SAND98-2016C
SAND-98-2016C

Air Sparging/High Vacuum Extraction to Remove Chlorinated Solvents in Groundwater and Soil

CONF-981048--

J.M.Phelan, Sandia National Laboratories and
M.D. Gilliat, Babcock and Wilcox of Ohio

Abstract

An air sparging and high vacuum extraction was installed as an alternative to a containment pump and treat system to reduce the long-term remediation schedule. The site is located at the DOE Mound facility in Miamisburg, Ohio, just south of Dayton. The air sparging system consists of 23 wells interspersed between 17 soil vapor extraction wells. The SVE system has extracted about 1500 lbs of VOCs in five months. The air sparging system operated for about 6 weeks before shutdown due to suspected biochemical fouling. Technical data is presented on the operating characteristics of the system.

Introduction

Mound OU-1 is a four-acre site, which includes a capped landfill. The site has a long history of cut and fill operations. These included gravel pit operations before the DOE occupied the site, and the operation of at least two landfills that accepted contaminated soils and debris. The contaminants of concern are PCE, TCE, and DCE. Groundwater contamination levels are generally low (less than 1 ppm), but isolated hot spots have been measured to be as high as 400 ppm. The contaminated ground water is in a shallow, high permeability, sandy-gravel, sole source, aquifer (Buried Valley Aquifer). The Buried Valley Aquifer provides drinking water for the Mound plant and many cities along the Miami River. In the vicinity of OU-1, the aquifer is wedge shaped and varies from 1 to 15 feet in thickness. The water table elevation fluctuates by as much as six feet in response to water levels in the Miami River. Groundwater contamination levels also seem to vary according to water table elevations, so a conceptual model is that contaminated soils above the aquifer act as a source of contamination when water levels rise into these contaminated zones. The contaminated vadose zone soil above the aquifer consists of lenses of glacial till, fill, and sand and gravel. The hydrogeologic setting is shown in Figure 1.

The Record of Decision (~1995) specifies hydraulic containment to restrict further contamination of the Buried Valley Aquifer. Successful restoration is achieved when contaminant concentrations in the compliance wells along the southern boundary can be maintained indefinitely below maximum contaminant levels without operating the containment system. A three well pump-and-treat system was installed to hydraulically contain the contaminated portion of the aquifer. A shallow-tray air stripper is used to treat the extracted groundwater.

The Innovative Treatment Remediation Demonstration (ITRD) Program is funded by the Department of Energy (DOE) Office of Environmental Restoration (EM-40) and was developed in cooperation with a Public-Private Partnership Project initiated by Clean Sites, Inc. and the Technology Innovation Office (TIO) of the Environmental Protection Agency (EPA). The purpose of the ITRD Program is for the DOE, EPA, industry, and regulatory agencies to cooperatively establish remediation demonstrations at DOE sites in order to generate full-scale and real-world operating, treatment efficiency, and cost data on emerging restoration technologies. The data generated will be used to improve the acceptance of the emerging technologies by regulators and industry, and accelerate their use and implementation nationwide.

An ITRD Project was initiated in 1995 between the Mound facility, the DOE Ohio Field Office, the State of Ohio Environmental Protection Agency, and the U.S. Environmental Protection Agency, Region V. Based on the identification and review of approximately twenty innovative technologies, the ITRD Technical Advisory Group suggested that the VOC contaminants at the Mound OU-1 site could be remediated most effectively with a combination of air sparging and soil vapor extraction.

DISCLAIMER

System Design

The soil vapor extraction (SVE) system is segregated into two zones. Zone 1 includes six wells in the southern portion of the site. Zone 2 includes six SVE wells and five French drain vents (that extend beneath the landfill) in the northern portion of the site. Table 1 shows the zone assignment, screen length and geologic strata where each well is located. Figure 2 shows a plan view of the SVE and AS well locations.

