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APPLICATION OF AMBERSORB 563 ADSORBENT TECHNOLOGY FOR TREATMENT OF CHLORINATED ORGANICS IN GROUNDWATER

Russell W. Frye, Joseph F. Martino, and Russell E. Turner
Roy F. Weston, Inc.
1 Weston Way
West Chester, PA 19380
610-701-6173

Eric G. Isacoff and Deborah A. Plantz
Rohm and Haas Company
Research Laboratories
Spring House, PA 19477
215-641-7255

INTRODUCTION

Roy F. Weston, Inc. (WESTON®), in conjunction with Rohm and Haas Company (Rohm and Haas), conducted a field pilot study to demonstrate the technical feasibility and cost-effectiveness of Ambersorb® 563 (A-563) carbonaceous adsorbent for the remediation of groundwater contaminated with volatile organic compounds (VOCs). The project was conducted under the Emerging Technology Program of the EPA Superfund Innovative Technology Evaluation (SITE) program.

Ambersorb adsorbents are a family of patented, synthetic, tailorable carbonaceous adsorbents that were developed by Rohm and Haas in the 1970's for the treatment of contaminated water. In specific applications, Ambersorb adsorbent technology may offer a cost-effective alternative to air stripping or granular activated carbon (GAC), which are typically used in pump and treat systems for remediating groundwater contaminated with organic compounds.

Ambersorb adsorbents have been found to be effective in the removal of low levels of VOCs and other synthetic organic compounds from contaminated water (1). Previous applications using Ambersorb adsorbents have demonstrated several key performance benefits over GAC (2,3,4,5). Ambersorb 563 adsorbent can be regenerated onsite using steam, solvents, or other techniques, permitting the recovery of a concentrated organic stream which can be disposed of or reclaimed. Ambersorb 563 adsorbent has a significantly greater adsorption capacity than GAC for chlorinated hydrocarbons when the contaminants are present at low concentrations. Ambersorb 563 adsorbent systems can operate at higher flow rates than GAC systems, while maintaining effluent water quality below drinking water standards.

METHODOLOGY

The Ambersorb technology demonstration was conducted at Pease Air Force Base (AFB) in Newington, New Hampshire. The base has been included on the National Priorities List (NPL) and WESTON has been conducting an Installation Restoration Program (IRP) Stage 3 Remedial Investigation (RI) at Pease AFB over the past several years. Based on a review of groundwater data for various sites at Pease AFB, Site 32/36 was selected for the Ambersorb 536 adsorbent field trial. The groundwater in this area is contaminated with a number of chlorinated organics including vinyl chloride (VC), 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), and trichloroethene (TCE).

The Ambersorb technology demonstration project under the SITE program used a 1-gallon-per-minute (gpm) continuous pilot system, consisting of two adsorbent columns, to evaluate the treatment of groundwater from Site 32/36 at Pease AFB. The field study was performed over a 12 week period during the spring/summer of 1994. The testing program included four service cycles and three steam regenerations. A summary of the conditions for the service cycles and steam regenerations is provided in Tables 1 and 2, respectively.

TABLE 1. SUMMARY OF CONDITIONS FOR SERVICE CYCLES

Parameter	Cycle 1		Cycle 2		Cycle 3		Cycle 4	
	Col. A	Col. B	Col. A	Col. B	Col. A	Col. B	Col. A	Col. B
	A-563 Virgin	F-400 Virgin	A-563 Regen	A-563 Virgin	A-563 Regen	A-563 Regen	A-563 Regen	A-563 Regen
Column Configuration	---	---	Lag	Lead	Lead	Lag	Lag	Lead
Column Diameter (inches)	4	6	4	4	4	4	4	4
Column Height (feet)	2	3	2	2	2	2	2	2
Flow Rate (gpm)	0.44/0.87*	0.29/0.58*	0.87	0.87	0.87	0.87	0.87	0.87
Hydraulic Loading (gpm/ft²)	5/10	1.5/3.0	10	10	10	10	10	10
Flow Rate Loading (gpm/ft³)	2.5/5	0.5/1.0	2.5†	5	5	2.5†	2.5†	5
Empty Bed Contact Time (EBCT) (minutes)								
Days to Saturation Breakthrough for Each Column‡	3.0/1.5	15.0/7.5	3.0†	1.5	1.5	3.0†	3.0†	1.5
Estimated Number of Bed Volumes (BV) Treated‡	12/6	12/6	12	6	6	12	12	6
	6,000	1,000	6,000	6,000	6,000	6,000	6,000	6,000

*Flowrate was increased after 7 days.
†Total system loading with columns operating in series.
‡Estimated value predicted from model using influent vinyl chloride concentration of 5 ug/L.

