REGENESIS

Hydrogen Release Compound (HRC â)

INSTALLATION INSTRUCTIONS
Direct-Push Injection

GENERAL GUIDELINES

The best method to deliver HRC into the subsurface is to inject the material through direct push rods using hydraulic equipment. This approach increases the spreading and mixing of HRC into the aquifer. This set of instructions is specific to direct push equipment.

Regenesis has found that very few pumps can adequately deliver HRC to the subsurface. Although other pumps may be capable of injecting HRC, we have developed the following instructions specifically for use with an R.E. RUPE Company Model ORC/HRC 9-1500 mixing and pumping machine. There is also strong evidence that the Geoprobe GS-2000 pump can effectively deliver HRC to the subsurface. In general, Regenesis strongly recommends using a pump with a minimum pressure rating of 1,500 pounds per square inch (psi) and a minimum delivery rate of 3 gallons per minute.

The installation of HRC should span the entire vertical contaminated saturated thickness. If the vertical extent of HRC application is confined to a limited interval, then the HRC material should be placed across a vertical zone extending a minimum of 2 feet above and below the screened Interval of monitoring wells to be used to evaluate the performance of the bioremediation project.

MATERIAL OVERVIEW, HANDLING, AND SAFETY

HRC is shipped in 4.25-gallon buckets and each bucket has a gross weight of approximately 32 pounds (net weight of HRC is 30 pounds). At room temperature, HRC is a sticky gel with a viscosity of approximately 20,000 centipoise (roughly equivalent to cold honey). The HRC material has a nominal density of 1.3 grams/cubic centimeter or approximately 10.8 pounds per gallon. The viscosity of HRC is temperature sensitive. Significant changes in viscosity are observed with large changes in product temperature. It should be noted that the temperature/viscosity relationship is not linear. For ease of installation, HRC should be stored in a warm, dry place that is protected from direct sunlight. It is common for stored HRC to settle somewhat in a container. Pre-heating HRC makes it easier to work with the material. Although HRC is manufactured as a food-grade material that is safe to ingest, field personnel should take precautions while handling and applying HRC. Field personnel should use appropriate safety equipment, including eye protection. The low pH when dissolved in water and the viscosity of the product make eye protection mandatory. Gloves should be used as appropriate based on the exposure duration and field conditions. A Material Safety Data Sheet is provided with each shipment. Personnel who operate field equipment during the installation process should have appropriate training, supervision, and experience.

SPECIFIC INSTALLATION PROCEDURES

1) Prior to the installation of HRC, 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) Regenesis recommends pre-heating HRC in a hot water bath. Place unopened buckets of HRC into an empty water tank. A Rubbermaid fiberglass Farm Trough Stock Tank (Model 4242-00-GRAY) is typically used for this application and can hold up to 16 buckets of HRC. Hot water (approximately 130-170°F or 54-77°C) should be added to the tank after the buckets of HRC have been placed inside. When the HRC reaches a minimum temperature of 95°F or 35°C (approximately 20-30 minutes) it is ready to be poured into the pump hopper.

4) Pre-mark the installation locations, noting any points that may have different vertical application requirements or total depth.

5) 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.

6) For most applications, Regenesis suggests using 1.25-inch O.D./0.625-inch I.D Geoprobe brand drive rods. However, some applications may require the use of 2.125-inch O.D./1.5-inch I.D. drive rods.

7) The HRC delivery sub-assemblies that Regenesis currently uses are designed for 1.25-inch Geoprobe rods. Other brands of drive rods can also be used but require the fabrication of a sub-assembly (see Regenesis Website).

8) Advance drive rods through the surface pavement, as necessary, following SOP.

9) Push the drive rod assembly with an expendable tip to the desired maximum depth. Regenesis suggests pre-counting the number of drive rods needed to reach depth prior to starting injection activities.

10) 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.

    a) 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.

11) In some cases, introduction of a large column of air 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 HRC application, fill the drive rods with water.