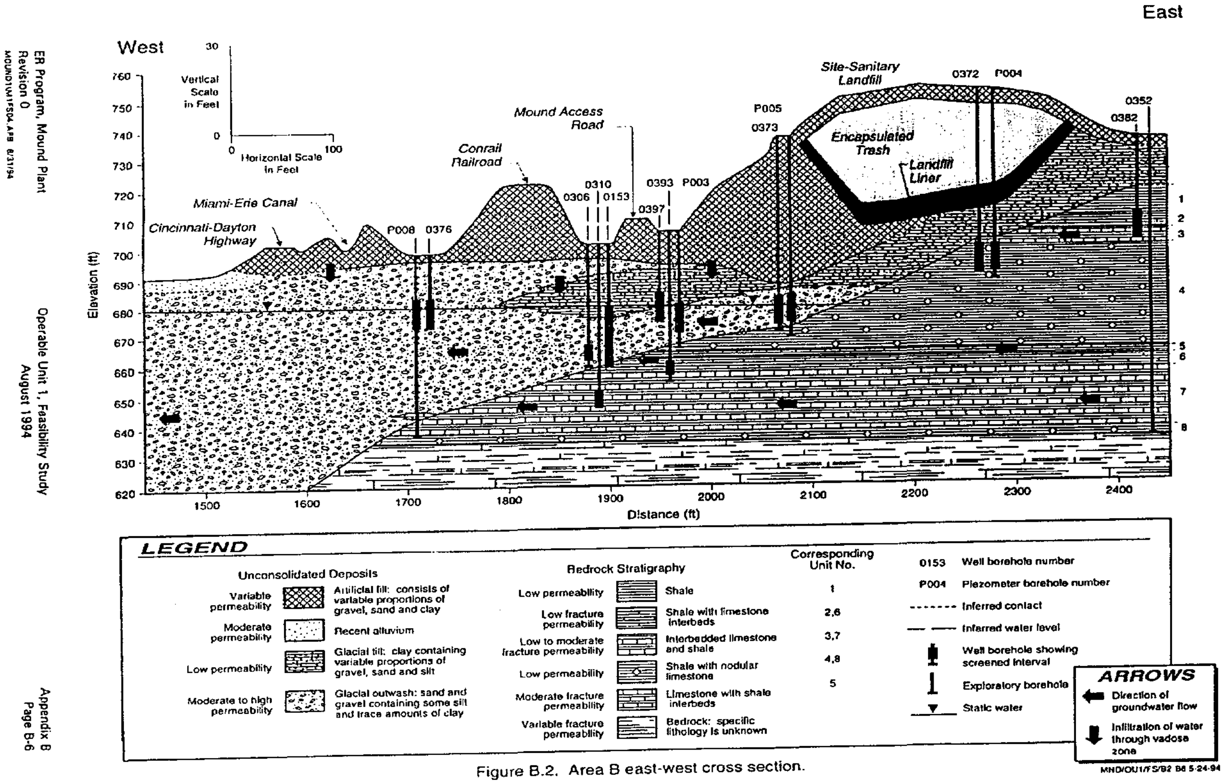

Figure B.2. Area B east-west cross section.

Figure 1. Hydrogeologic Setting at Mound OU-1

Table 1. Extraction Well Details

Extraction Well	Screen Length (ft)	Geologic Strata
	Zone 1	
EW-N1	2	till
EW-N2	15	non-till
EW-N3	3	till
EW-N4	22	non-till
EW-N5	2.5	clay
EW-N6	10	non-till
	Zone 2	
EW-N7	10	non-till
EW-N8	10	non-till
EW-N9	15	non-till
EW-N10	12.5	non-till
ED-1	5	base of French drain
ED-2	5	base of French drain
ED-3	5	base of French drain
ED-4	5	base of French drain
ED-5	5	base of French drain
ITRD-1	8.5	non-till
ITRD-2	4.5	till