TABLE 2. SUMMARY OF CONDITIONS FOR STEAM REGENERATION

Parameter	Regeneration 1	Regeneration 2	Regeneration 3
Column Regenerated	Cycle 1, Column A	Cycle 2, Column B	Cycle 3, Column A
Temperature (°C)	155	145	140
Time (hours)	16	16.5	17.5
Total Bed Volumes	7.6	7.0	8.9

The first cycle consisted of a direct comparison of the performance of Ambersorb 563 adsorbent and Filtrasorb® 400 (F-400) GAC. The remaining cycles evaluated Ambersorb 563 adsorbent under varying process conditions. Concentrations of VOCs in the influent contaminated groundwater and the treated column effluent were monitored during each cycle to establish breakthrough curves. Process parameters including groundwater influent flowrate, temperature, and pressure were also monitored at periodic intervals throughout the field trial.

Following contaminant breakthrough, the service cycles were terminated. Steam regeneration of the lead Ambersorb adsorbent column was then performed onsite. The regeneration process yielded a condensate consisting of a distinct separable organic layer and an aqueous phase. Both the aqueous and organic phases were measured and analyzed to assess regeneration efficiency.

A test to demonstrate the use of a "superloading" adsorbent column to treat the aqueous condensate from a typical steam regeneration process was also conducted during the field trial. The superloading column takes advantage of Ambersorb adsorbent's higher adsorption capacity at higher concentrations. The aqueous phase from the third steam regeneration was passed through an Ambersorb adsorbent superloading column with a diameter of 2 inches and a bed height of 2 feet. Effluent samples from the superloading column were collected and analyzed for VOCs.

RESULTS

The average VOC levels measured in the influent groundwater during each of the service cycles is summarized in Table 3. Note that due to analytical limitations, the vinyl chloride and 1,1-DCE concentrations for certain cycles were estimated based on the amount of the contaminant subsequently recovered during regeneration.

TABLE 3. INFLUENT GROUNDWATER QUALITY

Compound	Maximum Contaminant Level* (ug/L)	Average Influent Concentration (ug/L)				
		Cycle 1		Cycle 2	Cycle 3	Cycle 4
		A-563	F-400	A-563	A-563	A-563
VC	2	3.4†	3.9†	4.8	5.7	11
1,1-DCE	7	0.31†	0.31†	5.8†	6.6†	<10
cis-1,2-DCE	70	312	329	351	373	357
trans-1,2-DCE	100	101	101	121	116	89
TCE	5	4,330	4,120	4,490	3,600	3,883

*National Revised Primary Drinking Water Regulations (40 CFR 141.61).
†Estimated concentration based on recovery during regeneration of A-563 column.

Vinyl chloride, cis-1,2-DCE, trans-1,2-DCE, and TCE were present in the influent groundwater at concentrations exceeding the maximum contaminant levels (MCL) established in the National Revised Primary Drinking Water Regulations. TCE was the contaminant measured at the highest average concentration, ranging between 3,750 ug/L and 4,330 ug/L.

The results of the Ambersorb 563 adsorbent demonstration study are summarized for each cycle in Table 4.

TABLE 4. DEMONSTRATION STUDY PERFORMANCE RESULTS

Compound	Bed Volumes to Drinking Water Standard				
	Cycle 1		Cycle 2*	Cycle 3*	Cycle 4*
	A-563	F-400	A-563	A-563	A-563
VC	7,900	1,740	8,500	6,500	5,000
1,1-DCE	>12,600	4,270	>11,800	>7,500	>15,690
cis-1,2-DCE	9,000	3,700	10,500	8,500	9,900
trans-1,2-DCE	>12,600	4,890	>11,800	>11,450	>15,600
TCE	7,700	4,820	9,300	5,300	7,500

*Results presented for the lead column.

The monitoring results for Cycle 1 column effluents showed that both the Ambersorb 563 adsorbent and GAC achieved water quality below the drinking water standards for each compound. However, when comparing the bed volumes treated to the drinking water standard breakthrough for each contaminant, Ambersorb 563 adsorbent, while operating at 5 times the flowrate loading as Filtrasorb 400, treated approximately two to five times the volume of water as GAC. The TCE breakthrough curves for Cycle 1 are shown in Figure 1.

Comparison of the performance results for the Ambersorb adsorbent for the four cycles indicated minimal loss in adsorption capacity during the course of the field trial. The reduction in bed volumes treated to the drinking water standard breakthrough observed in Cycles 3 and 4 resulted from the increase in vinyl chloride concentration in the influent groundwater. There was no significant reduction in capacity for any of the other contaminants.