12) Pour the pre-heated HRC into the pump hopper (up to 40 gallons). Remove the separated HRC from the bucket bottom by tipping the bucket into the hopper and scraping out the smooth residual material. Use the pumps mixing and recirculation features to create a uniform consistency. This typically requires recirculation of approximately one hopper volume. NOTE: Do not attempt to mix HRC with water or other liquids to thin or decrease the viscosity of the material. This may adversely affect HRC longevity.

13) A volume check should be performed prior to injecting HRC. 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 HRC (use a graduated bucket for this)

    b) Divide 3 gallons by the results from the first step to determine the number of gallons of HRC delivered by each pump stroke.

    c) Level indicators present in the hopper are in 3 gallon increments.

    d) The volume of HRC displaced should be confirmed using the HRC level indicators located inside the pump hopper.

14) Connect the 1.25-inch O.D., 1-inch I.D. delivery hose to the pump outlet and the provided HRC delivery sub-assembly. Circulate HRC though the hose and the delivery sub-assembly to displace air in the hose.

15) Connect the HRC sub-assembly to the drive rod. After confirming that all of the connections are secure, pump the HRC through the delivery system to displace the water/fluid in the rods. **NOTE:** Prior to pumping HRC into the aquifer, close the pump recirculation valve; failure to do so will allow material to short-circuit into the hopper and change the volume of HRC delivered per pump stroke.

16) The pump engine RPM and hydraulic settings should remain constant throughout the day. However, if the hydraulic system starts to “squeal”, the pump speed should be decreased until the noise is mitigated.

17) Use the pump’s stroke counter and the provided volume/weight conversions to apply the appropriate HRC volume per injection location (and per vertical foot of contaminated saturated zone). Table 1 shows typical HRC delivery information followed by an example calculation.

Table 1: Pump Volume Calculation

Example: For each injection location, install 60 pounds of HRC across 10 vertical feet of aquifer (an application rate of 6 pounds per vertical foot).

Solution:

- 60 pounds/10.8 pounds per gallon ≈ 5.6 gallons for the injection location
- 5.6 gallons/0.2 gallons per stroke ≈ 28 pump strokes for the injection location
- 28 pump strokes/10 vertical feet = 2.8 strokes per vertical foot
- 2.8 strokes per vertical foot = 8.4 strokes per 3 foot drive rod
- 2.8 strokes per vertical foot = 11.2 strokes per 4 foot drive rod

18) Slowly withdraw the drive rods using Geoprobe Rod Grip or Pull Plate Assembly (Part AT1222-For 1.25-inch drive rods). While slowly withdrawing single lengths of drive rod (3 or 4 feet), pump the pre-determined volume of HRC into the aquifer across the desired treatment interval (Step 13). Use the stroke counter and pump on/off switch to control volume of injection. See Helpful Hints at the end of this section.

19) Remove one section of the drive rod. The drive rod may contain some residual HRC. Place the HRC-filled rod in a clean, empty bucket and allow the HRC to drain. Eventually, the HRC should be returned to the HRC pump hopper for reuse.

20) 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) HRC "surfacing" around the injection rods or previously installed injection points. If aquifer acceptance appears to be low, allow enough time for the aquifer to equilibrate prior to removing the drive rod.

21) Repeat steps 15 through 20 until treatment of the entire contaminated vertical zone has been achieved.

22) Install an appropriate seal, such as bentonite, above the HRC material through the entire vadose zone. Depending on soil conditions and local regulations, use a bentonite seal via chips or pellets after the probe rods have been removed. This assures that the HRC remains properly placed and prevents contaminant migration from the surface. If HRC 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 HRC stops surfacing.

23) Remove and clean the drive rods as necessary.

24) Finish the borehole at the surface as appropriate (concrete or asphalt cap, if necessary).

25) Periodically compare the pre- and post-injection volumes of HRC in the pump hopper using the 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.

26) Move to the next probe point, repeating steps 8 through 25.

HELPFUL HINTS

1) *Application in Cold Weather Settings*

The viscosity of HRC is directly related to the ambient temperature. As discussed in the Material Overview, Handling, and Safety section, cold weather tends to increase HRC viscosity and decrease ease of pumping. To maintain HRC at a temperature/viscosity at which it is easy to apply:

Raise and maintain the temperature of the HRC to at least 95°F (35°C) prior to pouring it into the pump hopper.