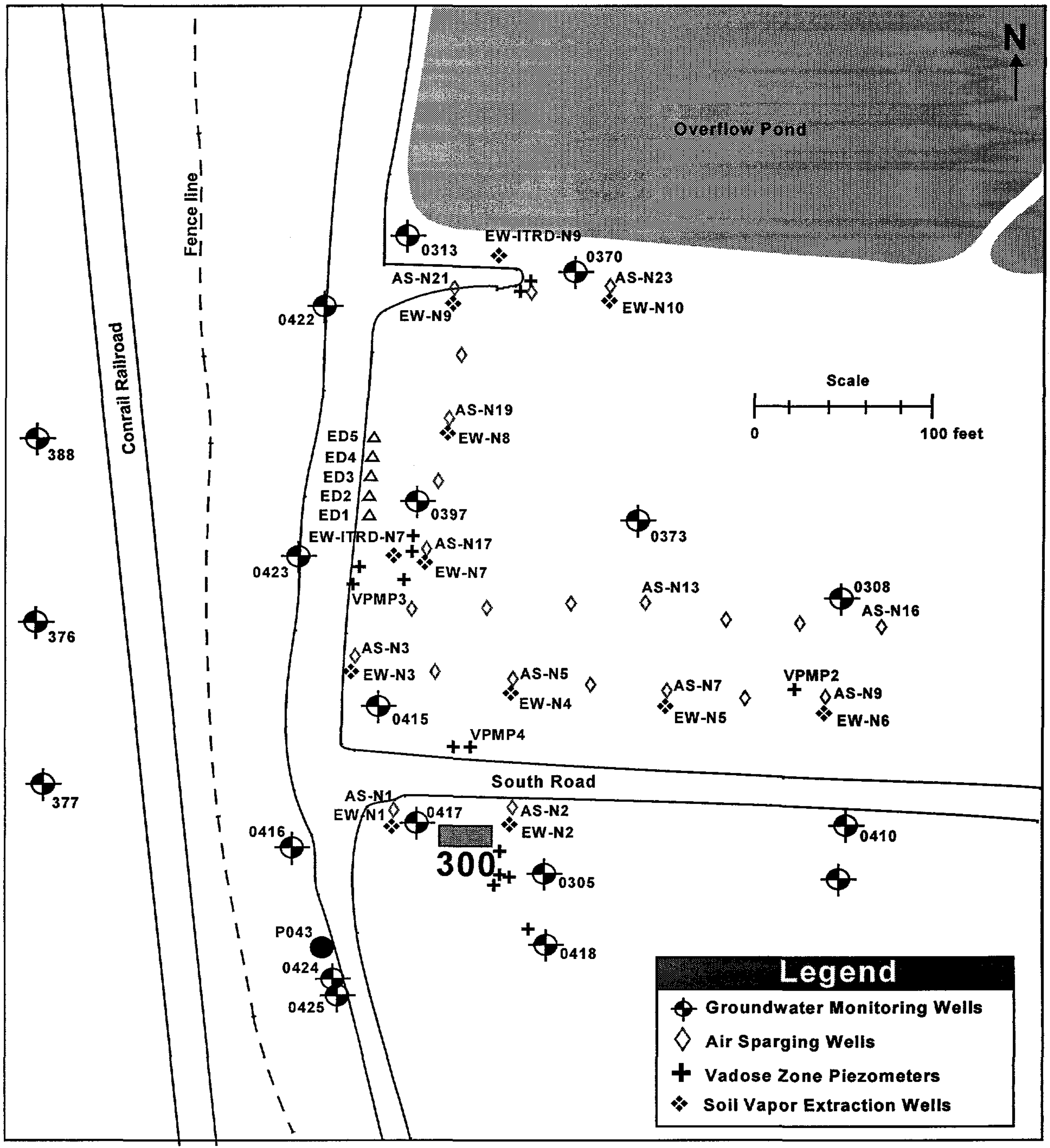

Figure 1. Air Sparge and Soil Vapor Extraction Well Locations

The SVE wells are spaced on about 50-foot centers. The system was designed to run at about 600 scfm at 18 inches mercury vacuum. Each SVE well is adjustable to vary the vacuum and flow. All of the SVE wells in each zone intersect a main manifold that enters the treatment building. The SVE system operates with an adjustable scheduler that alternates Zone 1 and Zone 2 at specified intervals. The manifolds are connected to a water knockout tank, which then pass the air through two carbon beds in series before the vapors are discharged to the atmosphere.

