Surfactant-Enhanced In Situ Chemical Oxidation (S-ISCO®)

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Resumo: VeruTEK® Technologies, Inc. é uma empresa internacional norte-americana que atua na área de tecnologia química. Dentre outros é responsável pela criação de uma solução inovadora para a locais onde há contaminação e plumas de NAPL: Surfactant-Enhanced In Situ Chemical Oxidation (S-ISCO®). S-ISCO envolve o transporte reativo de tensoativos e sistemas oxidantes para destruir a contaminação no local, eliminando a necessidade de escavação, por exemplo. à casos de contaminação no solo, para fase livre e dissolvida. Inúmeros ensaios laboratoriais, mais de 30 implementações em campo, incluindo 18 intervenções em remediações de grande porte ao redor do mundo, comprovam a atuação S-ISCO em empreendimentos com ocorrência de contaminação, eliminando grande parte de produtos como: LNAPL's, DNAPL's e fases residuais, tais como óleo de fluido hidráulico, PCB e solventes clorados. VeruTEK continua a aperfeiçoar e expandir a sua tecnologia, desenvolvendo aplicações através de pesquisas em parceria com universidades como Yale e Carnegie Mellon, bem como a EPA dos EUA.

Abstract: VeruTEK® Technologies, Inc. is a US-based international Green Chemistry technology company that has created an innovative solution to source zone contamination and NAPL plumes: Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO®). S-ISCO involves the reactive transport of surfactants and oxidant systems to destroy contamination on site and in place, eliminating the need for excavation, for example, and providing timely and permanent solutions to soil, free-phase and dissolved contamination. During extensive laboratory and over 30 field implementations, including 18 full-scale remediations around the world, S-ISCO has remediated LNAPLs, DNAPLs and sorbed residuals, such as hydraulic fluid oil, PCBs and chlorinated solvents, and provided "complete or near complete destruction of coal tar NAPLs and residues."[4] VeruTEK continues to refine and expand its technology and applications through ongoing research and development, including partnerships with universities such as Yale and Carnegie Mellon, as well as the US EPA.

Keywords: in situ chemical oxidation; remediation; surfactant; green; source destruction

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[4] The New York State Department of Environmental Conservation, Division of Environmental Remediation, included this statement in an approval of VeruTEK's S-ISCO implementation at an MGP site in New York.

1- INTRODUCTION

At the foundation of Surfactant-Enhanced In Situ Chemical Oxidation (S-ISCO) is the subsurface coelution of surfactants and free radical oxidant systems that increase the solubility of contaminants with normally low solubility, such as NAPLs, and make them available for oxidative destruction. S-ISCO incorporates the following three key elements: surfactant and co-solvent mixtures that emulsify NAPL-phase contaminants and desorb source zone contaminants; catalysts and oxidants that generate powerful free-radical oxidant systems; and free radical oxidant systems that destroy solubilized contaminants.

2 – S-ISCO TECHNOLOGY

2.1 – Surfactants

Because *in situ* chemical oxidation consists primarily of aqueous phase reactions, the highly hydrophobic contaminants that are sorbed to soil particles or in a separate NAPL state are not available for reaction with the oxidant chemistry. VeruTEK developed S-ISCO to address these sorbed or NAPL-phase contaminants. S-ISCO is highly differentiated from In Situ Chemical Oxidation (ISCO), for example, through its incorporation of VeruSOL®, food-grade and plant-based surfactant and co-solvent mixtures (e.g. coconut and castor oils, and citrus extracts), which are either Generally Recognized as Safe by the U.S. FDA or approved as indirect food additives and for dermal contact, to address NAPL. VeruSOL creates the most effective solubilized micro-emulsion with NAPL, that is, a Winsor Type I oil-in-water emulsion in which the NAPL is immobilized and can enter aqueous phase reactions, such as oxidation.

Figure 1 shows how VeruSOL increases NAPL solubility between one and three orders of magnitude. With more contamination available for oxidative destruction, the rate of

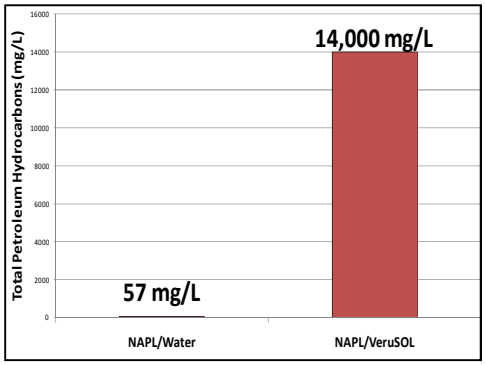

Figure 1. VeruSOL Desorption Enhancement

chemical oxidation is increased, over ISCO, for example. In addition, VeruSOL enhances the *in situ* chemical oxidation process by stabilizing the injected oxidants, coating injected catalysts for time-released activation, and depressing soil vapor concentrations.

