EHC® Reagent Slurry Preparation and Application Guidelines

EHC® *In Situ* Chemical Reduction (ISCR) Reagent is composed of food grade organic carbon and zero-valent iron for reduction of persistent organic and/or inorganic contaminants from the subsurface environment. EHC reagent has been applied for source area treatment, plume treatment, and plume management using methods such as:

- Application into an open excavation via
    - Direct placement in to the base of an excavation following source area removal
    - A trench style permeable reactive barrier (PRB)
    - Soil mixing
- Injection applications

The choice of installation method will depend on your site-specific conditions, including treatment depth and geology.

APPLICATION INTO AN OPEN EXCAVATION

Excavation base:

The most common application for direct placement of EHC reagent is the addition of EHC to saturated soil and/or standing groundwater at the base of an excavation following a source area removal (See Figure 1). EHC can either be mixed into the backfill material prior to placement or applied in lifts and then mixed in place. It is advisable to mix the EHC with sufficient backfill to cover the thickness of the excavation that is expected to encounter groundwater, taking into account seasonal variability in the groundwater table.

Figure 1. Backfill with 5% EHC by weight at an open excavation following source area removal

The EHC powder could also be physically mixed into saturated soil at the base of an excavation using a backhoe. Depending on the remaining impacts and the treatment goals, an application rate of 0.5 - 5% of EHC by soil mass is generally recommended for backfill applications.

Trench/PRB:

EHC reagent could also be added to a trench excavation to form a PRB for plume management (Figure 2). The trench is installed across the plume and backfilled with a mixture of EHC and sand up to the groundwater table to form a reactive zone. The groundwater is treated as it passes though the reactive barrier. In general, a higher application rate of 5 - 10% of EHC by soil mass is recommended to sustain continuous removal over time. The remainder of the trench is backfilled with clean fill material (e.g. pea gravel or sand).

Figure 2. Placement of a mixture of EHC and sand into a trench excavation to form a PRB for plume control

Mixing of EHC with Backfill Material:

If wind is low, the dry powder can be mixed with the backfill at ground surface using construction equipment. Alternatively, the powder can be mixed into the backfill in the excavation using construction equipment and safe construction methods. If winds are high, it may be necessary to prepare a slurry of EHC containing a high percentage of solids and mix the slurry into the backfill or it may help to spray with water during application. See Figure 3.

Figure 3. Dry mixing of EHC (provided in sacks) and sand

Direct Soil Mixing:

The EHC reagent may also be placed directly on the bottom of an excavation either in dry powder form if winds are low, or in slurry form if winds are high. In such a case, it may be advisable to mix the powder or slurry into the native soil at the bottom of the excavation using construction equipment and safe construction methods. This will be particularly useful if contaminants are expected to be present in the remaining soil. For deeper impacts, deep soil mixing equipment such as a Lang Tool could be used. See Figure 4.

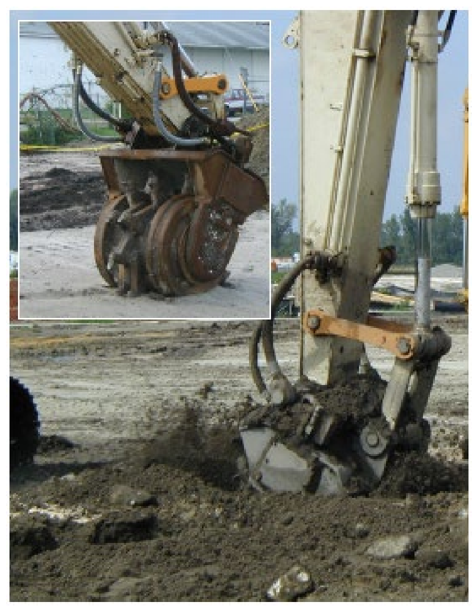

Figure 4. Deep soil mixing using a Lang Tool

APPLICATION VIA INJECTION

The most common application method for EHC is direct injection using direct push technology. The EHC is mixed with water to form a slurry and is injected directly through the direct push probe rods in to the saturated zone. The preferred approach for injections is often in the top-down direction using an injection tip that directs the slurry horizontally, for example pressure activated direct push tips have been successfully utilized. For each injection point, the rods are initially advanced to the top of the targeted depth interval and a specified volume of slurry is injected before proceeding down to the next depth. The injections are to be evenly distributed over the targeted depth interval, using a vertical injection spacing of approximately 2-4 ft.