The air sparging system has twenty-three air sparge points spaced on about 25 foot centers. The sparge point is constructed of PVC with holes designed to produce very small bubbles (~50 micron). The system was designed to run at 400 cfm and 15 psig. Each air sparge point is adjustable to vary the pressure and flow.

Air Sparging System Performance

The airflow rates in the air sparge wells showed a significant declining trend after an initial increase. In addition, the delivery pressures were gradually increasing. Figure 3 and 4 shows the trend for both Zone 1 and Zone 2. When the system flow rates dropped to about 50% of the starting flows and the pressures were about double, the system was turned off and an investigation was started to determine the cause. Potential causes for the decline in the flow rate and increase in pressure of the air sparge system include biofouling and formation of insoluble precipitates of iron and carbonate due to the addition of oxygen to the groundwater system. Testing showed that iron concentrations were low (< 1 ppm). However, alkalinity levels were 200 to 300 ppm and experience with carbonate fouling in the SVE knockout water air stripper indicate that carbonate fouling may be occurring in the air sparge points. Surging with acid well treatment material is planned.

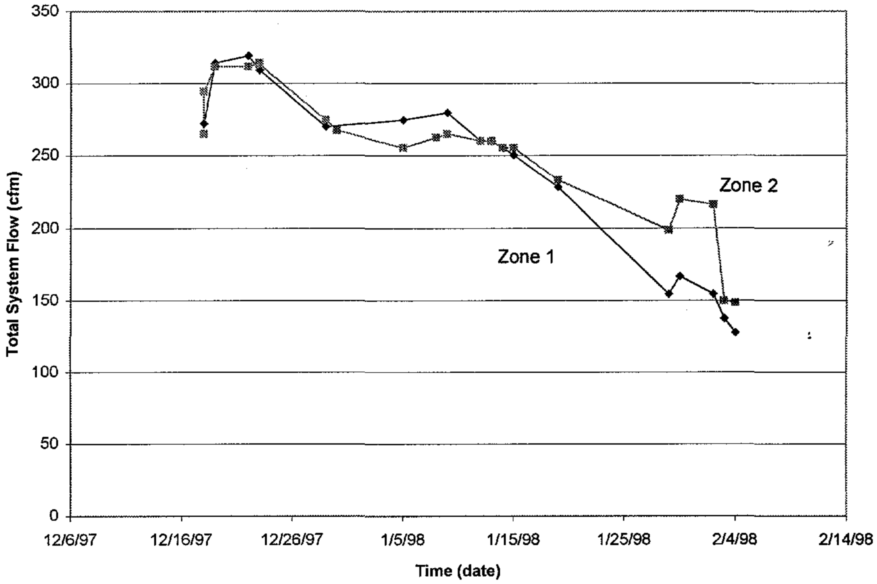

Figure 3. Air Sparge Flow Rates over Time

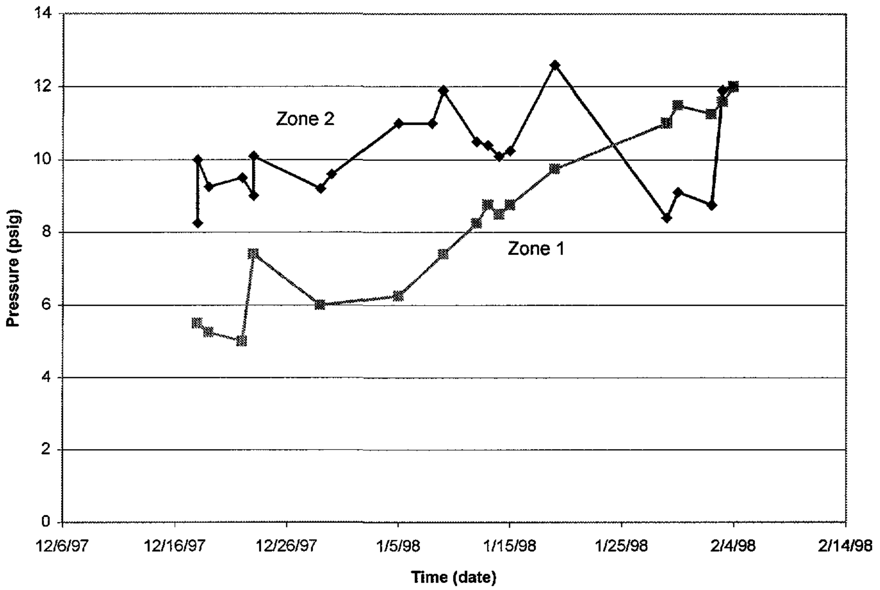

Figure 4. Air Sparge Delivery Pressures over Time

Soil Vapor Extraction System Performance

