



Florida Department of Environmental Protection

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May 11, 2012

Via Electronic Mail
REvans@gesonline.com

Richard K. Evans, P.E.
Groundwater & Environmental Services, Inc.
440 Creamery Way, Suite 500
Exton, Pennsylvania 19341

Re: **HypeAir**
HypeAir-EX
Six-Phase Chemical Oxidation

Dear Mr. Evans:

The Division of Waste Management (Division) hereby accepts HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation, which are chemical oxidation techniques associated with U.S. Patent 7,175,770 for the remediation of hydrocarbons, chlorinated hydrocarbons, and other suitable contaminants in soil and groundwater, in situ and ex situ. The oxidants used with the patented delivery system's single and nested "Max-Ox" injection points for each of the three techniques include but are not necessarily limited to hydrogen peroxide, ozone, and oxygen, and in the case of Six-Phase Chemical Oxidation, sodium persulfate as well. Enclosure 1 contains regulatory information and Enclosure 2 contains supplemental information.

HypeAir is a short-term treatment technique employed for approximately 5 days or less at a time, and it is suitable for situations in which a series of such short term events are conducted periodically over the course of approximately a year. The equipment associated with this technique is usually mobile, self-contained and self-powered. The oxidants are usually hydrogen peroxide and ozone, and their injection rates and concentrations are selected for short-term effectiveness.

HypeAir-EX is a medium to long-term technique employed for situations in which a treatment system must be operated continuously for 1 to 24 months. The equipment is usually trailer-mounted or container-mounted. The oxidants are usually hydrogen

peroxide and ozone, and their injection rates and concentrations are selected for medium to long-term effectiveness.

Six-Phase Chemical Oxidation can be used to enhance either HypeAir or HypeAir-EX. It uses sodium persulfate as an additional oxidant, and derives its name from the six oxidizing species involved: hydrogen peroxide, hydroxyl radicals, ozone, oxygen, sodium persulfate, and sulfate radicals.

The Division does not provide endorsement of specific or brand name remediation products or processes, but it does recognize the need to determine their acceptability in the context of environmental regulations, safety and the protection of public health. For that reason, the Division issues an “acceptance” letter, not an approval. In no way shall an acceptance be construed as a certification of performance. Additionally, vendors, upon receipt of an acceptance, must market their product or process on its own merits regarding performance, cost, and safety in comparison to competing alternatives in the marketplace.

Remedial Action Plans that propose the use of an accepted product or process should include a copy of the acceptance letter in the plan’s appendix, and reference it in the text of the document. It is not a requirement that a particular remediation product or process have an official acceptance letter in order for it to be proposed in a site-specific Remedial Action Plan. The plan, however, must contain sufficient information about the product or process to show that it meets all applicable rules and regulations.

The Division reserves the right to revoke its acceptance of a product or process if it has been falsely represented. Additionally, Division acceptance of any product or process does not imply it has been deemed applicable for all cleanup situations, or that it is preferred over other treatment or cleanup techniques in any particular case. A site-specific evaluation of applicability and cost-effectiveness must be considered for any product or process, whether conventional or innovative, and adequate site-specific design details must be provided in a Remedial Action Plan submitted for Department review and approval. If you have any questions, please contact us at the numbers below.

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HypeAir
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Sincerely,

X *Rick Ruscito*

Rick Ruscito, P.E.
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X *Gary Millington*

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enc: (1) Regulatory Information
(2) Supplemental Information

c: Tom Conrardy, P.E. – FDEP/Tallahassee
Rob Cowdery, P.E. – FDEP/Tallahassee

History

PPL #441, 442, 443
INN_188 - 5/11/12

REGULATORY INFORMATION

- a. Regulations: Chapters of the Florida Administrative Code (F.A.C.) that may be applicable, either in part or in their entirety, include but are not necessarily limited to Chapter 62-550, F.A.C., for primary and secondary water quality standards; Chapter 62-520, F.A.C. for groundwater classes and standards, and groundwater permitting and monitoring requirements; Chapter 62-528, F.A.C., for Underground Injection Control (UIC), particularly Part V, for Class V, Group 4 aquifer remediation projects; Chapters 62-770, 62-780, 62-782, and 62-785 F.A.C., for cleanup criteria; and Chapter 62-777, F.A.C., for cleanup target levels.

