

COMPARISON OF OXIDANTS

PROPERTY	SODIUM/POTASSIUM PERMANGANATE	ACTIVATED SODIUM PERSULFATE	MODIFIED FENTON'S REAGENT	TRADITIONAL FENTON'S REAGENT
Stability	Half life in days	Half life in hours to days	Half life in hours	Half life in minutes
Precipitation	Will form black MnO ₂ precipitate, which may reduce subsurface permeability.	Slight precipitation of iron, when iron activated persulfate is used, which will be adsorbed by soil matrix. Permeability is not significantly affected.	Slight precipitation of iron, which will be adsorbed by soil matrix. Permeability is not significantly affected.	Will precipitate excess dark brown iron hydroxide, which may cause iron fouling and reduce subsurface permeability.
Treatment of COCs	Can treat chlorinated alkenes such as TCE effectively but is ineffective with chlorinated alkanes such as TCA. Also, ineffective with benzene and chlorobenzene.	Can treat chlorinated alkenes effectively. It has been reported to be moderately effective with chlorinated alkanes. Persulfate may be combined with Fenton's reagent for carbon tetrachloride and chloroform treatment.	Can treat both chlorinated alkenes and alkanes effectively. Also effective with a wide range of petroleum hydrocarbons, carbon tetrachloride, chloroform and 1,4-dioxane.	Can treat both chlorinated alkenes and alkanes effectively. Also effective with a wide range of petroleum hydrocarbons. Not effective with carbon tetrachloride or chloroform.
Desorption Ability	Limited	Limited	Very effective at desorbing soil-bound contaminants.	Limited due to poor generation of superoxide radicals.
Radial Distribution	Good	Good for chelated iron activated persulfate. Poor for alkaline activated persulfate due to immediate pH buffering by native soils.	Good due to stabilized peroxide and chelated iron catalysts.	Poor due to immediate buffering of acidic pH by native soils and iron precipitation.
Matrix Treatment	Effective in groundwater phase but has limited effectiveness with soil-bound contaminant treatment due to inability to desorb contaminants. This may result in subsequent rebound in groundwater concentrations after purple/pink color disappears.	Effective in groundwater phase but has limited effectiveness with soil-bound contaminant treatment due to inability to desorb contaminants. This may result in subsequent rebound in groundwater concentrations after residual persulfate is decomposed.	Effective for aqueous phase contaminants. Also, effective in treating soil-bound contaminants because of the ability to desorb and destroy contaminants.	Effective for aqueous phase, but has limited effectiveness with soil-bound contaminant treatment due to limited ability to desorb contaminants. This may result in subsequent rebound in groundwater concentrations.
Treatment Cost	Similar or more expensive when compared to modified Fenton's if used as KMnO ₄ depending on the NOD. More expensive if used as NaMnO ₄ .	More expensive when compared to Fenton's reagent or KMnO ₄ but less expensive compared to NaMnO ₄ .	Similar or cheaper than KMnO ₄ and persulfate depending on the NOD.	Similar to modified Fenton's. Similar or cheaper than KMnO ₄ and persulfate depending on the NOD.
Free Radical Chemistry	None. Contaminant destruction occurs via direct oxidation.	Sulfate free radicals are produced.	Free radicals including hydroxyl and superoxide radicals are produced.	Hydroxyl radicals are produced.
Reaction off gases during injections	None noticeable.	None noticeable.	Gas formation occurs in the form of O ₂ , CO ₂ , and H ₂ O.	More aggressive gas formation occurs in the form of O ₂ , CO ₂ , and H ₂ O, which can result in explosive conditions
Reaction pH	Effective at natural subsurface pH (i.e. pH 5-8).	Native subsurface pH is lowered due to low pH of persulfate. At high pH (i.e. pH > 10), alkaline activation of persulfate may occur.	Modified Fenton's can function over a broad pH range (i.e. pH 2-10).	Requires acidic pH (i.e. pH ≤ 3.5). The addition of acid in the sub-surface often results in an exothermic reaction.