Figure 5. Injection tip with horizontal direction low pressure demonstration with water

Water Flushing during Injection:

It is not recommended to apply larger amounts of chase water for the purpose of distributing EHC, but it is recommended to inject a smaller volume of water upon completion of a point to clean the rods. Flushing with water between injection intervals can be required to avoid clogging of the injection tip, but normally, if the injection flow rate is kept >3 gpm and the time inbetween injections are kept to a minimum, water flushing between intervals is not required. In general, it is recommended to keep water flushing at a minimum to limit the risk of daylighting and only inject just enough water to clean out the injection tip.

Injection Spacing:

The recommended spacing between injection points are based on two factors: radius of influence distribution (ROI) and soil acceptance. Both of these factors may vary greatly depending on injection technique and lithology. It is recommended to be as flexible as possible during a field installation and/or to evaluate these parameters during a pilot-scale test injection. However, based on experience from a range of sites, a ROI of at least 5 ft is observed with direct injection; due to this an injection spacing of 10 to 15 ft (staggered rows) is generally recommended. Soil acceptance may also vary greatly depending on the lithology and injection depth. As a general guideline, we recommend no more than 100 lbs EHC per vertical foot for more permeable formations. For clayey formations, soil acceptance has in some instances been limited to 20 lbs per vertical foot. Therefore, a closer spacing may have to be applied in a scenario with a higher dosing requirement combined with a low permeability formation to limit the injection volume per point. Note that significantly greater ROIs has been observed with fracturing techniques with up to 8,000 lbs EHC injected per fracture and ROIs of more than 30 ft. Information on how to monitor the ROI and observations from a range of sites is available upon request.

Pump Requirements:

Using an injection pump that is capable of generating at least 500 psi of pressure at a flow rate of 5 gpm is recommended. The pump needs to be able to handle solids. For example piston pumps, grout pumps and progressing cavity pumps have worked well in the past, with a preference towards the piston and grout pumps. EHC would typically be injected at pressures of 100 to 200 psi. However, higher pressures are sometimes required to initiate the injection. It would be ideal to have a higher pressure pump available on site that can generate over 500 psi and as high a flow rate as possible. Deeper installations may require higher injection pressures.

Other injection considerations:

Sufficient rod length and injection tips are recommended to allow 3 to 5 injection points to be capped overnight to prevent backflow if need be (more for shallow depths and less for deep installations).

PREPARATION OF EHC SLURRY

EHC reagent may need to be mixed into a slurry to avoid loss of product or for direct push injections. The solids content of the slurry may be varied depending on the desired injection volume and slurry properties. When applied via direct injection, normally a concentration of between 25 and 35% solids is targeted as calculated as the mass of EHC divided by the mass of water plus EHC. This results in a final wet density of the slurry of approximately 1.09 to 1.13 g/cm^3. More dilute slurry may promote permeation (as opposed to fracturing) in more granular formations if the flow rate and pressure is kept low. More viscous slurry with up to 35% solids has been found to limit problems with daylighting during injection, particularly for shallow applications into low-permeability formations.

EHC is delivered as a dry powder in 50-lb bags or 2,000 lb supersacks. Table 1 indicates the volume of water required to attain a given percent solids level for a 50-lb bag of EHC.

	25% slurry	30% slurry	35% slurry
Mass EHC per bag (lbs)	50	50	50
Volume water per bag (USG)	18.0	14.0	11.1
Estimated specific gravity of slurry	1.09	1.11	1.13
Volume slurry per bag (USG)	22.0	18.0	15.2

Table 1. Volume of water required to attain different slurry solids contents per 50-lb bag of EHC.

Figure 6. EHC slurries

Preparing the EHC slurries on site in a mixing tank with a paddle-mixer at the bottom (grout mixers) is recommended (figure 7). The slurry is then transferred to a feed tank connected to a pump allowing for easy transfer of the slurry; the slurry could then be pumped straight into the application – either the excavation or injection pump. In general, we recommend continuous mixing in smaller batches (<100 USG / 400 L) to avoid settling of solids at the bottom.

The EHC slurry has also been prepared in a variety of other ways; everything from in-line automated mixing systems and recirculation of slurry using high-flow trash pumps to manual mixing using a hand-held drill with a mixing attachment. However, particularly for larger projects, a mechanical mixing system on site is recommended.

Figure 7. Grout / paddle mixing unit with feed-tank and injection pump.

Figure 8. Mixing of EHC slurry using recirculation

HEALTH AND SAFETY

Prior to working with EHC consult the Safety Data Sheet (SDS) to understand proper safety, handling, storage and disposal procedures. Any vessel that contains wet EHC or EHC and water must be vented due to potential pressure build up from fermentation gasses. When working with EHC, it is recommended to use standard personal protective equipment, including: safety glasses, steel toe boots, nitrile gloves, hearing protection (when direct push equipment is used), and hard hat. Dust mask may be required when in close contact with EHC under certain conditions.