Users of the HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation techniques shall comply with all applicable regulations. This includes meeting applicable groundwater cleanup target levels for the contaminants of concern, the residual concentrations of reagent ingredients, and any byproducts of concern produced by chemical and biological reactions induced by those ingredients during the timeframe of the cleanup project. For the ingredients of concern that are present in excess of their groundwater standards, the timeframe is that which is permitted for a temporary injection zone of discharge (ZOD) as described below.

- b. UIC and ZOD permits: Per Rule 62-528.630(2)(c), F.A.C., Class V injection-type aquifer remediation wells are exempt from the permitting requirements of Rule 62-528.635, F.A.C., when authorized by a Department-approved Remedial Action Plan or other enforceable mechanism, provided the requirements of the rules governing the remediation project, as well as the construction, operation, and monitoring requirements of Chapter 62-528, F.A.C., are met. Per Rule 62-528.630(2)(c), F.A.C., the issuance of an enforceable, site-specific Remedial Action Plan Approval Order by the Department for injection-type aquifer remediation constitutes the granting of a Class V injection well construction/clearance permit. And per Rule 62-520.310(8)(c), F.A.C., if a temporary ZOD is necessary, and permissible by way of that rule, then the issuance of the site-specific Remedial Action Plan Approval Order also constitutes the granting of permission for the temporary ZOD.
- c. UIC notification: Remedial Action Plans proposing injection-type aquifer remediation shall include information pursuant to Rules 62-528.630(2)(c)1 through 6, F.A.C., for the inventory purposes of the UIC program. Reviewers of those plans, upon issuance of an enforceable Remedial Action Plan Approval Order by the Department, must submit a completed copy of the UIC inventory notification form to the UIC program in Tallahassee.

- d. Injection volumes and concentrations: Site-specific Remedial Action Plans shall indicate both the volume and concentration of each chemical to be injected. For ozone, oxygen, and other gases, the number of pounds to be injected during the operating period of active remediation can be indicated instead if it is more convenient, otherwise express the amount of each gas as a volume at a specified or standard temperature and pressure.
- e. General information about temporary ZODs: For groundwater remediation, the composition of an injected material must meet the primary and secondary drinking water standards set forth in Chapter 62-550, F.A.C., and the minimum groundwater criteria of Chapter 62-520, F.A.C., pursuant to UIC Rule 62-528.600(2)(d), F.A.C. Aquifer remediation products that do not meet these requirements must seek relief from water quality criteria by one of two mechanisms. Permission for a temporary ZOD may be obtained via Rule 62-520.310(8)(c), F.A.C. If a ZOD cannot be obtained by rule, it will be necessary to seek a variance from Department rules in accordance with Section 120.542, Florida Statutes.

Rule 62-520.310(8)(c), F.A.C., allows for a temporary ZOD for closed-loop re-injection systems, for the prime constituents of the reagents used to remediate site contaminants, and for groundwater secondary standards. In order to obtain permission for a temporary ZOD by rule, a site-specific Remedial Action Plan must indicate: (a) the chemical ingredients of concern in the fluid to be injected that will be present in excess of groundwater standards; (b) the size of the ZOD that is needed; (c) the amount of time that the ZOD will be needed; and (d) a plan for monitoring the injected chemical ingredients of concern. The size of the temporary ZOD will usually be the injection well radius of influence when the treatment system is a single injection point. For a multiple point system, the ZOD can usually be expressed and illustrated as the total area of the cluster formed by all the injection points, located side-by-side with overlapping radii of influence.

- f. Specific ZOD information: Seek permission for a temporary ZOD by way of Rule 62-520.310(8)(c), F.A.C., for the parameters associated with each chemical listed below when it is used in conjunction with the HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation methods. Seek such permission only if the value of the parameter in the fluid to be injected is in excess of one or more of its established groundwater standards for concentration, pH, and total dissolved solids. These are the chemicals most commonly injected when these methods are used. Not every cleanup will require the use of every chemical on the list, but it is likely that more than one will be used.

