

RegenOx™

CHEMICAL OXIDATION REDEFINED...

INSTALLATION INSTRUCTIONS

Direct-Push Injection

GENERAL GUIDELINES

One of the best methods to deliver RegenOx™ into the subsurface is to inject the material through direct push rods using hydraulic equipment. This approach increases the spreading and mixing of RegenOx into the aquifer. This set of instructions is specific to direct push equipment. For advice on other injections methods such as soil mixing, hydraulic and pneumatic fracturing, and vertical injection, please contact Technical Services directly.

The installation of RegenOx should span the entire vertical contaminated saturated thickness, or in the case of vadose zone treatment the entire affected vadose zone targeted for treatment.

TYPICAL INSTALLATION EQUIPMENT

- Direct push rig
- Drive Rods (typically 1 ½-inch O.D.) & Injection Tooling with fluid deliver sub-assembly
- Injection Pump rated for 5 gpm @ 200 psi for sandy formations and 800 psi for silt and clay formations (Geoprobe DP-800, Yamada, Moyno, Rupe Models 9-1500 and 9-1600, Wilden, etc.)
- Injection hosing and a pressure relief valve with a bypass
- Clear hosing between mixing tank/drum and pump
- Pressure gauges
- Power drill paint stirrer (3-inch diameter or smaller propeller tip)
- Plastic bucket lid puller tool/opener tool
- 5-amp sump pump (such as Little Giant) and hose
- Three to four 55-gallon drums or similarly sized mixing tanks for RegenOx mixing
- Sand, bentonite chips, granular bentonite, cement, hydraulic cement, and quick-set concrete for closing and sealing temporary injection holes
- Wood plugs or similar for temporarily sealing injection holes prior to grout sealing
- Access to water
- Access to electricity

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personnel working with or in areas of potential contact with RegenOx should be required at a minimum to be fitted with modified Level D personal protective equipment:

- Eye protection – Wear well sealed goggles or a face shield (face shield recommended for full face protection)
- Head – Hard hat when required
- Respiratory – Use dust respirator approved by NIOSH/MSA
- Hands – Wear neoprene gloves
- Feet – Wear steel toe shoes with chemical resistant soles or neoprene boots
- Clothing – Wear long sleeve shirts and long pant legs. Consider using a Tyvek® body suit, Carhartt® coverall or splash gear

MATERIAL OVERVIEW, HANDLING, AND SAFETY

RegenOx is packaged in two parts. Part A is the RegenOx Oxidizer complex and Part B is the RegenOx Activator complex. Part A and Part B are shipped in separate 5-gallon buckets and each bucket has a gross weight of approximately 32 pounds (net weight of RegenOx material in each bucket is 30 pounds). The RegenOx Oxidizer complex is shipped as a fine white powder and the RegenOx Activator complex is shipped as a liquid gel. The Activator has a viscosity roughly equivalent to honey. It is common for stored RegenOx Activator to settle somewhat in a container, so it is imperative to adequately pre-mix the RegenOx Activator prior to mixing it with the RegenOx Oxidizer. Mixing the RegenOx Part B Activator with water at a ratio of roughly 1 gallon water per bucket of Activator makes the activator pourable and easier to work with. A Material Safety Data Sheet for Part A (RegenOx Oxidizer) and for Part B (RegenOx Activator) is provided with each shipment. Personnel who operate field equipment during the installation process should have appropriate training, supervision, and experience.

INSTALLATION PROCEDURES

- 1) Prior to the installation of RegenOx, any surface or overhead impediments should be identified as well as the location of all underground structures. Underground structures include but are not limited to: utility lines; tanks; distribution piping; sewers; drains; and landscape irrigation systems.
- 2) The planned installation locations should be adjusted to account for all impediments and obstacles.
- 3) Pre-mark the installation locations, noting any points that may have different vertical application requirements or total depth.