2.2 – Free-Radical Oxidant Systems

S-ISCO oxidant systems often include sodium persulfate and/or hydrogen peroxide in conjunction with activators and/or catalysts, including alkaline conditions; iron chelates, such as Fe-EDTA and Fe-EDDS; a green, designer catalyst for peroxide, Fe-TAML[5]; and green-synthesized nanoscale zero valent iron (G-nZVI). S-ISCO implementation consists of targeted injections of the oxidant, its activator or catalyst and VeruSOL, in a formulation optimized for the contamination, and hydrological and geological characteristics of a given site. Laboratory dosage studies that often precede a field implementation, along with groundwater monitoring of the progress and performance of the injected chemistry during treatment, are used to optimize the process.

2.2.1 – Sodium Persuflate Systems

Persulfate treats more chemically complex contaminants, often in silty clay or bedrock environments, and at deeper depths. A sulfate radical is one of strongest aqueous oxidizing species with a redox potential of approximately 2.6 V[6]. In addition to its oxidizing strength, sulfate radical systems are stable, lasting weeks to months in the soil and enhancing both the radius of influence of injections and also the contact time with recalcitrant compounds, such as chloroethenes. After a S-ISCO implementation at a New York MGP, for example, groundwater monitoring results showed that persulfate remained active for more than four months after the seven months of VeruSOL and Fe-EDTA-activated persulfate injections ceased.[7] This treatment destroyed 91% of the 7,900 kg of PAH targeted, reduced visual staining by more than 80%, and improved soil vapor concentrations in nearby buildings.

2.2.1 – Hydrogen Peroxide Systems

Hydrogen peroxide is an optimal oxidant for more chemically straightforward hydrocarbon contaminants, such as petroleum hydrocarbons and lower concentrations of

[5] Developed by the Institute for Green Oxidation Chemistry at Carnegie Mellon University.
[6] Compared to 2.1 V for persulfate and 1.9 V for hydrogen peroxide.
[7] Measured persulfate and elevated conductivity indicated continued oxidation reactions.

BTEX. Hydrogen peroxide can be used alone but is most often catalyzed to produce hydroxyl radicals. Although peroxide is shorter-lived than persulfate, VeruSOL enhances its stability and extends the longevity of its reactions in the subsurface (Figure 2). In addition, peroxide can be used with persulfate as a first treatment stage. Peroxide quickly destroys the shallower, more reactive contamination before persulfate provides a longer-lasting treatment for deeper, more recalcitrant impacts.

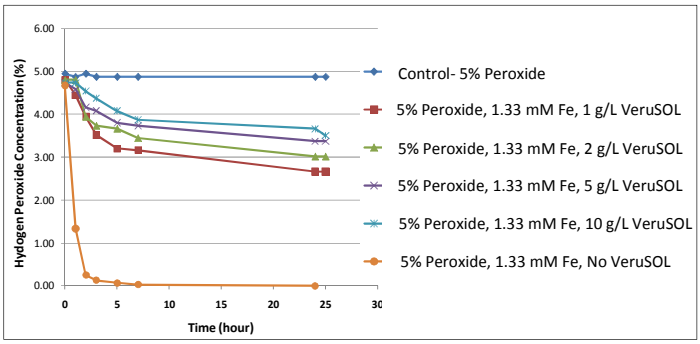

Figure 2. VeruSOL Stabilization of G-nZVI-Catalyzed Peroxide

3 – APPLICATIONS

S-ISCO is an effective and environmentally friendly solution to contamination that threatens the human and natural environmental. S-ISCO injections can target contamination beneath structures, without impact to the building or its users, and can be used at former MGPs; underground storage tanks; fueling stations; residences; and in industrial settings, such as laboratories. In addition to its basis in Green Chemistry, S-ISCO is aligned with US EPA's criteria for greener remediations[8] —criteria including reduced energy and water use; air pollution and greenhouse gas (GHG) emissions; and waste material, and ecosystem improvement. Because S-ISCO reactions are more efficient than ISCO, for example, a project's length and energy use are reduced (energy). S-ISCO chemistry travels with groundwater and does not require re-circulating or extraction pumps (energy). I*n situ* remediation does not require heavy machinery used in excavations, for example (energy), and treats material on site, reducing wastes hauled to landfills (waste, air pollution). S-ISCO improves water quality by destroying dissolved contaminants and their source, without disturbing the land (ecosystems). At the same time that VeruSOL is biodegradable and made from renewable plant material, waste products of S-ISCO reactions are non-hazardous (CO_2, H_2O and O_2) (ecosystem, waste).

[8] US EPA, Office of Solid Waste and Emergency Response. "The Principles for Greener Cleanups".