RegenOx™

Advanced Chemical Oxidation

Comparison of RegenOx™ to Permanganate

Contaminant Applicability

RegenOx™ rapidly oxidizes a broad range of organic compounds, including petroleum products and chlorinated solvents (both alkanes and alkenes), and is a powerful tool for the remediation of contaminated soil and groundwater. Permanganate-based products, by contrast, have not been successfully used to treat soil and groundwater impacted by petroleum alkanes or chlorinated solvent alkanes such a trichloroethane (TCA).

Relative Oxidizing Capacities

RegenOx is a two-part product composed of an oxidizer/catalyst complex (Part A) and an activator complex (Part B). The RegenOx oxidizer (Part A) contains sodium percarbonate and a surface catalyst as the principal ingredients by mass. Sodium percarbonate has approximately the same oxidizing capacity as potassium permanganate on a per–unit-mass basis. This is based on the formula weights and number of oxidation electrons per formula unit:

Sodium percarbonate $(Na_2CO_3)_2(H_2O_2)_3$	Formula Weight 314 (6-electron oxidant)
Potassium permanganate KMnO4	Formula Weight 158 (3-electron oxidant)

On a per-unit-mass basis:

(3/158)/(6/314) = 99% = (Oxidizing capacity of potassium permanganate)/(Oxidizing capacity of sodium percarbonate)

As shown above, sodium percarbonate and potassium permanganate have almost identical theoretical oxidizing capacity per unit weight. RegenOx is a form of activated percarbonate designed to efficiently degrade a wide variety of contaminants. The added weight of the activator (RegenOx Part B) results in a lower theoretical oxidizing capacity for RegenOx when compared with permanganate on a per-pound basis. However, this is more than compensated by RegenOx' higher selectivity toward contaminant destruction and its ability to treat a much broader spectrum of contaminants.

Cost of Treatment

Table 1 compares the costs associated with treating a "typical" project site with RegenOx™ to the costs of treating that site with potassium permanganate. The calculations are based on a site that has a soil volume of 16,000 cubic yards with an average perchloroethene (PCE) concentration of 50 ppm and 30 percent porosity. In this scenario, RegenOx™ provides a cost savings of $39,000 over potassium permanganate, or $2.43 less per cubic yard treated. Naturally, these cost savings will vary depending on site characteristics; however, this typical example is significant.

Table 1: Cost Comparison Between RegenOx™ and Permanganate

Cost	Permanganate*					RegenOx			
Direct Capital Costs	No.	Units	Unit Cost	Cost		No.	Units	Unit Cost	Cost
Direct-Push Mob	1	ea.	$5,000	$5,000		1	ea.	$5,000	$5,000
Direct-Push Contractor	20	days	$2,500	$50,000		20	days	$2,500	$50,000
Oxidant Costs	55,689	lbs	$1.85	$103,025		16,020	lbs	$2.00	$32,040
Activator Costs	0	lbs		$0		16,020	lbs	$2.00	$32,040
	55,689			$158,025		32,040			$119,080

* P. Block and W. Cutler, "Klozur™ Activated Persulfate for Site Remediation: Comparative Evaluation of Treatment Efficacy and Implementation Costs.", Presented at 4th International Conf. on Oxidation and Reduction technologies for In-Situ Treatment of Soil and Groundwater, October 23-27, 2005.

Most contaminated sites treated by chemical oxidation require retreatment to minimize rebound. Because RegenOx uses a true catalyst (i.e., in both Part A and Part B), which remains active in the subsurface for years, retreatment costs will be significantly lower. For retreatment, the use of RegenOx™ in the scenario described above provides a cost savings of $55,000 over potassium permanganate, or $3.44 less per cubic yard (see Table 2). Again, the cost savings achieved by using RegenOx will vary depending on site characteristics.

