Klozur® One Application Guidelines

Klozur® One is a blend of Klozur SP and carefully selected patented[1] activator reagents that can be used to treat highly contaminated source areas and plumes. Klozur One is fully soluble which increases the ability to successfully distribute the persulfate and the activators together in the subsurface. Combining the activator and Klozur SP in the same product allows field contractors to batch Klozur One at the injection concentration and utilize a single mixing tank, simplifying field applications.

Klozur One is part of PeroxyChem's Klozur Portfolio which also includes Klozur SP, Klozur KP, and Klozur CR. Klozur products are typically applied using an injection, soil mixing, or backfill strategies to establish contact between the activated persulfate and the contaminants of concern. This document will provide general application guidelines for Klozur One. For more information on Klozur One or other products in PeroxyChem's Klozur Portfolio, please visit www.klozur.com.

FIELD APPLICATIONS

Batching

Klozur One is a fine granular product that is completely soluble and can be dissolved into clean water in preparation for injection. When batching any Klozur product, it is important to ensure that the tank, water, mixing equipment and any other parts that will contact the reagent solution are clean and devoid of impurities that might react with the oxidant. Klozur One should be batched in systems where all wetted parts, and parts that could become wetted, are chemically compatible with Klozur One. Please refer to PeroxyChem's Technical Bulletin: *Corrosion and Material Compatibility with Klozur Persulfate*, which can be found at peroxychem.com/remediation, for a list of chemically compatible materials. A chemically compatible secondary containment is also recommended beneath the batching system.

Klozur One, a soluble blend of Klozur SP and a carefully crafted activator blend, can be batched at the same concentration as the intended injection concentration. This is a key benefit as it eliminates the need for additional dilution water or in-line mixing with a separate activator which simplifies both design and field activities when applying Klozur One. PeroxyChem recommends that Klozur One be batched and injected in a range from 50 to 200 grams per liter (g/L). It is recommended that batches of Klozur One be injected or applied within four hours of the dilution of Klozur One in water. Solutions of Klozur One stored longer than four hours are expected to be stable; however, the Klozur SP within Klozur One will slowly degrade.

Klozur One can be mixed using a variety of methods. The most common methods are mechanical and hydraulic mixers. Most mechanical mixers are mounted to the top of the batch tank and involve a motor, shaft and propeller that mixes the solution. Hydraulic mixers usually include some form of recirculating the batch solution. The time required to dissolve Klozur One will increase with increasing concentrations, but in the 50 to 200 g/L range and an adequate mixing system, Klozur One should be completely dissolved within 5 to 15 minutes.

Injection Equipment

Klozur One can be injected using a single chemically compatible pump. Common pumps used include centrifugal and double diaphragm pumps sized according to the anticipated injection rate and down gradient pressure. Most double diaphragm pumps have the secondary benefit of creating inlet negative pressure that can be used to pull Klozur One through a wand from the batch tank. The wand inlet is usually placed at the base of the tank with a foot valve. This removes the need for a gravity feed coming from the bottom of the batch tank.

Depending on the injection objectives, other common components that may be necessary in an injection system include flow meters, pressure gauges, pressure relief valves, temperature gauges, valves to open and close portions of the system (i.e. ball valves or equivalent), and valves to help moderate injection rates (i.e. gate valves or equivalent). If injecting into multiple locations simultaneously, multiple injection lines can be split off down gradient of the injection pump with each line typically having its own set of valves, gauges, and flow meters. All components of the injection system must be chemically compatible with Klozur One.

Establishing Contact

Effective treatment of site contaminants is achieved by establishing sufficient contact between Klozur One and the contaminants. To help estimate the quantity of Klozur One needed, please contact your PeroxyChem Technical Representative or email us at remediation@peroxychem.com.

The method used to establish sufficient contact between Klozur One and the contaminants of concern (COCs) is a critical aspect of the remedial application with injection and soil mixing being the most common strategies used for establishing contact.