Since the SVE system operates at a system vacuum of about 12 to 18 inches of mercury, grab samples must be collected on a zone that has just been turned off. Both Summa canister/off-site contract lab and an automated on-site process monitor are being used. For the Summa canisters, a short section of teflon tubing is connected to the manifold sampling port, then the valve on the Summa canister is opened and the internal vacuum is allowed to fill the canister. Samples are shipped to an off-site contract laboratory for chemical analysis by EPA Method TO-14.

The automated process monitoring system is a commercial on-line multipoint monitoring system called a SSC Model SCENTOSCAN available from Sentex Systems, Inc (Ridgefield, NJ). The Sentex process monitor pulls vapors through a coalescing filter to remove entrained water and through a heated tubing bundle from the SVE/AS building to the analytical shed. The Sentex uses a 30m capillary column, micro argon ion detector, combination preconcentrator or sample loop and a scanner system capable of 16 points. The Sentex process monitor was put on line in February 1998. Frequent heavy spring rains at the site would produce more water than the coalescing filters could manage. Thus, careful monitoring was required to prevent liquid water from being injected into the gas chromatograph.

The results of the grab samples for both Zones 1 and 2 show exponential declines of the VOCs over time. Figure 4 through 6 show the time history for Zone 1 for the three compounds with the greatest concentrations (toluene, cis-1,2 dichloroethene and trichloroethene). Figures 7 through 9 show the time history for Zone 2. Curve fits to the data were completed with TableCurve 2D (Ver 4, SPSS, Inc.) to estimate concentrations before and in between the sampling events.