- 4) Set up the direct push unit over each specific point and follow the manufacturer standard operating procedures (SOP) for the direct push equipment. Care should be taken to assure that probe holes remain in the vertical.
- 5) For most applications, Regeneration suggests using 1.5-inch O.D./0.625-inch I.D drive rods. However, some applications may require the use of 2.125-inch O.D./1.5-inch I.D. or larger drive rods.
- 6) Advance drive rods through the surface pavement, as necessary, following SOP.
- 7) Push the drive rod assembly with an expendable tip to the desired maximum depth. Regeneration suggests pre-counting the number of drive rods needed to reach depth prior to starting injection activities.
- 8) After the drive rods have been pushed to the desired depth, the rod assembly should be withdrawn three to six inches. Then the expendable tip can be dropped from the drive rods, following SOP. If an injection tool was used instead of an expendable tip, the application of material can take place without any preliminary withdrawal of the rods.
- 9) In some cases, introduction of a large column of air prior to RegenOx application may be problematic. This is particularly the case in deep injections (>50 ft) with large diameter rods (>1.5-inch O.D.). To prevent the injection of air into the aquifer during RegenOx application, as well as to prevent problems associated with heaving sands, fill the drive rods with water, or the RegenOx mixture prior dropping the expendable tip or exposing the injection tool.
- 10) Open one of the buckets of RegenOx Part B Activator and pour/spoon the entire bucket of Activator into a small mixing bucket or tank, making sure that any Activator that settled in the bottom of the bucket was scraped out of the Activator bucket and into the mixing tank. Stir the Activator with the power drill mixer for roughly 2 to 3 minutes. Add roughly one gallon of water to the activator, and stir again for at least 2 to 3 minutes. The net weight of Activator in a bucket is 30 pounds. The pounds of Activator required for one vertical foot of injection can be divided by 30. Pour the stirred/mixed Activator into empty buckets based on that fraction. (For example, if 5 pounds of activator are required per foot, pour 5/30 or 1/6 of the contents into each of 6 empty buckets.)
- 11) Measure the appropriate quantity of RegenOx Oxidizer for each vertical foot of injection.
- 12) RegenOx % oxidizer in solution should typically range between 4% to 8%. Solutions up to 10% can be used, but flocculation of the solution prior to injection may result. Solutions with greater than 10% oxidizer in solution will result in excess reaction and flocculation prior to injection and are not normally recommended.

Into a 55-gallon drum or mixing tank, pour the required amount of water for one to four vertical feet of injection. The volume of water per injection location can be calculated from the following equation:

Volume of water (gallons/vertical foot of injection):

$$\frac{\text{RegenOx Oxidizer lbs/foot}}{(8.34 \text{ lbs/gal water})(\% \text{ RegenOx_Oxidizer solids})} [1 - (\% \text{ RegenOx_Oxidizer solids})]$$

Tighter formations (clays and silts), and even some fine sand formations will likely require higher oxidant percentages since less volume can be injected per location. The following are guides to various RegenOx mixing ratios based on the above equation.

- to make a roughly 5% oxidant solution for every 10 lbs of oxidant and 10 lbs of activator (20 lbs total RegenOx), use 22 gallons of water.
- to make a roughly 8% oxidant solution for every 10 lbs of oxidant and 10 lbs of activator (20 lbs total RegenOx), use 13.5 gallons of water.
- to make a roughly 10% oxidant solution for every 10 lbs of oxidant and 10 lbs of activator (20 lbs total RegenOx), use 11 gallons of water.

13) Pour the pre-measured quantity of RegenOx Oxidizer to make the desired target % oxidant in solution mixture into the mixing drum or tank. Mix the water and oxidant with a power drill paint stirrer to ensure that the Oxidizer has dissolved in the water.

14) Pour the applicable amount of the pre-mixed RegenOx Activator into the oxidant mixing tank or pump hopper. Mix the Oxidant and Activator using a power drill paint stirrer or hand paddle mixer for at least 5 minutes until a homogenous mixture is formed. After mixing the RegenOx mixture should be injected into the subsurface as soon as possible.

15) Do not mix more RegenOx material than will be used over roughly 1 to 4 feet of injection so as to minimize potential above ground reaction/flocculation prior to injection.

16) Transfer the contents of the mixing tank to the pump hopper using a gravity drain or a sump pump.

17) For some types of pumps, it may be desirable to perform a volume check prior to injecting RegenOx. Determining the volume displaced per pump stroke can be accomplished in two easy steps.

- a) Determine the number of pump strokes needed to deliver 3 gallons of RegenOx (use a graduated bucket for this)
- b) Divide 3 gallons by the results from the first step to determine the number of gallons of RegenOx delivered by each pump stroke.

