Florida Department of
Environmental Protection

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August 13, 2008

John Archibald
inVentures Technology, Inc.
670 Wilsey Road
Fredericton, New Brunswick E3B 5C8, Canada

Re: **in situ Submerged Oxygen Curtain (iSOC®) and iSOC with Hydrogen (HiSOC®)**

Dear Mr. Archibald:

The Bureau of Waste Cleanup (Bureau) hereby accepts the in-situ Submerged Oxygen Curtain (iSOC®) and in-situ Submerged Oxygen Curtain with Hydrogen (HiSOC®) as devices that dissolve oxygen and other gases into groundwater for the purpose of in-situ biodegradation of contaminants and has no objections to their use provided a site-specific Remedial Action Plan (RAP) for the cleanup of contamination pursuant to Chapters 62-780, 62-782, or 62-785, F.A.C., is approved by the Department. Regulatory information is provided in Enclosure 1.

The Bureau does not provide endorsement of specific or brand name remediation products or processes; however, it does recognize the need to determine their acceptability in the context of environmental regulations and protection of public health and safety. In no way shall this regulatory acceptance letter be construed as Department certification of performance. Additionally, the Department emphasizes a distinction between its regulatory "acceptance" letter and an approval. Products and processes are accepted but they are not approved. Vendors must market the products and processes on their own merits regarding performance, cost, and safety in comparison to competing alternatives in the marketplace.

RAPs that include the use of an "accepted" product should include a copy of the acceptance letter in the RAP's appendix and reference it in the text of the document. To aid regulatory agency reviewers, supplemental information is provided as Enclosure 2. 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 RAP. The RAP, however, must contain sufficient information about the product or process to show that it meets all applicable rules and regulations.

The Bureau reserves the right to revoke its acceptance of a product or process if it has been misrepresented. Additionally, Bureau 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 RAP. Please contact me at (850) 245-7502, if there are any questions.

Sincerely,

Gary Millington, P.E.
Program & Technical Support Section
Bureau of Waste Cleanup

c: Don Ray
Performance Technologies, Inc.
337 Hunters Crossing
Tallahassee, Florida 32312

T. Conrardy - FDEP/Tallahassee
R. Cowdery - FDEP/Tallahassee

REGULATORY INFORMATION

1. Regulations: Users of the iSOC and HiSOC technologies shall ensure that all applicable groundwater contaminant standards are met at the time of project completion for the contaminants of concern, any residuals associated with the gases dissolved into the groundwater, and any byproducts of concern produced as a result of chemical or biochemical reactions involving those gases. The following chapters of the Florida Administrative Code (F.A.C.) are cited: Chapter 62-550, F.A.C., for primary and secondary water quality standards; Chapter 62-520, F.A.C. for groundwater classes and standards; Chapter 62-522, F.A.C., for groundwater permitting and monitoring requirements; Chapter 62-528, F.A.C., for underground injection control, 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.

   Chapter 62-520, F.A.C., requires groundwater to be free from substances that are harmful to plants, animals, and organisms, and free from substances that are carcinogenic, mutagenic, teratogenic or toxic to human beings. These "free from" requirements prohibit injection of potentially harmful products that are not regulated as specific primary or secondary drinking water contaminants.

2. Gases covered by this acceptance: Since the iSOC® and HiSOC® delivery devices are capable of infusing a wide range of gases into water, an attempt to cover every conceivable application in this acceptance would be impractical. Therefore, the scope of this acceptance is limited to ten (10) gases. For iSOC: the gaseous alkanes (methane, ethane, propane and butane); ammonia; carbon dioxide; ethylene; hydrogen sulfide; and oxygen. For HiSOC: hydrogen.

   It is incumbent on the submitter of a site-specific RAP to take into account the gas flammability, reactivity, toxicity, and any other safety considerations that are necessary. The residual concentration of the gas and any degradation byproducts of concern that remain in the groundwater upon completion of a remediation project must meet the minimum groundwater criteria of Chapter 62-520, F.A.C.

3. Groundwater criteria for gases covered by this acceptance: For the ten gases covered by this acceptance, the table below provides minimum groundwater criteria that serve as the groundwater cleanup target levels (GCTLs). For ammonia, butane, and hydrogen sulfide, the GCTLs are specified in Table 1 of Chapter 62-777, F.A.C. For the other gases listed in the table below, GCTLs were calculated using the method provided in Chapter 62-777, F.A.C., for non-carcinogens. For these calculations, it is assumed that an oral reference dose is equivalent to the inhalation reference dose in a route-to-route exposure conversion. No GCTL was calculated for oxygen.