Injection Strategies

Injection strategies introduce the previously dissolved (batched) Klozur One solution into the subsurface through chemically compatible wells or rods. The wells or rods are typically solid (blank) until reaching the intended depth where the reagents can flow through screens and out into the targeted interval of the subsurface. The reagents are then distributed into the subsurface for a certain radius of influence (ROI) depending upon the site characteristics and injection volume. At most sites, Klozur One can be expected to persist for weeks to months which may be sufficient time for it to migrate with groundwater flow after injection.

Common types of injection strategies include direct injection and recirculation.

Direct Injection

With a direct injection strategy Klozur One is injected into the subsurface and the volume of the injection is used to push Klozur One out a distance from the injection point to contact contamination in soil, non-aqueous phase liquid, and groundwater. There is no extraction with a direct injection strategy. The injection is typically under a pressure lower than the fracture pressure of the soils at the top of the injection interval. The volume of reagents injected can be critical in terms of the distance from each injection point the reagents are distributed. This distance is commonly referred to as the radius of influence, or ROI.

There are typically three ROIs:

- Design ROI. The design ROI is the radius intended to be treated by each injection point. This can include the injection ROI, as well as additional distribution of the reagent due to diffusion and advection with groundwater flow after the injection event. Injection point spacing is often set so that the design ROIs overlap, typically by 15 to 20 percent, which minimizes untreated areas and results in additional treatment of soils furthest from the injection points.
- Injection ROI. The injection ROI is a design parameter estimating the distance the injection volume will distribute the reagents from the injection point. This is typically estimated by equating the injection volume to the effective pore volume or pore volume at different distances from an injection point. For example, assuming 1,500 gallon injection volume and an effective pore volume of 0.15, the injection ROI would be R = sq root (1,500 gal/(π * h (ft) * 7.48 gal/ft^3 * 0.15)).
- Observed ROI. This is the actual ROI from an injection point confirmed in field optimization studies or field pilot tests. The observed ROI may vary vertically with different soil types and preferential flow paths even from the same injection point.

The injection volume is typically set so that that injection ROI is less than or equal to the design ROI. If less than the design ROI, it is typically assumed that the Klozur One solution will be distributed either by natural groundwater flow (advection) or diffusion.

Recirculation

In a recirculation strategy, groundwater is extracted from one set of wells, amended with Klozur One, and then reinjected into another set of injection wells. A recirculation strategy is commonly used to help control or limit the distribution of the reagent solution. Extraction wells typically out number injection wells as reagents injected under pressure typically flow at a higher rate than groundwater can be extracted.

Constructed Injection Wells

Constructed wells are typically made with materials compatible with Klozur One including stainless steel, polyvinyl chloride (PVC), or chlorinated polyvinyl chloride (cPVC). The wells are typically constructed with a screen interval, sand pack interval, a bentonite seal directly above the sand pack, and lastly a bentonite or grout slurry to surface. The sand pack interval is typically slightly larger than the screen interval to prevent the bentonite seal from impacting the screen. It is generally best to align the sand pack interval with the targeted contaminant interval in most applications where Klozur One is injected under pressure and the sand pack is more permeable than the native soils. Constructed wells can also be made using “pre-pack” screen, sand pack, and bentonite seals. For these wells, the screen and sand pack intervals are typically the same.

Direct Push Technology Injection Points

Injecting Klozur One through direction push technology (DPT) points is also possible. Care should be taken to make sure Klozur One contacts compatible materials. Many DPT points are made of carbon steel which will react with Klozur One. Injection through carbon steel DPT points is not recommended. However, injecting through DPT systems utilizing stainless steel or other chemically compatible materials is possible with Klozur One. PeroxyChem

recommends coordinating with the DPT contractor to ensure they are using a chemically compatible system if utilizing DPT systems to inject Klozur One.

Soil Mixing

Soil mixing is the second common method of establishing contact between Klozur One and contamination in the subsurface. A soil mixing strategy typically involves the mechanical agitation of subsurface soils blending in both Klozur One and the necessary activator reagents. The mechanical agitation breaks apart the natural soil structure and helps to establish contact between activated Klozur persulfate and the contamination found in the soils. This contact is key for successful remediation and can be particularly useful in treating source zones and lower permeable soils such as silts or clays.