Table 2: Retreatment Cost Comparison Between RegenOx™ and Permanganate

Cost	Permanganate*					RegenOx			
Direct Capital Costs	No.	Units	Unit Cost	Cost		No.	Units	Unit Cost	Cost
Direct-Push Mob	1	ea.	$5,000	$5,000		1	ea.	$5,000	$5,000
Direct-Push Contractor	20	days	$2,500	$50,000		20	days	$2,500	$50,000
Oxidant Costs	55,689	lbs	$1.85	$103,025		16,020	lbs	$2.00	$32,040
Activator Costs	0	lbs		$0		8,010	lbs	$2.00	$16,020
	55,689			$158,025		24,030			$103,060

* P. Block and W. Cutler, "Klozur™ Activated Persulfate for Site Remediation: Comparative Evaluation of Treatment Efficacy and Implementation Costs.", Presented at 4th International Conf. on Oxidation and Reduction technologies for In-Situ Treatment of Soil and Groundwater, October 23-27, 2005.

Safety

RegenOx is engineered for ease of handling in the field and is safely mixed without the risks and potential hazards associated with other chemical oxidants, such as permanganate-type products. Permanganate, especially sodium permanganate, is a highly reactive material that can, if contacted with clothing and or paper products, result in fire. (See an example in Figure 1.)

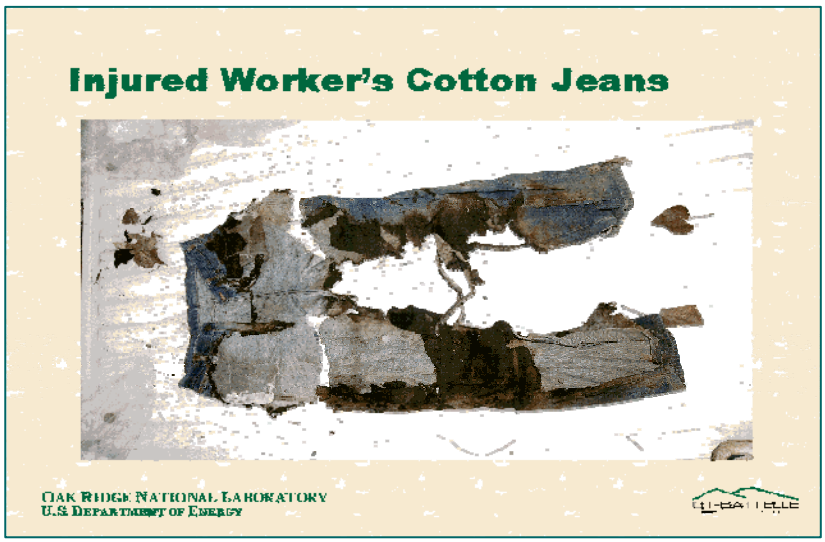

Figure 1: Results of Improper Safety Procedures When Using Permanganate

Longevity

RegenOx™ remains effective in the subsurface for a period lasting approximately 15 days to 1 month. The length of time it will last is adjustable by adding more or less of the Part B activator. However, after the designed period of effectiveness ends, the product is spent. In comparison, permanganate can persist in the subsurface for months, causing an undesired effect as the remaining material may surface in storm drains and surface water.

Formation of MnO_2

The end product of permanganate oxidization is manganese dioxide (MnO_2), which is precipitated in the subsurface. This compound, once formed, interferes with the establishment of conditions suitable for reductive dechlorination, thus working against beneficial bioremediation following chemical oxidation. Additionally, in the presence of dense nonaqueous-phase liquid (DNAPL) contaminants, $Mn0_2$ formation is known to encrust DNAPL ganglia, often retarding the dissolution of the material. This ultimately and negatively affects the remediation process by inhibiting efficient dissolution and treatment of the subsurface contamination. RegenOx, in contrast, does not produce MnO_2 and does not produce any treatment-inhibiting byproducts.

Summary

The information written in this technical bulletin provides compelling evidence that when comparing RegenOx with permanganate, RegenOx is clearly superior in many ways. Relative to material efficiency, cost-effectiveness, safety, ease of use, and post-bioremediation compatibility, RegenOx is clearly the better choice.

For more information on RegenOx or a free application design and cost estimate contact Regenesis at 949-366-8000 or visit www.regenesis.com.