Hydrogen peroxide: pH

Ferrous sulfate (catalyst): iron, sulfate, and total dissolved solids

Oxygen: none

Ozone: None, but notify the Underground Injection Control Section about the amount of this short-lived but reactive substance to be injected.

Sodium persulfate: sodium, sulfate, total dissolved solids and pH. If FMC Klotz brand is used, then include iron and manganese. If the concentration of FMC sodium persulfate in the fluid to be injected is greater than 20% by weight, then also include chromium and seek permission by way of variance for a chromium ZOD. Other brands of sodium persulfate can be used but an assay of heavy metals and other impurities must be provided to determine whether their concentrations in the fluid to be injected will meet groundwater standards, or whether they are high enough to trigger the need to seek ZOD permission by way of variance.

Chloride (byproduct): If the cleanup project is for the remediation of chlorinated contaminants, and the potential exists for chloride byproduct to be formed in excess of its groundwater standard, then seek permission for a chloride ZOD by way of Rule 62-520.310(8)(c), F.A.C.

Other chemicals: HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation are associated with a patented method and delivery system that may use a variety of chemicals. If a chemical other than those listed above will be used, then the site-specific Remedial Action Plan shall include all the information necessary to obtain permission for a ZOD by way of Rule 62-520.310(8)(c), F.A.C., or by variance if permission by rule is not possible. If the Division of Waste Management has already issued a separate acceptance for a chemical not listed above, then follow the ZOD advice for that chemical when used in conjunction with HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation.

- g. ZOD monitoring advice: For the ZOD parameters listed in paragraph f above, quarterly monitoring of groundwater should suffice in most cases. The current groundwater standards for those chemical species and parameters are as follows: pH, range 6.5-8.5; iron, 0.3 mg/L; total dissolved solids, 500 mg/L; sodium, 160 mg/L; sulfate, 250 mg/L; and chloride, 250 mg/L. Upon expiration of the time period granted for the ZOD, the concentration of each must meet its respective groundwater standard, or its natural-occurring background value at the specific cleanup site, whichever is less stringent.
- h. Utilization of wells: If a remediation site happens to have an abundance of monitoring wells, then the Division has no objection to the use of some wells for the application of chemicals associated with HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation. However, no "designated" monitoring well, dedicated to the tracking of remediation progress (by sampling) shall be used to apply reagents. This will avoid premature conclusions that the entire site meets cleanup goals. By making sure that designated tracking wells are not also used for treatment, there

will be more assurance that the treatment process has permeated the entire site and that it did not remain localized to the area immediately surrounding each injection well.

- i. Avoidance of migration: Pursuant to Rule 62-528.630(3), F.A.C., for injection-type, in-situ aquifer remediation, the injection of remediation products shall be performed in such a way, and at such a rate and volume, that there is no undesirable migration of either the site's contaminants of concern, the products' ingredients of concern, or any byproducts of concern that are produced by any chemical and biological reactions induced by the product's ingredients.
- j. Abandonment of wells: Upon issuance of a Site Rehabilitation Completion Order, injection wells shall be abandoned pursuant to Section 62-528.645, F.A.C., and the Underground Injection Control Section of the Department shall be notified so that the treatment wells can be removed from the injection well inventory-tracking list.
- k. Open-pit application: The use of chemicals associated with HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation to remediate the exposed groundwater in an open pit is not an injection, and notification of the UIC Section is not required. But as a prudent measure, the groundwater in the application area should be monitored for the same zone of discharge parameters as if the chemicals applied had actually been injected and subject to the requirements of rule 62-520.310(8)(c), F.A.C.

ENCLOSURE 2

HypeAir
HypeAir-EX
Six-Phase Chemical Oxidation
May 11, 2012

SUPPLEMENTAL INFORMATION

- a. Operating parameters: Tables 1,2 and 3 below are reprints of the operating parameters provided by Groundwater & Environmental Services Incorporated for HypeAir, HypeAir-EX, and Six-Phase Chemical Oxidation.

