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SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

Treatability Study Bulletin

Enzyme-Activated Cellulose Technology

Thorneco, Inc.

Technology Description: The Enzyme-Activated Cellulose Technology developed by Thorneco, Inc. uses cellulose placed into one or more cylindrical towers to remove metals and organic compounds from an aqueous solution. The cellulose is coated with a proprietary enzyme. Operating parameters that can affect the process efficiency include flow rate, cellulose dosage, enzyme solution, and pH.

A schematic of the Thorneco treatment process is shown in Figure 1. Following enzyme treatment, the cellulose is placed into one or more cylindrical towers that operate in series. Contaminated water enters the tower from the bottom and flows upward through the enzyme-activated cellulose to the discharge pipe located at the top of the tower.

Waste Applicability: This treatment technology is directed at the removal of metals and organic compounds from an aqueous solution in the form of ions, particulates or colloidal compounds.

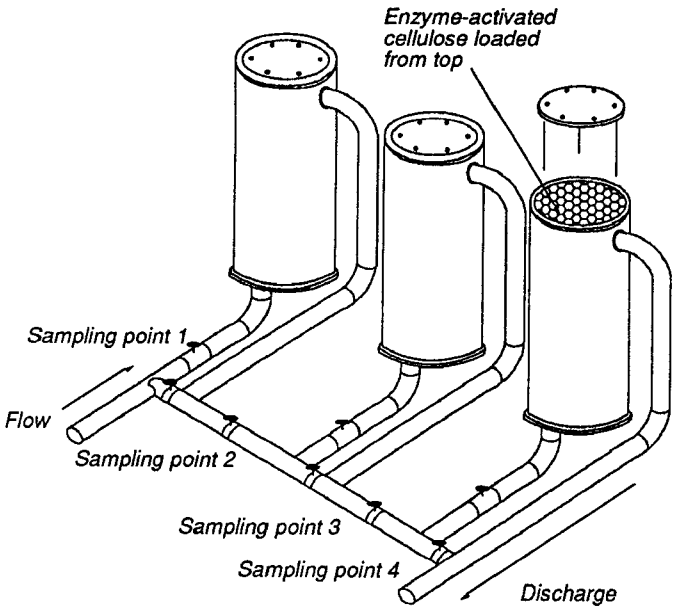

Figure 1. Thorneco enzyme — Activated cellulose technology — 3 tower system.

Treatability Study Results: Key findings from the Thorneco, Inc. treatability study are summarized as follows:

- A strong trend could not be established for volatile organic compound (VOC) removal in relation to pH and cellulose dosage. The results for other contaminants showed that generally higher pH levels resulted in better removal.
- Biological activity was not enhanced by the treated cellulose in this study.
- Freundlich and Langmuir (linear and non-linear) isotherm models were inadequate to represent concentration data obtained during the 48-hr batch contact experiments. Therefore, the adsorption removal mechanism could not be fully evaluated and the capacity and lower limits of treatment of the cellulose could not be determined.
- Removal of volatile organic compounds was primarily the result of volatilization. The treated cellulose was capable of increasing volatile organic compound removal, on the average, by 10% to 31%, but the exact removal mechanisms were not determined.
- Metals and nitrate removals were enhanced by the treated cellulose. Precipitation appeared to be the primary removal mechanism for metals. The removal mechanism for nitrate was not determined.
- Phenols removal was very limited and was not consistently enhanced by the treated cellulose.
- Voluminous solids residuals produced from this study required incineration at a hazardous waste incineration facility due to the concentration of chlorinated hydrocarbons. Costs associated with waste disposal were not analyzed because the amount of solids generated by the process was not a component of the study.

Treatability Study Approach: The Thorneco, Inc. technology was selected by EPA as a candidate technology for the Superfund Innovative Technology Evaluation (SITE) program. Due to a lack of complete background data and uncertainty concerning the technology's removal mechanism(s), a bench-scale treatability study of the process was proposed.

The treatability study was conducted at the Engineering Science (ES) treatability laboratory in Atlanta, GA. Experiments were conducted between August 26, 1991 and September 30, 1991. Contaminated groundwater for the study was obtained from Stream A of the Stringfellow Superfund site in Glen Avon, CA.

The specific objectives of the study were to:

- estimate the removal capacity and treatability limits of the Thorneco process for individual pollutants in the Stringfellow groundwater
- determine the appropriate operating conditions (pH and loading) for effective treatment of Stringfellow groundwater by the Thorneco process
- characterize the residuals from the process and discuss their disposal requirements
- evaluate the suspected removal mechanisms (exchange/sorption, biodegradation and volatilization) in the Thorneco process.

Prior to the study, the primary potential mechanisms for contaminant removal were identified to be volatilization, biodegradation and/or adsorption. Adsorption was considered the most likely removal mechanism based on information provided by the developer.

A series of preliminary screening experiments were conducted to determine the most effective operating pH and cellulose dosage for the subsequent 48-hr batch contact study and to evaluate suspected biodegradation and volatilization removal mechanisms. Mass loadings of 0.5-, 4-, and 20-gram treated cellulose per liter were investigated at four pH values; as received (which ranged from 3.3 - 3.56), and approximately 5, 7 and 9. An optimum pH and cellulose dosage could not be established from the data obtained from the screening experiments.

Based on the results of a follow-up pH/dosage study, the 48-hr batch contact tests, including one control and two tests, were conducted with cellulose dosages in the range of 80 to 180 g/L and on groundwater at an "as-received" pH in order to study the adsorption mechanism and the effectiveness of the treated cellulose. The control experiment was conducted using untreated cellulose and the two test experiments were conducted using enzyme-treated cellulose.

