RegenOx™ *In Situ* Chemical Oxidation Application Instructions

Using Fixed Wells (Overview of Methods)

On some projects, it may appropriate to apply RegenOx using fixed wells. This will allow the RegenOx to be reapplied multiple times and reduce a large mass of contaminant incrementally over time.

Application of RegenOx via a series of fixed wells can be accomplished most effectively by separate application of RegenOx Part A and Part B via multiple separate application events. **Most sites require 3-4 applications to ensure contact and minimize rebound.** NOTE: for the purposes of this discussion, it is assumed that the hydraulic conductivity of this aquifer is sufficient to accept the volumes of material associated with this approach.

Well Installation:
It is critical that the delivery wells associated with this application are installed across the appropriate vertical application interval. These wells should be constructed using 2 or 4-inch diameter Schedule 80 PVC and preferably with the screened section composed of wire-wound PVC with a slot size >0.2 inch. The surrounding filter pack should be composed of an appropriately sized sand/gravel that is a reasonable match to the surrounding soil type. An adequate seal above the screen zone is critical. When possible we recommend a least a one-foot bentonite seal above the filter pack and an addition 3 feet or more or a cement-bentonite(<10%) grout to the surface.

Hydraulic Testing of Wells:
A hydraulic test should be performed prior to implementation of the RegenOx application. This testing consists of the injection of clear water at a volume equivalent to 1.3x the designed injection volume of the RegenOx Part A material.

It is critical that you understand the hydraulic conductivity/volumetric limitation of the aquifer prior to installation of the RegenOx material. Each sites aquifer conductivity and capacity will directly affect the volume of RegenOx applied and the application rate.

RegenOx - Part A Estimation/Application:
Using a designed application rate of 5,970 pounds of Part A material per event, a 5% solution will result in an application volume of 14,214 gallons of total fluids per event.

$$682 \text{ gals Part A} + 13{,}532 \text{ gals } H_2O = 14{,}214 \text{ gals of fluid}$$

Detailed steps for estimation of this volume are provided below. Using a five well application array results an application volume of 2,843gallons/well/event.

14,214 gals of fluid/5 wells = 2,843 gals/well/event

Hydraulic Test Volume Estimation:
The hydraulic test volume per well is estimated based on the above application rate (2,843 gallons) x (application factor of 1.3). This yields a total clear water test volume of 3,696 gallons/well.

RegenOx – Part B Application:
This method is significantly different from a direct-push application. This method requires application of a solution of the catalyst material separately and prior to application of the Part A oxidant material. As discussed previously, application of Part B is typically installed at a low concentration, spread over two events and is followed by a clear water chaser equal to 1.5-3x the wells borehole volume.

Step 1:
Mix Part B at solution that is 3-8% by weight, see Table 1 (below) for a volumetric estimation per bucket of material for each percentage solution. This range in volume is provided to allow for variations in aquifer types and specifically to adjust for each site's aquifer hydraulic conductivity and effective porosity. The aquifers hydraulic characteristics should dictate the solution percentage.

For example, Part B application in a fine grained aquifer (hydraulic conductivity of 10^{-5} to 10^{-6}cm/sec) should be mixed at approximately a 7% solution by weight while a coarse grained aquifer (10^{-2} to 10^{-3}cm/sec) should be mixed at approximately a 3% solution by weight.

TABLE 1.

No. of Buckets	Weight of Material (lbs.)	Desired Solution (%)	Volume of Water (gals.)
1	30	3	116
1	30	4	86
1	30	5	68
1	30	6	56
1	30	7	48
1	30	8	41

Example:
Based on application into a silty sand aquifer (10^{-4} cm/sec) the Part B solution should be mixed at 5%.
Using the previous example, this application will require a total of 5,970 pounds of Part B applied via two events of 2,985 pounds or 100 bucket/event

$$2,985 \text{ lbs.}/30 \text{ lbs./bucket} = 100 \text{ buckets}$$

Thus, for each of the two Part B applications, the water volume necessary is calculated using the following equation:

$$100 \text{ buckets Part B} \times 68 \text{ gallons water/bucket} = 6,800 \text{ gallons of water}$$

This yields a total solution application per event estimation of:

$$(6,800 \text{ gals of } H_2O + 260 \text{ gals Part B})/5 \text{ wells} = 1,412 \text{ gals Part B Solution/well/event}$$

Step 2:
Clear Part B material from the injection well and surrounding well pack by application of a clear water chaser equivalent to the volume of 1.5-3x the borehole volume.

