released hydrogen which can serve as an electron donor for biological reductive dechlorination.

Claim 3 – Perchloroethylene (PCE) and trichloroethylene (TCE) have been shown to be bioremediated in the presence of the hydrogen electron donor in microbially competent aquifers.

Claim 4 – During the period that the HRC releases lactic acid, the potential for the enhancement of natural rates of reductive dechlorination exist.

5. Treatment System Performance and Technical Evaluation and Verification of Performance Claims

The NJCAT Technology Verification for HRC is attached as Appendix 1. Based on the evaluation of the results from laboratory studies, field demonstrations and peer-reviewed journal articles there is sufficient evidence to support Regenesis Claims 1,2,3 and 4.

This verification signifies NJDEP's acceptance of these claims, and as such, the department will not require Regenis or the responsible party using this technology at a site to resubmit this type of basic technology information in the future. The acceptance of HRC will allow the Department in subsequent cases to simply review the site-specific application of HRC. This should reduce the workload for case managers and shorten the review time for work plans.

6. Limitations of HRC Performance

The review of this information also indicates that there are some limitations of HRC that should be discussed. HRC is best utilized for the remediation of dissolved phase plumes and the associated hydrophobically sorbed contaminant. The use of HRC for the remediation of free-phase DNAPL is generally not appropriate, since the stoichiometrically required levels of product would be excessive, unless the total mass to be remediated is within the scope of economic feasibility in comparison to alternative treatments.

HRC injected into highly heterogeneous aquifers will not effect dechlorination in contaminated areas that are not hydraulically connected to the HRC injection zone.

In some instances, extremely high background sulfate levels (on the level of several hundred ppm or greater) generate concern, as the reduction of sulfate will consume some of the available hydrogen from the lactic acid fermentation reducing the efficiency of dechlorination during the early phase of the treatment.

Dechlorination (degradation) rates of compounds like perchloroethylene (PCE) and trichloroethylene (TCE) are highest under anaerobic conditions. However, daughter products of PCE and TCE, such as dichloroethylene (DCE) and vinyl chloride (VC) – a known carcinogen, degrade more slowly under anaerobic conditions. The reactions from DCE on down may actually degrade faster under aerobic conditions. Frequently the HRC application is sufficient to degrade the VC to ethylene, a non-toxic compound. Some sites may benefit from a dual phase approach where an electron donor, e.g., HRC and an electron acceptor, e.g., ORC (Oxygen Release Compound) are used either concurrently on separate areas of a plume, or sequentially within the plume area.

7. Net Environmental Benefit

The NJDEP encourages the development of IETs and has established a performance partnership between their verification/certification process and NJCAT's third party independent technology verification program. The NJDEP, using the IETs data and technology verification/certification process will work with any New Jersey-based company that can demonstrate a Net Beneficial Effect (NBE) irrespective of the operational status, class or stage of an IET. The NBE is calculated as a mass balance of the IET in terms of its inputs of raw materials, water and energy use and its outputs of air emissions, wastewater discharges, and solid waste residues. Overall the IET should demonstrate a significant reduction of the impacts to the environment when compared to baseline conditions for the same or equivalent inputs and outputs. The Regenesis HRC process is compared with two existing chlorinated hydrocarbon remediation processes to demonstrate the NBE required by NJDEP.

The two alternative remediation technologies chosen are pump and treat and air sparging with soil vapor extraction (SVE). The NBE comparison is based on the KWhr requirements for each remediation technology, assuming a remediation schedule, e.g., five years, for three different size sites. In addition to the information shown in Table 2, the following assumptions were made:

- Well Installation
  - 400 hp engine drilling-rig
  - Three (3) hours per well installation
- HRC Application via Direct Push Methods
  - 150 hp engine – direct push rig
  - 20 hp injection pump (6 hrs per day)
  - Fifteen (15) injections per eight (8) hours

Table 2 – Design Data for Remediation Technologies Selected for Net Environmental Benefit Determination