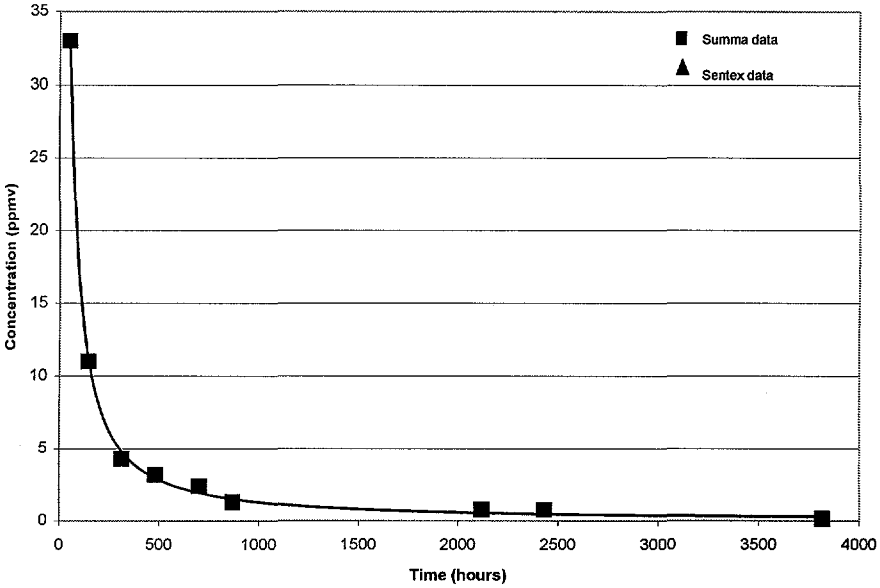

Figure 4. Zone 1 Time History – cis1,2-Dichloroethene

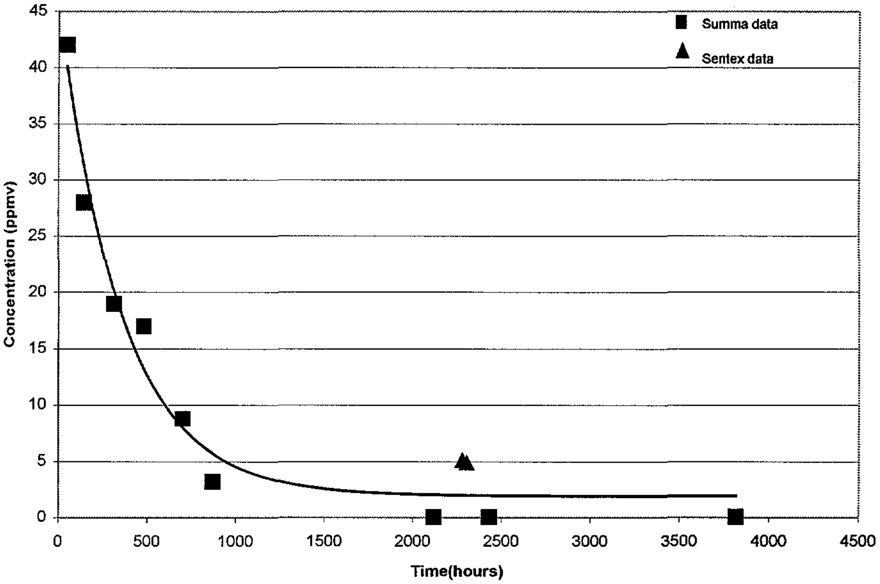

Figure 5. Zone 1 Time History - Toluene

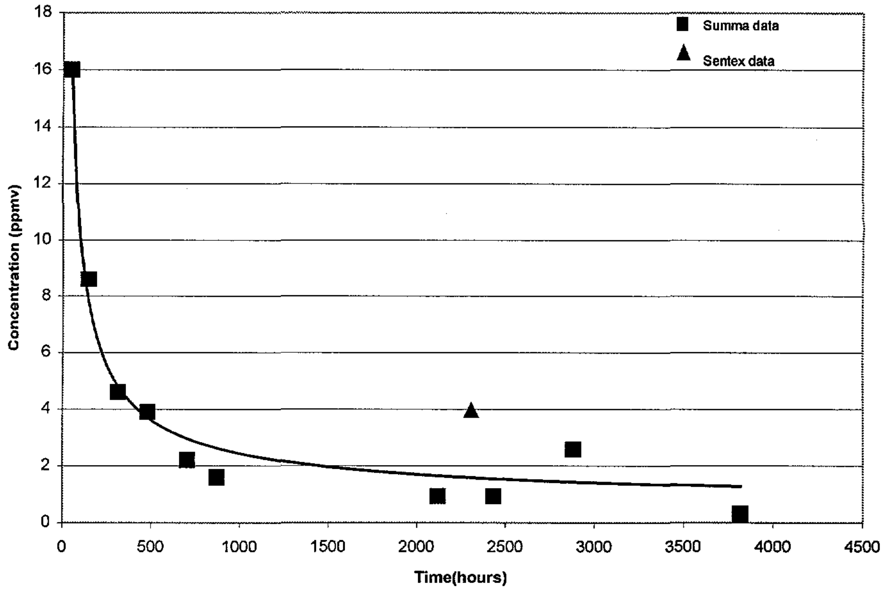

Figure 6. Zone 1 Time History – Trichloroethene

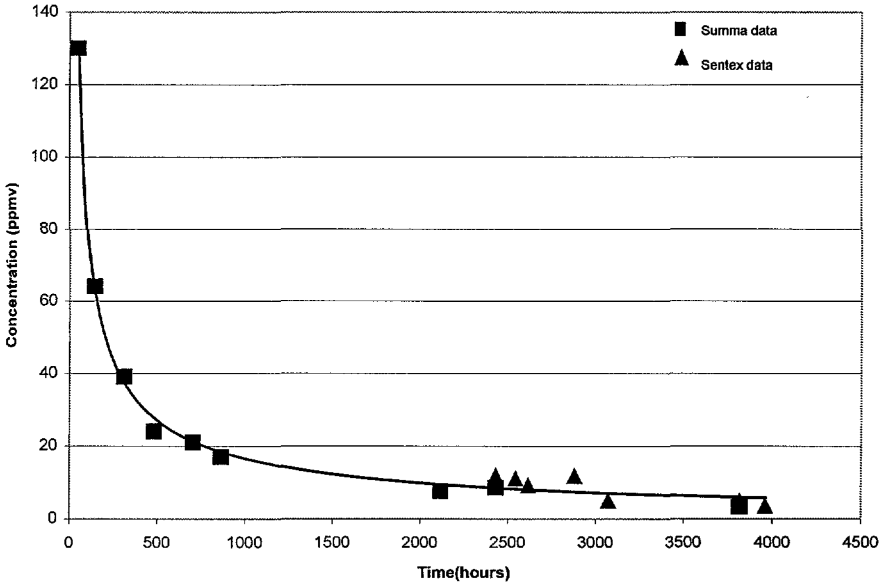

Figure 7. Zone 2 Time History – cis1,2-Dichlorethene

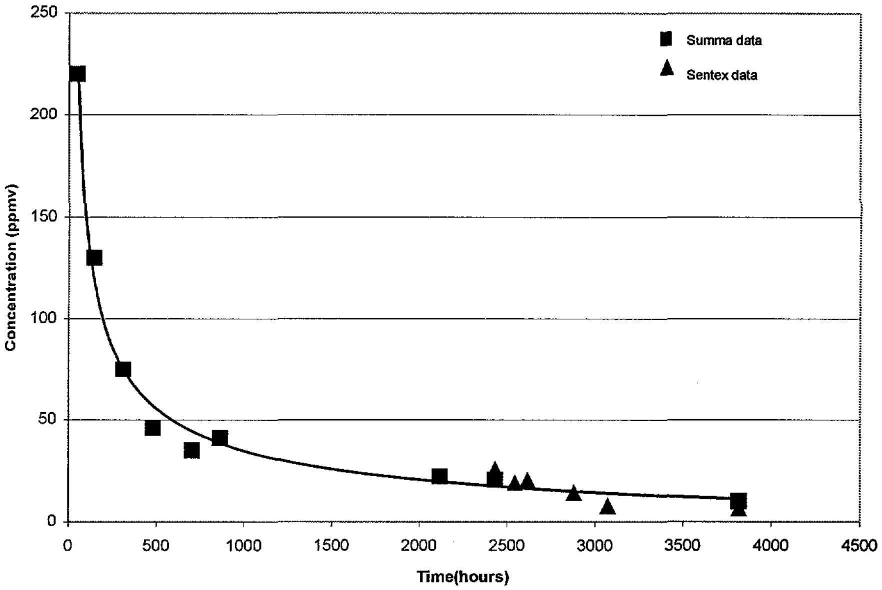

Figure 8. Zone 2 Time History – Toluene

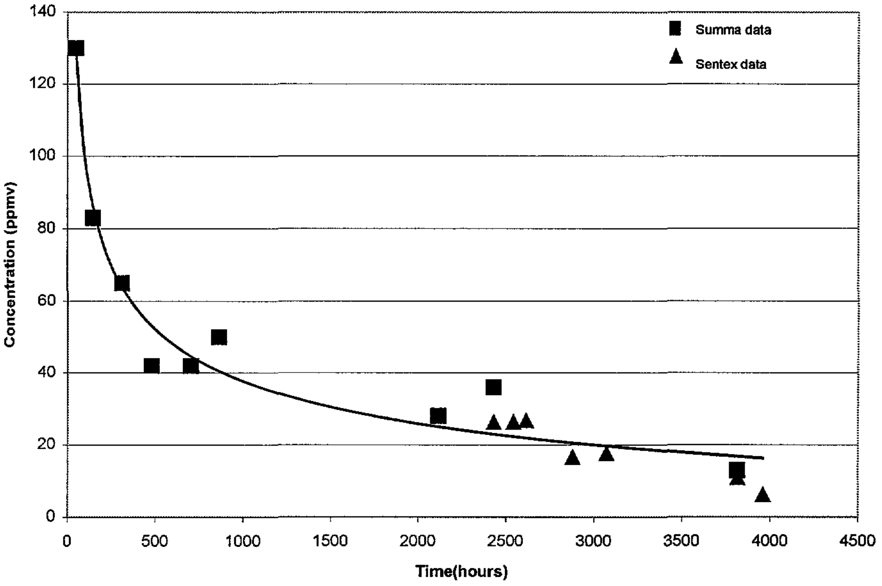

Figure 9. Zone 2 Time History - Trichloroethene

As shown in Figures 4 through 9, the early time concentrations fall very steeply and the curve fit lines may not be representative of the actual concentrations in the first 50 hours before the first sample was obtained on December 