Example:
For a 2-inch diameter well with a 6-inch borehole diameter, a total depth of 20 feet (10 feet of blank and 10 feet of screen). A single borehole volume with an assumed sand pack void space of 30% would be the sum of the following:
Borehole Volume = (screened interval borehole volume + blank casing volume)

$$[(10 \text{ feet} \times 0.543 \text{ gals/ft}) + (10 \text{ feet} \times 0.163 \text{ gals/ft})] = 7 \text{ gals}$$

Using a clear water chaser application factor of 1.5-3x yields a total clear water chaser volume ranging from 11 to 21 gallons/well.

For a 4-inch diameter well with a 8.25-inch borehole diameter, a total depth of 20 feet (10 feet of blank and 10 feet of screen). A single borehole volume using an assumed sand pack void space of 30% would be the sum of the following:
Borehole Volume = (screened interval borehole volume + blank casing volume)

$$[(10 \text{ feet} \times 1.23 \text{ gals/ft}) + (10 \text{ feet} \times 0.65)] = 19 \text{ gals}$$

Using a clear water chaser application factor of 1.5-3x yields a total clear water chaser volume ranging from 28 to 57 gallons/well.

Step 3:
Mix Part A at a solution of between 3-5%. As discussed previously the transmissivity and reactivity of a particular aquifer as well as hydraulic testing should be factored into the application volume decision. The stability of RegenOx Part A is optimal at approximately 3%. In coarse grained aquifers it is best to apply Part A at or near a 3% solution. In fine grained aquifers it may be necessary to decrease the water content to near a 5% solution. NOTE: Do not apply a Part A that is >5% solution.

Example:
Based on application of Part A solution into a silty sand aquifer, the Part A solution should be mixed at 5%. As discussed previously this application is designed for application of 5,970 pounds of Part A per event via a 5 well application array. Using Table 1 the number of buckets of Part A is required is estimated as follows:

5,970 lbs Part A/30 lbs/bucket = 199 buckets

The volume of water necessary to create a 5% Part A solution is calculated using Table 1 and the following equation:

199 buckets Part A x 68 gallons H_2O/bucket = 13,532 gallons of H_2O

This yields a total solution application per event estimation of:

(13,532 gals of H_2O + 682 gals Part A)/5 wells = 2,843 gals Part A Solution/well/event

Step 4:
Clear the Part A solution from the injection well and some of the surrounding well pack by application of a clear water chaser equivalent to the volume of 1.5-3x the borehole volume.

Example:
For a 2-inch diameter well with a 6-inch borehole diameter, a total depth of 20 feet (10 feet of blank and 10 feet of screen). A single borehole volume with an assumed sand pack void space of 30% would be the sum of the following:
Borehole Volume = (screened interval borehole volume + blank casing volume)

[(10 feet x 0.543 gallons/ft) + (10 feet x 0.163)] = 7.1 gallons

Using a clear water chaser application factor of 1.5-3x yields a total clear water chaser volume ranging from 11 to 21 gallons/well.

For a 4-inch diameter well with a 8.25-inch borehole diameter, a total depth of 20 feet (10 feet of blank and 10 feet of screen). A single borehole volume using an assumed sand pack void space of 30% would be the sum of the following:
Borehole Volume = (screened interval borehole volume + blank casing volume)

[(10 feet x 1.23 gallons/ft) + (10 feet x 0.65)] = 19 gallons.

Using a clear water chaser application factor of 1.5-3x yields a total clear water chaser volume ranging from 28 to 57 gallons/well.

Repeat the above series of steps as needed. As discussed previously the first two injection events will consist of application of Part B followed by Part A and thereafter as a series of Part A only injections.

Pump Selection (Wells)

It stands to reason that application of RegenOx via a series of wells is best accomplished using a pump that can deliver high volumes of fluids in a relatively low pressure setting. Regenesis has evaluated a number of pumps that are capable of delivery of these volumes of RegenOx in a reasonably efficient manner. These pumps are typically the positive displacement pumps and the diaphragm pumps. The positive displacement pumps are generally a stader driven (auger) and are electrically driven via a generator while the diaphragm pump is composed of one or two diaphragms that use pneumatic pressure to drive the pump. Both of these types of pumps can provide a relatively high volume of reagent while allowing significant control of volume and pressure.

Pressure Gauge System:
It is critical that application of RegenOx by preformed with proper pressure gauge set up. The gauges used should be configured to read PSI at the pump effluent and either along the delivery line or at the well head. This provides on-site personnel with adequate information on the pumps working pressure as well as the well delivery pressure. The difference in the two is the result of line loss. It is critical that application of RegenOx not exceed the burst pressure of the application well casing.

Pump Cleaning (Wells)

For best results, flush all moving parts and hoses with clean water at the end of the day, flush the injection system with a mixture of water and biodegradable cleaner such as Simple Green.

For more information or technical assistance please call Regenesis at 949-366-8000