Remediation Technology	Site Size		
	50' x 75'	0.25 Acre	0.50 Acre
HRC Enhanced Bioremediation (4 applications)	60 injection pts.	110 injection pts.	220 injection pts.
Air Sparging/SVE (5 yrs. operation)	12 AS/4 VE wells 1-5 hp blower	36 AS/12 VE wells 1-10 hp blower	72 AS/24 VE wells 1-20 hp blower
Pump & Treat (10 gpm, 20 yrs)	2–extraction wells 2-1 hp extraction pumps	2–extraction wells 2–2 hp extraction pumps 1–1 hp injection pump	2–extraction wells 2–3 hp extraction pumps 1–1 hp injection pump

Using the information on well installation and HRC application, along with the design data shown in Table 2, life-cycle energy requirements for the three remediation technologies were calculated and are shown in Table 3. The NBE of HRC remediation is clearly evident. In addition, the HRC remediation process avoids the carbon treatment system reactivation or disposal requirements associated with the other two technologies.

Table 3 – Energy Requirements for Current/Proven Remediation Technologies Selected vs. HRC in KWh

Remediation Technology	Site Size		
	50' x 75'	0.25 Acre	0.50 Acre
HRC Enhanced Bioremediation (4 applications)	15,760	28,760	57,524
Air Sparging/SVE (5 yrs operation)	177,715	369,770	950,680
Pump & Treat (10 gpm, 20 yrs)	263,190	689,825	1,393,030

The significant energy savings reflected in the Table 3 can be converted into estimated avoided air emissions for gases of concern such as CO_2, SO_2, and NO_x. Using data on emission factors for CO_2, SO_2, and NO_x for electricity purchase obtained from the Pennsylvania, New Jersey, and Maryland (PJM) power pool, Table 4 compares the current proven technologies with HRC applications for the pounds of air emissions that will be avoided over the lifecycle time periods required. This same methodology can be used to estimate the particulate emissions reductions for total, PM10 and PM 2.5. It can be used to estimate the specific metal emissions reductions resulting from avoided emission including cadmium lead, mercury or any specific metal emissions.

Table 4 – Avoided Air Emission for CO2, SO2 and NOx from Energy Use for Current/Proven Remediation Technologies vs. HRC (in pounds and (tons-rounded to 1 SF))

Remediation Technology	Site Size								
	50' x 75'			0.25 Acre			0.50 Acre		
	CO_2	SO_2	NO_x	CO_2	SO_2	NO_x	CO_2	SO_2	NO_x
Air Sparging/SVE (5 yrs operation)	210,760 (105.4)	1,623 (0.8)	538 (0.3)	443,773 (221.9)	3,478 (1.7)	1,091 (0.5)	1,162,309 (581.2)	8,949 (4.5)	2,858 (1.4)
Pump & Treat (10 gpm, 20 yrs)	321,993 (161.0)	2,479 (1.2)	792 (0.4)	860,271 (430.0)	6,624 (3.3)	2,115 (1.0)	1,737,961 (869.0)	13,382 (6.7)	4,274 (2.1)

The data from Table 3 can also be related to non-contact non- consumptive cooling water use, wastewater discharges and waste generated in the same methodology as for air emissions. The avoided water use, wastewater discharged and waste generated is assessed based on the avoided use of electricity. The NJDEP methodology of Uniform Cross Media Electricity Generation Evaluation System was developed using data on the externality costs of electricity documented by Pace University in their report, *Environmental Costs of Electricity, 1991*. For example, the 0.25 Acre site using HRC would save over 340,000 kilowatt hours (kWhs) of electricity over a typical air sparging operations/SVE for 5 years and over 660,000 kWhs of electricity over a typical 20 year pump and treat operations.

Utilizing the NJDEP's methodology this would result in the avoid use of 22 and 42.8 million gallons of non-consumptive cooling water use over the lifecycle of the proven technologies of air sparging and pump and treat respectively when compared to the HRC use. It would result in 13,600 and 26,400 of avoided wastewater discharge in the use of HRC when compared to the proven technologies over the lifecycle of their use. Further the use of HRC when compared to the proven technologies over their lifecycles would result in 54,400 pounds (27.2 tons) and 105,600 pounds (52.8 tons) of avoided waste generation. Individually the quantity of the avoided impacts are relatively small but when aggregated at a number of sites across New Jersey these avoided impacts can become significant.