- 18) Connect the delivery hose to the pump outlet and the delivery sub-assembly. Circulate RegenOx through the hose and the delivery sub-assembly to displace air in the hose.
- 19) Connect the sub-assembly to the drive rod. After confirming that all of the connections are secure, pump the RegenOx through the delivery system to displace the water/fluid in the rods.
- 20) Slowly withdraw the drive rods. Commonly, RegenOx injections progress at 1-foot intervals. However, continuous injection while slowly withdrawing single lengths of drive rod (3 or 4 feet) is an acceptable option. The pre-determined volume of RegenOx should be pumped into the aquifer across the desired treatment interval.
- 21) Remove one section of the drive rod. The drive rod may contain some residual RegenOx. Place the RegenOx-filled rod in a clean, empty bucket and allow the RegenOx to drain. Eventually, the RegenOx should be returned to the RegenOx pump hopper for reuse.
- 22) Observe any indications of aquifer refusal. This is typically indicated by a high-pitched squeal in the pump's hydraulic system or (in the case of shallow applications) RegenOx "surfacing" around the injection rods or previously installed injection points. At times backpressure caused by gassing will impede pump movement. This can be corrected by bleeding the pressure off using a pressure relief/bypass valve (placed inline between the pump discharge and the delivery sub-assembly) and then resume pumping. If aquifer acceptance appears to be low, allow enough time for the aquifer to equilibrate prior to removing the drive rod.
- 23) Repeat steps 13 through 23 until treatment of the entire contaminated vertical zone has been achieved. It is recommended that the procedure extend to the top of the capillary fringe/smear zone, or to the top of the targeted treatment interval.
- 24) Install an appropriate seal, such as bentonite, above the RegenOx material through the entire vadose zone. Prior to emplacing the borehole seal, we recommend placing clean sand in the hole to the top of the RegenOx treatment zone (especially important in holes that stay open). Bentonite chips or granular bentonite should be placed immediately above the treatment zone, followed by a cement/bentonite grout to roughly 0.5 feet below ground surface. Quick-set concrete should then be used as a surface seal.
- 25) Remove and clean the drive rods as necessary.
- 26) Finish the borehole at the surface as appropriate (concrete or asphalt cap, if necessary). We recommend a quick set concrete to provide a good surface seal with minimal set up time.

- 27) A proper borehole and surface seal assures that the RegenOx remains properly placed and prevents contaminant migration from the surface. Each borehole should be sealed immediately following RegenOx application to minimize RegenOx surfacing during the injection process. If RegenOx continues to “surface” up the direct push borehole, an appropriately sized (oversized) disposable drive tip or wood plug/stake can be used to plug the hole until the aquifer equilibrates and the RegenOx stops surfacing. If wells are used for RegenOx injection, the RegenOx injection wells and all nearby groundwater monitoring wells should be tightly capped to reduce potential for surfacing through nearby wells.
- 28) Periodically compare the pre- and post-injection volumes of RegenOx in the pump hopper using pre-marked volume levels. Volume level indicators are not on all pump hoppers. In this case, volume level markings can be temporarily added using known amounts of water and a carpenter’s grease pencil (Kiel crayon). We suggest marking the water levels in 3-gallon increments.
- 29) Move to the next probe point, repeating steps 8 through 29. We recommend that the next RegenOx injection point be as far a distance as possible within the treatment zone from the previous RegenOx injection point. This will further minimize RegenOx surfacing and short circuiting up an adjacent borehole. When possible, due to the high volumes of liquid being injected, working from the outside of the injection area towards the center will limit expansion of the plume.

HELPFUL HINTS

1) RegenOx Pump Information

Regenesis has evaluated a number of pumps that are capable of delivering RegenOx to the subsurface at a sufficient pressure and volumetric rate. Although a number of pumps may be capable of delivering the RegenOx to the subsurface at adequate pressures and volume, each pump has a set of practical issues that make it difficult to manage in a field setting. In general, Regenesis strongly recommends using a pump with a minimum pressure rating of 200 pounds per square inch (psi) in sandy formations or 800 psi in silt, clay or weathered bedrock formations, and a minimum delivery rate of 5 gallons per minute (gpm). A lower gpm rated pump can be used; however, they are not recommended due to the amount of time required to inject the volume of liquids typically associated with a RegenOx injection (i.e. 1,000 lbs of RegenOx [500 lbs Oxidant/500 lbs Activator] require roughly 1,100 gallons of water to make a 5% Oxidant solution).

2) Pump Cleaning

For best results, use a hot water pressure washer (150 - 170 °F or 66 - 77 °C) to clean equipment and rods periodically throughout the day. Internal pump mechanisms and hoses can be easily cleaned by circulating hot water and a biodegradable cleaner such as Simple Green® through the pump and delivery hose. Further cleaning and decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier’s standard procedures and local regulatory requirements.