   Hydrogen sulfide deserves the most attention because of its toxicity. By the time a remediation project involving this gas is completed, its residual groundwater concentration cannot exceed 21 micrograms per liter (µg/L). For ammonia, the minimum criteria set forth in Chapter 62-777, F.A.C., is 2,800 µg/L. With a relatively high solubility of 34%, prospective users of this gas may need to take into account its potential to remain in the groundwater at high residual concentrations after the contaminants of concern at a cleanup

site have been remediated. To avoid a lengthy waiting period during which the ammonia concentration attenuates to the acceptable level, it may be advisable to use no more than the necessary amount to accomplish remediation objectives. Butane is a gaseous alkane for which the Department has developed a minimum groundwater criterion of 9,100 µg/L.

For hydrogen at 20 degrees C and 1 atmosphere, the calculated 6,700 µg/L GCTL is greater than its 1,600 µg/L solubility limit. Therefore, the solubility limit will be the maximum allowable (possible) residual concentration for hydrogen applications until a depth is reached at which the pressure and temperature are such that the solubility is no longer less than or equal to 6,700 µg/L. Below that depth, the maximum allowable residual guidance concentration shall be 6,700 µg/L.

Gas	Groundwater Cleanup Target Level per Chapter 62-777, F.A.C. (micrograms per liter, µg/L) ♦
Methane	3,100 ■ †
Ethane	5,900 ■ †
Propane	8,700 ■ †
Butane	9,100
Ammonia	2,800
Carbon Dioxide	43,600 ● †
Ethylene	1,100 ▲ †
Hydrogen	6,700 ‡
Hydrogen Sulfide	21
Oxygen	Not calculated. Relatively benign

♦ The criteria for ammonia, butane, and hydrogen sulfide are specified in Table 1 of Chapter 62-777, F.A.C. The other criteria listed here are calculated in accordance with the method provided in Chapter 62-777, F.A.C., for non-carcinogens.

■ When calculating the 3,100 µg/L for methane, the 5,900 µg/L for ethane and the 8,700 µg/L for propane, the 1,000 parts per million by volume (ppm/v) 8-hour, 5-day Time-Weighted Average (TWA) Threshold Limit Value (TLV) exposure recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for each of these alkanes was mathematically adjusted to a 24-hour, 7-day basis.

● When calculating the 43,600 µg/L for carbon dioxide, the 5,000 ppm/v, 8-hour, 5-day TWA TLV exposure recommended by the ACGIH was mathematically adjusted to a 24-hour, 7-day basis.

▲ When calculating the 1,100 µg/L for ethylene, the 200 ppm/v, 8-hour, 5-day TWA TLV exposure recommended by the ACGIH was mathematically adjusted to a 24-hour, 7-day basis.

† Conversion of TLV ppm/v to milligrams per cubic meter (mg/m^3) was calculated at 21.1 degrees Centigrade. The 8-hour, 5-day TWA TLV in mg/m^3 was mathematically adjusted to a 24-hour, 7-day Inhalation Reference Dose (RfDi). This RfDi is assumed equivalent to an Oral Reference Dose (RfDo) for extrapolation of route-to-route exposure, a reasonable assumption in this case if bioavailability by the inhalation and oral routes are both assumed to be 100%. A safety factor (SF) of 100 is used. The amount of air breathed by a human in one day is 20 m^3, and the average adult body weight is 70 kilograms (kg). 2 liters per day (L/d) is the amount of water consumed by an adult human. 0.2 is a Relative Source Contribution (RSC) factor for other sources of exposure, and 1,000 µg/mg is a conversion factor. Equations used to determine the calculated values of Groundwater Cleanup Target Levels (GCTL) in micrograms per liter (µg/L) are shown below.

‡ ACGIH TWA TLV information is not available for hydrogen. However, NASA, for spacecraft, and the U.S. Navy, for submarines, occupied for lengthy periods of time, both consider 4,100 ppm/v hydrogen (or 10% of its 41,000 ppm/v lower explosive limit) a reasonable 90-day Continuous Exposure Guidance Level (CEGL). Since 4,100 ppm/v is already a continuous exposure concentration, it was not adjusted to a 24-hour, 7-day exposure basis in the equations below. That is, the (8/24) and (5/7) adjustment terms in the equation below were omitted when calculating the residual groundwater concentration of 6,700 µg/L.