Insulate the delivery hose and keep the pump and hot water bath inside an enclosed structure such as a cargo van or trailer.

Periodically check the HRC temperature in the hopper.

Occasionally re-circulate HRC through the pump and hose to maintain temperature and viscosity.

The volume of HRC recirculated should not exceed the volume of HRC in the hopper.

Do not constantly recirculate HRC through the pump and hoses, as this may adversely affect the longevity of HRC.

2) *HRC Pump Information*

Regenesis has evaluated a number of pumps that are capable of delivering 20,000 centipoise HRC to the subsurface at a sufficient pressure and volumetric rate. Although a number of pumps may be capable of delivering the HRC 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. As a result of this evaluation, Regenesis has determined that the R.E. RUPE Company Model ORC/HRC 9-1500 meets the pressure and volume requirements needed to successfully inject HRC in the field. In general, Regenesis strongly recommends using a pump with a minimum pressure rating of 1,500 pounds per square inch (psi) and a minimum delivery rate of 3 gallons per minute. When applying measured volumes of HRC via probe boreholes, it is useful to know the volume of a single pump stroke (Table 1 above) and the associated delivery system lines. The following additional information is provided for reference:

Table 2: HRC Physical Characteristics

Density	1.3 g/cc or 10.8 lbs/gal
Viscosity	Approx. 20,000 centipoise

Table 3: Equipment Volume and HRC Weight per length

Equipment	Volume	HRC weight
1-inch OD; 0.625-inch ID hose (10 feet long)	0.2 gallon	1.8 lbs.
1.25-inch OD; 0.625-inch ID drive rod (3 feet length):	0.05 gallon	0.5 lbs.
1.25-inch OD; 0.625-inch ID drive rod (4 feet length):	0.06 gallon	0.7 lbs.

3) *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.

NOTE: The remote control/pump counter should be kept dry at all times. If it gets wet, it will short-circuit and will need to be replaced.

Before using the Rupe Pump, check the following:

- Fuel level prior to engaging in pumping activities (it would be best to start with a full tank)
- Remote control/pump stroke counter LCD display (if no display is present, the electronic counter will need to be replaced (Grainger Stock No. 2A540))

Monitor pump strokes by observing the proximity switches (these are located on the top of the piston).

4) *HRC Bedrock Applications*

When contaminants are present in competent bedrock aquifers, the use of direct push technology as a delivery method is not possible. *Regenesis is in the process of developing methods for applying HRC via boreholes drilled using conventional rotary techniques.* To develop the best installation strategy for a particular bedrock site, it is critical that our customers call the technical support department at Regenesis early in the design process.

HRC can be applied into a bedrock aquifer in cased and uncased boreholes. HRC can be delivered by simply filling the borehole without pressure or by using a single or straddle packer system to inject HRC under pressure. Selection of the appropriate delivery

method is predicated on site-specific conditions. The following issues should be considered in developing an HRC delivery strategy:

- Is the aquifer's transmissivity controlled by fractures?
- Backfilling may be the better delivery method in massive, unfractured bedrock. This is particularly true in an aquifer setting with high permeability and little fracturing (such as that found in massive sandstone).
- Down-hole packer systems may be more advantageous in fractured bedrock aquifers.
    - In this case the fracture type, trends, and interconnections should be evaluated and identified.
- Are the injection wells and monitoring wells connected by the same fractures?
- Determine if it is likely that the HRC injection zone is connected to the proposed monitoring points.
- If pressure injection via straddle packers is desired, consideration should be given to the well construction. Specific issues to be considered are:
    - Diameter of the uncased borehole (*will casing diameter allow a packer system to be used*?).
    - Diameter of the casing (*same as above*).
    - Strength of the casing (*can it withstand the delivery pressures?*).
    - Length of screened interval (*screened intervals greater than 10 feet will require a straddle packer system*).