All contact experiments were conducted in 1-gal, high density polyethylene (HDPE) containers. The containers were placed into a tumbler with a 10-container capacity. The tumbling time for the screening experiments was 24 hr. After tumbling, the samples were settled and then pressure-filtered and placed into the appropriate bottleware for analysis. The tumbling time for the 48-hr batch contact tests was 48 hr. After tumbling, the contactors were placed in a 4 °C refrigerator to facilitate settling of solids.

Although the Thorneco technology operates in a packed tower configuration, batch contact experiments were chosen for the study in order to obtain basic information about the adsorptive capacity, stimulation of biological activity, and overall effectiveness in removing selected contaminants for the treated cellulose in a cost-effective manner.

The waste characteristics of the treatability samples were determined by collecting initial samples for VOCs prior to contact experiments. Initial samples for all other parameters were collected from contactors that did not contain cellulose, but were tumbled, settled and filtered. Table 1 presents the range of detectable contaminants that were found in the initial stream A groundwater samples collected from Stringfellow during the treatability study. A summary of the maximum percentage removals for 48-hr batch contact experiments are given in Table 2.

Sampling and analyses were conducted for three sets of preliminary screening experiments (Operation Conditions Assessment, Assessment of Biological Activity and Volatilization Losses) and the 48-hr batch contact experiments (one control and two test cases). A total of 13 aqueous samples were collected for the Operating Conditions Assessment experiment; 17 aqueous samples were collected from the aerobic and anaerobic biological studies; and 24 aqueous samples and 3 solid residue samples were collected during the 48-hr batch contact experiments. Aqueous samples were collected from the filtration apparatus for the volatilization loss experiment.

Table 1. *Concentration Ranges for Stream A Groundwater*

Parameter	*Reporting Unit*	*Concentration Range*
Chlorobenzene	*ug/l*	*160-480*
Chloroform	*ug/l*	*400-600*
1,2-Dichlorobenzene	*ug/l*	*<100-430*
1,4-Dichlorobenzene	*ug/l*	*<10-110*
Dichloromethane	*ug/l*	*<500-1,600*
Trichloroethylene	*ug/l*	*1,000-2,200*
Toluene	*ug/l*	*<10-76*
2-Chlorophenol	*ug/l*	*55-89*
4-Chloro-3-Methylphenol	*ug/l*	*<10-44*
2,4-Dichlorophenol	*ug/l*	*<10-46*
2,4-Dinitrophenol	*ug/l*	*<200-260*
2,4-Dimethylphenol	*ug/l*	*<10-90*
2-Nitrophenol	*ug/l*	*<10-100*
4-Nitrophenol	*ug/l*	*160-740*
Pentachlorophenol	*ug/l*	*<100-160*
Phenol	*ug/l*	*87-200*
Cadmium	*mg/l*	*1.9-2.3*
Chromium	*mg/l*	*75-99*
Lead	*mg/l*	*<0.10-0.28*
Nitrate	*mg/l*	*53-67*
Total Organic Carbon	*mg/l*	*1,200-1,300*
Total Dissolved Solids	*mg/l*	*27,000-28,000*
Total Suspended Solids	*mg/l*	*<4-12*

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Table 2. *Summary of Maximum Percentage Removals for 48-hr Isotherm Experiments*

Compound	Control	Cellulose Dosage(s) (g/L)	Test 1	Cellulose Dosage(s) (g/L)	Test 2	Cellulose Dosage(s) (g/L)
Volatile Halogenated Organics						
Chlorobenzene	*85*	*(120)*	*75*	*(100,180)*	*95**	*(180)*
Chloroform	*63*	*(80)*	*81*	*(140)*	*78*	*(180)*
Dichloromethane	*58*	*(120)*	*83**	*(80)*	*U*	
Trichloroethylene	*78*	*(120)*	*95*	*(120)*	*98*	*(180)*
Benzene	*ND*		*ND*		*U*	
Range	*58-85*		*75-95*		*78-98*	
Phenols						
2-Chlorophenol	*88**	*(110)*	*U*		*88**	*(140,180)*
4-Chloro-3-Methylphenol	*77**	*(100,110)*	*U*		*U*	
2,4-Dinitrophenol	*ND*		*13**	*(100,110,120)*	*U*	
2-Methyl-4,6-Dinitrophenol	*ND*		*ND*		*U*	
2-Nitrophenol	*90**	*(80-110)*	*U*		*ND*	
4-Nitrophenol	*83**	*(110)*	*86**	*(100-120)*	*72*	*(80-180)*
Phenol	*94**	*(80,100)*	*95**	*(100-120)*	*92**	*(80,100,160)*
Range	*77-94*		*13-95*		*72-92*	
Metals						
Cadmium	*14*	*(140)*	*79*	*(80)*	*58*	*(80,110)*
Chromium	*22*	*(140)*	*88*	*(80)*	*57*	*(180)*
Lead	*ND*		*U*		*U*	
Range	*14-22*		*79-88*		*57-58*	
Nitrate	*13*	*(125)*	*84**	*(80-160)*	*85**	*(100,110,140,180)*
Range	*0-13*		*81-84*		*68-85*	

**Percent removals computed using ND as equal to concentration at the detection limit.*
ND - Not detected in any samples.
U - Unknown percent removal because concentration in initial sample was below detection limit.

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