



The Solution to Klozur® SP Solutions

This edition of Peroxygen Talk has the scoop on Klozur® SP solutions. Klozur SP is delivered as a white, crystalline material in bags, drums or super sacks. In order to safely and successfully prepare persulfate solutions for injection, it is important to understand the physical and chemical properties of Klozur SP.

Solution physio-chemical properties

1. Key Concentration Equations

Definition of wt%:

$$(1) \text{ wt\%} = \text{wt of sodium persulfate} / \text{wt of solution} \times 100 = \text{wt of sodium persulfate} / (\text{wt of sodium persulfate} + \text{wt of water}) \times 100$$

Example: 20 wt% means 20 lbs of sodium persulfate per 100 lbs of solution

Conversion of wt% to g/L:

$$(2) \text{ g/L} = 0.1049 * \text{wt\%} * \text{wt\%} + 9.1501 * \text{wt\%} + 3.1347$$

Conversion of wt% to lb/gal:

$$(3) \text{ lb / gal} = 0.0083 * \text{g/L}$$

2. Solubility

Klozur SP is a highly soluble salt that is easy to dissolve. Table 1 shows the maximum solubility of Klozur solutions as a function of temperature:

Temperature	Maximum Solubility in wt%
~ 0 °C (32 °F)	37
25 °C (77 °F)	42
50 °C (122 °F)	46

Table 1: Solubility as a function of temperature

3. Density

The density of Klozur SP solutions is a function of persulfate concentration and can be determined by the following equation:

$$\text{Density (g/mL)} = 6 \times 10^{-5} * \text{wt\%} * \text{wt\%} + 0.0061 * \text{wt\%} + 0.9999$$



Table 2 lists the density of Klozur SP solutions for several concentrations.

Concentration (wt %)	Density (g / mL)
10	1.067
20	1.146
30	1.237
40	1.340

Table 2: Density as a function of concentration

The change in solution density as a function of concentration may have practical implications when preparing a batch of Klozur SP solution. As an example, Table 3 displays the effect on solution volume as a function of concentration when batching Klozur SP into 500 gallons of water.

Target Concentration (wt %)	Amount of Klozur Added (lbs)	Solution Volume (gal)	% Change in Volume Upon Klozur Addition
10	464	528	6
20	1,042	548	10
30	1,787	576	15
40	2,780	620	24

Table 3: Solution volume as a function of concentration for an initial 500 gallons of water

As a result, adequate tank headspace needs to be assured for safety, especially when formulating higher sodium persulfate concentration solutions.

4. Viscosity

Klozur SP solutions have low viscosities and flow like typical salt solutions. Table 4 shows the viscosity at room temperature as a function of solution concentration.



Solution Concentration (wt %)	Viscosity (cp)
10	0.970
20	1.200
30	1.607
40	2.220

Table 4: Viscosity as a function of solution concentration at room temperature

Persulfate Aqueous Solution Decomposition

If stored and handled properly, Klozur SP as delivered has a shelf life in excess of one year. It is not recommended storing bulk Klozur SP in direct sunlight or under tarps, especially in hot locations, such as the southwestern US during the summer. This may lead to excessive decomposition. However, once in solution, persulfate will auto-catalytically decompose. The rate of decomposition depends on several factors, including: persulfate concentration, temperature, pH and the presence of an activator.

At dilute concentrations, such as encountered typically for *in situ* groundwater concentrations which range from 5 – 50 g / L, the decomposition rate is relatively slow. As a result, persulfate may persist in the subsurface for weeks to months, depending on the soil oxidant demand for the site. However, the decomposition rate can significantly increase at concentrations ranging from 10 – 40 wt%, which are typical of injection concentrations. The rate of decomposition for Klozur SP solutions will be the topic of a forthcoming *Peroxygen Talk*. In general, for concentration between 10 – 30 wt% there is sufficient stability in the persulfate solution to allow batching of a day tank without significant loss of persulfate (< 1%). It is highly recommended that the Klozur solution be utilized the day of formulation, especially if the persulfate activators are added to the batch tank.

The by-product of persulfate decomposition is HSO_4^- . As a result, unless alkaline activation (see January 2006 *Peroxygen Talk* for discussion on activation chemistries) is used, the pH of a persulfate solution will decrease, and may reach a pH as low as 1.9. As a result, low pH corrosion is a potential when working with persulfate solutions. Corrosion and general materials compatibility and handling concerns will be the topic of an upcoming *Peroxygen Talk*.

Injection Design with Klozur SP Solutions

One advantage of using Klozur SP over other oxidants such potassium permanganate is that solutions concentrations up to 40 wt% can be formulated. This provides a high degree of freedom in designing an injection plan. One frequently asked question regarding Klozur solutions is: What persulfate concentration should I use for my site? The answer is that it is entirely dependent on how many pore volumes you wish to inject.



As an example to illustrate:

The injection plan calls for ten injection wells. The site has the following characteristics:

Radius of influence	10 feet
Soil porosity	30%
Total groundwater	281,250 gallons (28,125 gallons per well)

Calculations based on contaminant type and loading, verified by subsequent treatability testing, indicate:

Target Klozur groundwater concentration	25 g / L
Total Klozur demand	59,000 lbs (5,900 per well)
Maximum volume in batch tank	900 gal

Table 5 illustrates the formulation recipe and the volume of Klozur SP solution that will be injected as a percentage of total pore volume.

Target Solution Concentration (wt %)	Amount of Klozur SP Added to Make 900 gal of Solution (lb)	Amount of Water Added to Make 900 gal of Solution (gal)	Number of Tanks to Be Batched to Inject all Persulfate	% Pore Volume to be Injected
20	1,713	821.6	34.4	11
40	4,033	725.3	14.6	5

Table 5: The % pore volume to be injected as a function of solution concentration.

As expected, as the Klozur SP solution concentration decreases, more water needs to be injected into the formation to reach the target *in situ* persulfate concentration, resulting in a greater percentage pore volume being displaced.

The high solubility of Klozur SP gives you the flexibility in tailoring the injection volume to your needs. If you desire low pore volume turnover, then you can batch higher concentration solutions. If high pore volume turnover is desired, then lower concentration persulfate solutions can be utilized. Please contact the Environmental Solutions Team for support in oxidant calculations and chemical supply needs.

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