RfDi (as milligrams per kilogram per day) = [(TLV mg/m^3) x (8hr/24hr) x (5days/7days) x (20 m^3)] / [(100 sf) x (70 kg)]

RfDi = RfDo (assumption)

GCTL (in µg/L) = [(RfDo) x (0.2 RSC) x (70 kg) x (1,000 µg/mg)] / [2 L/d]

By the time a cleanup project is completed, the residual concentration of each gas injected during the course of remedial action must not exceed the GCTL listed above, or its natural-occurring groundwater concentration at the cleanup site, whichever is less stringent.

4. Temporary injection zone of discharge: Rule 62-522.300(2)(c), F.A.C., applies to the iSOC® and HiSOC®. Rule 62-522.300(2)(c), F.A.C., allows a temporary injection zone of discharge (ZOD) for the primary groundwater standards that apply to the contaminants of concern, the prime constituents of the reagents used to remediate a site's contaminants (the reagents being gases in this case), and for the secondary groundwater standards. In order for users of iSOC® and HiSOC® to comply with this rule, a Department-approved RAP must address the duration and size of the ZOD, and provide for groundwater monitoring of the remediation agent and any site contaminants in the injected fluid that do not meet their respective primary or secondary drinking water standards, or their respective minimum groundwater criteria.

   For most gases that will be used by iSOC® and HiSOC®, the Department anticipates that the temporary injection ZOD --- when such a zone is needed --- will be permitted most often by Rule 62-522.300(2)(c), F.A.C., not by variance. A variance granting permission for a temporary injection ZOD will be necessary in cases where a chemical species classified as a primary groundwater contaminant is present as an impurity in the remediation agent to be injected if the impurity plays no role in the remediation process, and the concentration of the impurity in the fluid to be injected or re-injected/re-infiltrated is in excess of its primary groundwater standard. More information on this topic can be found in the Bureau of Petroleum Systems' guidance document "BPSS-10, In Situ Chemical Additives", currently located at web page www.dep.state.fl.us/waste/categories/pcp/pages/active.htm.

5. Citation of selected rules of Chapter 62-528, F.A.C., for Underground Injection Control:

   a. Injection well: Per Rule 62-528.200(39), F.A.C., an injection well is defined as a well into which fluids are being or will be injected, by gravity flow or by pressure.

   b. Well: Per Rule 62-528.200(67), F.A.C., a well is a bored, drilled or driven shaft, or a dug hole which has a depth greater than the diameter of the largest surface dimension; or, an improved sinkhole; or, a subsurface fluid distribution system.

   c. Construction/Clearance Permit: 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., provided they are authorized under the provisions of a RAP or other enforceable mechanism, and 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. In other words, the issuance of an enforceable, site-specific RAP Approval Order by the Department for injection-type aquifer remediation constitutes the granting of a Class V injection well construction/clearance permit.

6. Utilization of wells: If a remediation site happens to have an abundance of monitoring wells, then the Department has no objection to the use of some wells for gas infusion. However, no "designated" monitoring well, dedicated to the tracking of remediation progress (by sampling) shall be used as a treatment well. This will avoid a premature conclusion that the entire site meets cleanup goals. By making sure that designated tracking wells are not used for the introduction of treatment gases, there will be more assurance that the dissolved gas has permeated and treated the entire site, and that it did not remain localized to the immediate area surrounding each treatment well.

7. Groundwater monitoring: A distinction can be made between two categories of groundwater monitoring that are conducted during the course of aquifer remediation. The first category is that which is always conducted, regardless of the cleanup method employed, to monitor the concentration of the contaminants being cleaned up (i.e. the contaminants of concern). The second category is that which is conducted to monitor the concentration of chemical remediation agents when the cleanup method involves the injection or re-injection/re-infiltration of such agents into the groundwater. Chapter 62-528, F.A.C., Underground Injection Control, and Chapter 62-522, F.A.C., Groundwater Permitting and Monitoring Requirements, are the major regulations that apply to the latter type of monitoring.

