

Klozur[®] SP Application Guidelines

Klozur[®] SP is a high purity environmental grade sodium persulfate that has been successfully used to remediate contaminants of concern (COC) at environmental sites around the world. Klozur persulfate can be activated using PeroxyChem's patented technologies¹ to form powerful oxidative and reductive radicals that aggressively treat the targeted contaminants. PeroxyChem's persulfate activation technology is well established having been successfully applied in thousands of field applications and scientifically validated in hundreds of independent peer-reviewed journal articles and conference presentations.

Klozur SP is part of PeroxyChem's Klozur Portfolio which also includes Klozur One, 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 SP. For more information on Klozur SP or other products in PeroxyChem's Klozur Portfolio, please visit klozur.com.

FIELD APPLICATIONS

PeroxyChem recommends activation of Klozur SP with alkaline, iron-chelate, heat, and hydrogen peroxide activation chemistries. For more information on each activation chemistry, please visit www.klozur.com.

PeroxyChem recommends batching and storing the activation chemistry and Klozur SP separately. It is also recommended that all the wetted components of the injection system be chemically compatible with all chemistries. The reagents can then be combined via in-line mixing prior to being injected or pulsed into the subsurface separately. In-line mixing requires an injection skid capable of blending the two reagents just prior to injection at the wellhead. A pulsed strategy involves injecting one solution at a time and allowing them to mix *in situ*. This can require oscillating between the reagent solutions frequently. Typically, this would involve the injection of 400 gallons (gal), or approximately 1,500 liters (L), of Klozur SP followed by 100 to 200 gal (approximately 400 to 800 L) of activator solution.

Batching Klozur SP

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 SP should be batched in systems where all wetted parts or parts that could become wetted are chemically compatible with Klozur SP. 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 SP is highly water soluble over normal temperatures providing a great deal of flexibility in the field in terms of batch concentration. PeroxyChem recommends that Klozur SP be injected in a range from 50 to 250 grams per liter (g/L). To achieve these concentrations, it is recommended that Klozur SP be batched at a concentration less than the theoretical solubility (Table 1).

It is recommended that batches of Klozur SP be injected or applied within eight hours of the dilution in water and that Klozur SP, batched, or otherwise stored, not be left unsecured or unsupervised. Solutions stored longer than eight hours are expected to be stable; however, the Klozur SP will slowly degrade and is expected to generate acid. If impurities are present or at elevated temperatures, the rate of reaction will increase.

Klozur SP 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 SP will increase with increasing concentrations. Generally, with an adequate mixing system, Klozur SP should be completely dissolved within 5 to 20 minutes.

Temperature (°C)	Klozur SP	
	(wt%)	(g/L)
0	36.5	480
10	40.1	540
20	41.8	570
25	42.3	580

Table 1: Solubility of Klozur SP in Water at Various Temperatures

Injection Equipment

Klozur SP 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 SP from the batch tank. The 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 which is necessary for most centrifugal pumps.

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 SP and the activator chemistry.

Establishing Contact

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

The method used to establish sufficient contact between Klozur SP and the 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 SP 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 SP 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 SP is injected into the subsurface and the volume of the injection is used to push Klozur SP 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 $R = \sqrt[3]{(1,500 \text{ gal}/(\pi * h \text{ (ft)} * 7.48 \text{ gal/ft}^3 * 0.15))}$.
- **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 the injection ROI is less than or equal to the design ROI. If less than the design ROI, it is typically assumed that the Klozur SP 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 SP, 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 outnumber injection wells since reagents injected under pressure typically flow at a higher rate than groundwater can be extracted.

Constructed Injection Wells

Constructed wells should be made with materials compatible with Klozur SP 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 that 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 SP 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 SP through direction push technology (DPT) points is also possible. Since carbon steel is the common material for DPT rods, most practitioners prefer to use alkaline activated persulfate to help minimize possible corrosion. Other steps to mitigate corrosion that are commonly taken include taping or otherwise protecting the rod threads with materials compatible with Klozur SP, and rinsing the rods after use and prior to storage. The rinse solution often includes a pH buffer, such as sodium bicarbonate and a reactant such as an alcohol or sodium ascorbate.

Other activation methods can be used with DTP systems utilizing stainless steel or other chemically compatible materials. PeroxyChem recommends coordinating with your DPT contractor to make sure they are using a chemically compatible system to inject Klozur SP.

Soil Mixing

Soil mixing is the second common method of establishing contact between Klozur SP and contamination in the subsurface. A soil mixing strategy typically involves the mechanical agitation of subsurface soils blending in both Klozur SP 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. Good contact is key for successful remediation and soil mixing can be particularly useful in treating source zones and lower permeable soils such as silts or clays.

Soil mixing has been used:

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

Soil mixing equipment often includes equipment containing carbon steel. Klozur SP, by itself, is corrosive to carbon steel. Most practitioners prefer alkaline activated persulfate for soil mixing as it helps protect the carbon steel mixing equipment. 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 prior to the full-scale application of Klozur SP. 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 SP with contaminated site soils and groundwater. The non-target demand test is a critical design element for Klozur SP. 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 SP. 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 SP 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 SP is a UN Class 5.1 oxidizer. It should be stored in a secure, cool and dry location. The temperature of Klozur SP should not exceed 45°C (113°F). PeroxyChem does not recommend storing Klozur SP in field conditions for extended periods of time. Do not store liquid solutions of Klozur SP. For more information on storage and handling, please see guidelines for persulfate at peroxychem.com/chemistries/persulfates/safe-storage-handling.

MATERIALS OF COMPATIBILITY

As specified by the safety data sheet (SDS), Klozur SP is a DOT class 5.1 oxidizer and a corrosive material. All materials contacting Klozur SP 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 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.

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