Table 1: HypeAir Operating Parameters

Category	Parameter	Typical Operating Range	Comments
Hydrogen Peroxide	Concentration	8 – 17.5 %	May be pre-diluted or diluted on site.
Hydrogen Peroxide	Injection Flow Rate	0.5 – 5 gallons per minute (gpm) per well	Site specific; HypeAir platforms usually inject in up to three wells simultaneously.
Hydrogen Peroxide	Injection Pressure	0 – 30 pounds per square inch (psi)	Injection pressures up to 50 psi can be obtained with standard HypeAir equipment.
Hydrogen Peroxide	Injection Volume	200 – 5,000 gallons per day (gpd)	
Ozone	Concentration	4,000 – 17,000 parts per million (ppm)	Ozone concentration decreases as total air/gas injection rate increases. HypeAir ozone units can produce up to 45,000 ppm of ozone.
Ozone	Mass Flow Rate	2 – 8 pounds per day (lb/day)	Based on ozone unit installed on HypeAir platform.
Ozone	Volumetric Flow Rate	Up to 23 standard cubic feet per hour (scfh) ozone	Co-injected with air or oxygen. Typical total gas injection flow rate is 1 – 5 standard cubic feet per minute (scfm) but may vary.
Ozone	Injection Pressure	< 30 psi	
Groundwater	Dissolved Oxygen Concentration	2 milligrams per liter (mg/L)	Dissolved oxygen (DO) increases are observed during injection with less increase as distance increases. DO may increase by > 100 %.
Groundwater	pH	4 – 8 standard units (SU)	HypeAir can be applied at a range of groundwater pH. HypeAir does not require pH adjustment though groundwater pH may decrease during injection depending on soil buffering capacity (free H ⁺ ions generated)
Groundwater	Temperature	10 – 20 degrees Celcius (°C)	Temperature increases may be observed during HypeAir, but increases greater than 10 °C are not expected. Temperature excursions above this range typically result in a temporary work stoppage to evaluate site activities before proceeding.
Groundwater	Oxidation-Reduction Potential	< 0 microSiemens (uS)	Oxidation-Reduction Potential (ORP) is often negative at petroleum impacted sites (reductive) and increases to positive ORP as oxidant is added. ORPs > 300 uS may be observed during operation.

Table 2: HypeAir-EX Operating Parameters

Category	Parameter	Typical Operating Range	Comments
Hydrogen Peroxide	Concentration	10 – 33 %	May be pre-diluted or diluted on site.
Hydrogen Peroxide	Injection Flow Rate	0.5 – 3.5 gallons per hour (gph) per well	Site specific; HypeAir-EX platforms usually inject into multiple wells simultaneously.
Hydrogen Peroxide	Injection Pressure	0 – 30 pounds per square inch (psi)	Injection pressures up to 50 psi can be obtained with standard HypeAir-EX equipment.
Hydrogen Peroxide	Injection Volume	20 – 80 gallons per day (gpd)	
Ozone	Concentration	4,000 – 100,000 parts per million (ppm)	Ozone concentration decreases as total air/gas injection rate increases.
Ozone	Mass Flow Rate	5 – 80 pounds per day (lb/day)	Based on ozone generators currently installed on HypeAir-EX platforms.
Ozone	Volumetric Flow Rate	Up to 40 standard cubic feet per hour (scfh) ozone	Co-injected with air or oxygen. Typical total gas injection flow rate is 1 – 5 standard cubic feet per minute (scfm) but may vary.
Ozone	Injection Pressure	< 30 psi	
Groundwater	Dissolved Oxygen Concentration	2 milligrams per liter (mg/L)	Dissolved oxygen (DO) increases are observed during injection with less increase as distance increases. DO may increase by > 100 %.
Groundwater	pH	4 – 8 standard units (SU)	HypeAir-EX can be applied at a range of groundwater pH. HypeAir-EX does not require pH adjustment though groundwater pH may decrease during injection depending on soil buffering capacity (free H ⁺ ions generated)
Groundwater	Temperature	10 – 20 degrees Celcius (°C)	Temperature increases may be observed during HypeAir-EX, but increases greater than 10 °C are not expected. Temperature excursions above this range typically result in a temporary work stoppage to evaluate site activities before proceeding.
Groundwater	Oxidation-Reduction Potential	< 0 microSiemens (uS)	Oxidation-Reduction Potential (ORP) is often negative at petroleum impacted sites (reductive) and increases to positive ORP as oxidant is added. ORPs > 300 uS may be observed during operation.