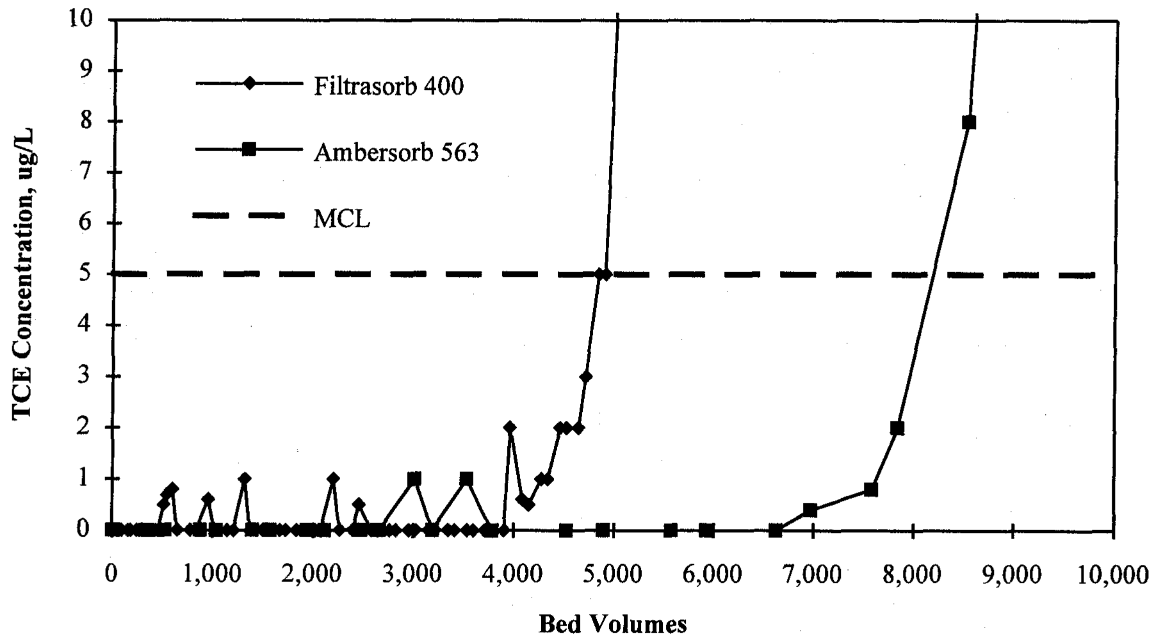

Figure 1 . Cycle 1 Ambersorb 563 and Filtrasorb 400 Breakthrough Curves for Trichloroethene.

The results of the steam regenerations are provided in Table 5.

TABLE 5. STEAM REGENERATION RESULTS

Parameter	Regeneration 1	Regeneration 2	Regeneration 3
Total Bed Volumes	7.6	7.0	8.9
VOC Mass Recovery in 3 Bed Volumes (%)	70	70	90
Total VOC Mass Recovery (%)	79	74	>95
VOC Mass Recovery Associated with Organic Phase (%)	86	90	81

The steam regeneration results indicated that a significant recovery of the VOC mass loaded onto the Ambersorb adsorbent during the service cycles, ranging from 74% to >95%, was achieved during the regeneration process. The results showed that the bulk of the VOC mass recovery occurred within the first 3 bed volumes of steam as condensate. Furthermore, the results indicated that approximately 80% to 90% of the VOC mass recovered was associated with the easily separable organic phase.

The differences observed in the VOC mass recovery for the three steam regenerations may be related to the dehydrohalogenation of chlorinated organics under elevated temperatures. The pH profiles for the steam condensate for each of the regenerations suggest the possibility of a dehydrohalogenation mechanism.

The results of the superloading test indicate that the condensate was effectively treated to levels below the drinking water standards. A total of 15 bed volumes of condensate, which averaged 700,000 ug/L VOCs (predominately TCE) was passed through the superloading column at an EBCT of 7.5 minutes (8.0 BV/hr). The effluent samples from the superloading column showed no detectable leakage of any VOCs for 11 bed volumes. TCE at 2 ug/L was the only compound detected in the final superloading column effluent sample collected after 15 bed volumes.

CONCLUSIONS

Ambersorb 563 adsorbent is an effective technology for the treatment of groundwater contaminated with chlorinated organics. The effluent groundwater from the Ambersorb 563 adsorbent system consistently met drinking water standards. The adsorption capacity of the Ambersorb system remained essentially unchanged following onsite regeneration of the adsorbent and multiple service cycles.

Direct comparison of the performance of Ambersorb 563 with Filtrasorb 400 using the bed volumes treated to the drinking water standard breakthrough indicated that Ambersorb 563 adsorbent was able to treat approximately two to five times the volume of water as GAC while operating at 5 times the flowrate loading.

Onsite steam regeneration was successfully demonstrated. The steam regenerations yielded a separate organic phase which contained approximately 80% to 90% of the total VOC mass loaded onto the adsorbent. The majority of VOC recovery was shown to occur within 3 bed volumes of steam as condensate.

The principle of superloading was demonstrated as an effective treatment method for the aqueous condensate layer resulting from the steam regeneration of the Ambersorb adsorbent. A condensate stream containing 700,000 ug/L VOCs was treated to below the drinking water standards using a superloading column.

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For More Information:

Ronald J. Turner
Project Officer
U.S. EPA
Risk Reduction Engineering Laboratory
Cincinnati, OH 45268
513-569-7775

Russell E. Turner
Project Manager
Roy F. Weston, Inc.
1 Weston Way
West Chester, PA 19380
610-701-3097