Soil mixing has been used to target:

- Source areas as the primary method of treatment
- To treat residual contamination after excavation as a secondary method of treatment
- Combined with *in situ* stabilization (ISS) and other technologies

Soil mixing equipment often includes equipment containing carbon steel. Klozur One, by itself, is corrosive to carbon steel. If interested in a soil mixing application, please contact your PeroxyChem Technical Representative or email remediation@peroxychem.com to discuss how to decrease the potential corrosion of the mixing equipment.

For more information, please refer to the *Klozur Persulfate Soil Mixing Recommendations and Applications Guidelines* document, which can be found at peroxychem.com/remediation.

OPTIMIZATION STUDIES: BENCH AND PILOT SCALE TESTS

Projects often include a series of tests to help develop and confirm a variety of design parameters and assumptions for a full-scale application of Klozur One. PeroxyChem recommends performing bench scale tests to estimate the non-target demand associated with the soil and, if desired, to confirm the treatment effectiveness of different concentrations of Klozur One with contaminated site soils and groundwater. The non-target demand test is a critical design element for Klozur One. PeroxyChem refers to our non-target demand, or soil oxidant demand (SOD), test as the Klozur Demand Test (KDT). PeroxyChem has a full-service treatability laboratory to conduct bench scale studies using Klozur One. More information on these lab tests is available from your PeroxyChem Technical Representative or by emailing remediation@peroxychem.com.

Field optimization studies or field pilot tests can be used to further assess the application of Klozur One prior to a full-scale application. In addition to confirming treatment effectiveness, common objectives of these field evaluations include assessing injection pressures, flow rates, reagent distribution, and using the observed ROI to confirm the assumptions made in determining both the design and injection ROI.

STORAGE AND HANDLING

Klozur One is a UN Class 5.1 oxidizer. It should be stored in a secure, cool and dry location. The temperature of Klozur One should not exceed 45°C (113°F). PeroxyChem does not recommend storing Klozur One in field conditions for extended periods of time. Klozur One should only be temporarily stored onsite prior to use. Do not store liquid

solutions of Klozur One. For more information on storage and handling, please see guidelines for persulfate at www.peroxychem.com/chemistries/persulfates/safe-storage-handling.

MATERIALS OF COMPATIBILITY

As specified by the safety data sheet (SDS), Klozur One is a DOT class 5.1 oxidizer and a corrosive material. All materials contacting Klozur One should be chemically compatible including tanks, pumps, injection rods, seals, gaskets, tubing, hoses, and mixing equipment.

Compatible materials include: stainless steel (304L and 316L), polyethylene (PE), polyvinylchloride (PVC), polytetrafluoroethylene (PTFE), Viton®, polyvinylidene fluoride (PVDF), and butyl rubber. Materials NOT compatible include, nitrile rubber, carbon steel, aluminum, brass, galvanized steel, or any other metal susceptible to corrosion. Please refer to PeroxyChem's Corrosion and Material Compatibility of Klozur Persulfate Technical Bulletin for more detailed information, available at www.peroxychem.com/remediation.

HEALTH AND SAFETY

Klozur persulfate has been applied safely and effectively at thousands of sites. However, as with any chemical, proper procedures should be followed and recommended equipment used. When working with Klozur persulfate, ensure adequate ventilation and use the appropriate personal protective equipment, including safety glasses, suitable protective clothing, boots (steel toed or equivalent), chemical resistant gloves, hard hat, and hearing protection. For dust, splash, mist, or spray exposures wear a filtering dust mask and chemical protective goggles. A face shield can also be used in addition to goggles.

Please consult the appropriate safety data sheets (SDS) for guidelines regarding proper handling procedures. Klozur persulfate SDS's can be found at www.peroxychem.com/remediation. Additional safety equipment may be required for mechanical and site operations.

Please contact PeroxyChem for additional guidance.

Notes

1. A limited use license is included with the purchase of Klozur Persulfate for PeroxyChem's suite of national and international patents for the *in situ* activation of persulfate to remediate environmental contaminants of concern including US 6019548, US 6474908, US 7524141, US 7576254B2, US 7785038, and US 9375768B2.