Table 3: Six-Phase Chemical Oxidation Operating Parameters

Category	Parameter	Typical Operating Range	Comments
Hydrogen Peroxide	Concentration	8 – 33 %	May be pre-diluted or diluted on site.
Hydrogen Peroxide	Injection Flow Rate	0.5 – 5 gallons per minute (gpm) per well	Site specific; Six-Phase Chemical Oxidation platforms usually inject in up to three wells simultaneously.
Hydrogen Peroxide	Injection Pressure	0 – 30 pounds per square inch (psi)	Injection pressures up to 50 psi can be obtained with standard Six-Phase Chemical Oxidation equipment.
Hydrogen Peroxide	Injection Volume	200 – 5,000 gallons per day (gpd)	
Sodium Persulfate	Concentration	5 – 25%	May be pre-mixed or mixed on site from manufactured granular solid.
Sodium Persulfate	Injection Flow Rate	0.5 – 5 gallons per minute (gpm) per well	Site specific; Six-Phase Chemical Oxidation platforms usually inject in up to three wells simultaneously.
Sodium Persulfate	Injection Pressure	0 – 30 pounds per square inch (psi)	Injection pressures up to 50 psi can be obtained with standard Six-Phase Chemical Oxidation equipment.
Sodium Persulfate	Injection Volume	200 – 5,000 gallons per day (gpd)	
Ozone	Concentration	4,000 – 100,000 parts per million (ppm)	Ozone concentration decreases as total air/gas injection rate increases. Six-Phase Chemical Oxidation ozone units can produce up to 45,000 ppm of ozone.
Ozone	Mass Flow Rate	2 – 80 pounds per day (lb/day)	Based on ozone unit installed on Six-Phase Chemical Oxidation platform.
Ozone	Volumetric Flow Rate	Up to 40 standard cubic feet per hour (scfh) ozone	Co-injected with air or oxygen. Typical total gas injection flow rate is 1 – 5 standard cubic feet per minute (scfm) but may vary.
Ozone	Injection Pressure	< 30 psi	
Groundwater	Dissolved Oxygen Concentration	2 milligrams per liter (mg/L)	Dissolved oxygen (DO) increases are observed during injection with less increase as distance increases. DO may increase by > 100 %.
Groundwater	pH	4 – 8 standard units (SU)	Six-Phase Chemical Oxidation can be applied at a range of groundwater pH. Six-Phase Chemical Oxidation does not require pH adjustment though groundwater pH may decrease during injection depending on soil buffering capacity (free H ⁺ ions generated)
Groundwater	Temperature	10 – 20 degrees Celcius (°C)	Temperature increases may be observed during Six-Phase Chemical Oxidation, but increases greater than 10 °C are not expected. Temperature excursions above this range typically result in a temporary work stoppage to evaluate site activities before proceeding.

b. Safety reminders: Considerations to keep in mind include but are not necessarily limited to the items below.

- Use of proper protective clothing.
- Observe all safety precautions associated with oxidizers.
- Proper handling and storage of catalysts and oxidizers, and consideration for their compatibility with other chemicals that may be placed alongside them in storage facilities.
- Do not mix catalysts and oxidizers prior to application because it is a reactive mixture.
- Use of containers, tanks and piping constructed from materials that are compatible with the chemicals being used.
- Proper disposal of unused or unwanted catalysts and oxidizers.

Additional safety items to consider for chemical oxidation processes at petroleum cleanup sites are listed in the Bureau of Petroleum Storage Systems' Remedial Action Plan Checklist. The chemical oxidation safety topics in that checklist are general in nature and applicable to hazardous waste cleanup projects as well.