   For in-situ, injection-type aquifer remediation, monitoring for Underground Injection Control purposes must be addressed in a RAP approved by the Department for any chemical species and parameters in the injected or re-injected/re-infiltrated fluid that do not the meet their primary, secondary or minimum groundwater criteria. As indicated in paragraph no. 4 above, upon expiration of the time permitted for a temporary injection ZOD, either by Rule 62-522.300(2)(c), F.A.C., or by variance, each chemical species and parameter for which the temporary ZOD was established must meet its respective groundwater water standard, or be no worse than its natural-occurring background level at the cleanup site, whichever is less stringent. In most cases, the Department anticipates that monitoring on a quarterly basis for underground injection control purposes will suffice.

8. Underground injection control inventory: RAPs proposing in-situ, 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 underground injection control. Per Rule 62-528.630(2)(c), F.A.C., aquifer remediation projects involving injection wells may be authorized with approval of a RAP, provided the construction, operation, and monitoring requirements of Chapter 62-528, F.A.C., are met. A memorandum providing injection well inventory information must be transmitted by DEP remediation plan reviewers to the Underground Injection Control Section in Tallahassee.

9. Avoidance of migration: Per Rule 62-528.630(3), F.A.C., in-situ, injection-type aquifer remediation projects shall be conducted in such a way that there is no undesirable migration of either the remediation agents used or the contaminants of concern.

10. 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. The Underground Injection Control Section of the Department shall be notified so that injection-type treatment wells can be removed from the inventory tracking list.

ENCLOSURE 2

SUPPLEMENTAL INFORMATION

1. Equipment: The iSOC® and HiSOC® devices are designed to fit into wells that are 2 inches or larger in diameter. The only items needed for its installation are a gas cylinder, pressure regulator, a distribution header, polyurethane tubing, and a suspension line that connects to a lifting eye on the unit.

2. Nature of the device: The devices contain hydrophobic microporous hollow fibers that provide interface area for mass transfer of gas into the surrounding groundwater. The underlying scientific principle is the equilibrium that exists between the dissolved concentration of a gas in a liquid and the partial pressure of that gas above the liquid. The proportionality constant that relates the partial pressure to the concentration in the dissolved phase is the Henry's Constant, for which additional information is readily available in textbooks.

3. Safety: Like any other equipment item used for the remediation of contaminated sites, the Department expects all appropriate safety practices to be observed. Not every item in the list that follows may be applicable to every location where iSOC® and HiSOC® are installed, and it is not intended to be an exhaustive list. Rather, it is intended as a starting point for safety considerations that designers of iSOC® and HiSOC® installations may need to take into account.

   - The handling and use of high pressure gas cylinders;
   - Whether the site-specific location where the gas cylinder and associated tubing, valves, and fittings will be installed is a non-hazardous area or, for example, a Class 1, Group D, Division 1 or 2 hazardous area as defined by the National Electrical Code;
   - Whether the gas being used is heavier or lighter than air;
   - The toxicity and flammability, and reactivity of the gas with any other chemicals that may be present at a specific remediation site;
   - Static electricity and other potential ignition sources in the event of a flammable gas leak;
   - The lower explosive level (LEL) of the gas being used, if it is flammable; and
   - Fail-safe features for the system itself.

4. Utilization of wells: If a remediation site happens to have an abundance of monitoring wells, then the Department has no objection to the use of some wells for injection purposes. However, no "designated" monitoring well, dedicated to the tracking of remediation progress (by sampling) shall be used as an injection well. This will avoid premature conclusion that the entire site meets cleanup goals. Not using designated tracking wells for the introduction of remediation agents will ensure that remediation agents have permeated the entire site and did not remain localized to the immediate area surrounding each injection well.

5. Design considerations: For in-situ remediation strategies, the spacing of treatment points depends on site-specific conditions. However, the inVentures Technology literature indicates that radius of influence of 10 to 20 feet have been observed. The extent to which the dissolved gas extends in the downgradient direction from each injection well depends on the concentration of gas at the well, the velocity of the groundwater and the demand for the gas.

inVentures suggests that measurement of dissolved gas concentration at various distances from the infusion well should not be the only means by which to determine a radius of influence. Measurement of other biological indicators should be made as well.

6. Operating conditions: When using the micro-flow controller for an immersion depth of less than 60 feet the recommended pressure regulator setting is 50 psi. This will result in an average gas flow rate of 15 standard cc/min. For immersion depths greater than 60 feet, the regulator should be adjusted such that it is a minimum of 25 psi greater than the head pressure of the water.