18, 1997. Therefore, mass removal estimates have been made starting from the first sample date. Figure 10 shows the Zone 1 and Zone 2 manifold flow rates during this initial operating period. From time zero to the operating time of 178 hours the system ran on six-hour intervals. The system was switched to four-hour intervals from hour 178 to 552 and to a two-hour interval from hour 552 to 2422. These changes were made to keep automatic shutdowns from occurring when large amounts of water were being extracted from the French drains soon after rainfall events occurred. The system was changed to one hour on Zone 1 and 3 hours on Zone 2 from hour 2422 to 3453. From hour 3453 to date the system was set to only extract from Zone 2. Table 2 shows the total mass of each VOC removed estimated from the curve fits of the grab samples and measured flow rates. Figure 11 shows the cumulative mass of all VOCs extracted from each zone.

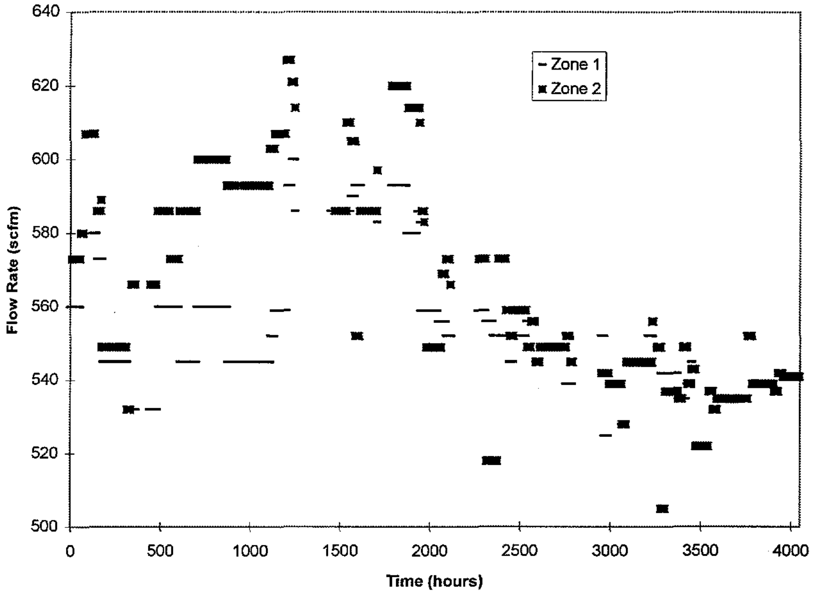

Figure 10. Total System Flow Rates

Table 2. VOC Mass Removal

	Zone 1	Zone 2	Zone 1 + Zone 2
Vinyl Chloride	1.98	9.81	11.79
cis1,2 Dichloroethene	21.76	231.36	253.12
Trichloroethene	35.29	673.27	708.56
Toluene	64.54	434.27	498.81
Tetrachloroethene	33.66	62.10	95.77
Freon 113	1.15	15.01	16.16
Acetone	3.27	*	3.27
Xylene	0.72	20.61	21.32
Benzene	0.36	4.61	4.97
Ethylbenzene	0.19	3.98	4.18
Dichloromethane	0.36	8.14	8.50
Chloroform	0.47	9.16	9.63
Trichlorofluoromethane	*	6.72	6.72
Total	163.76	1479.04	1642.80

* - insufficient concentration data to estimate mass

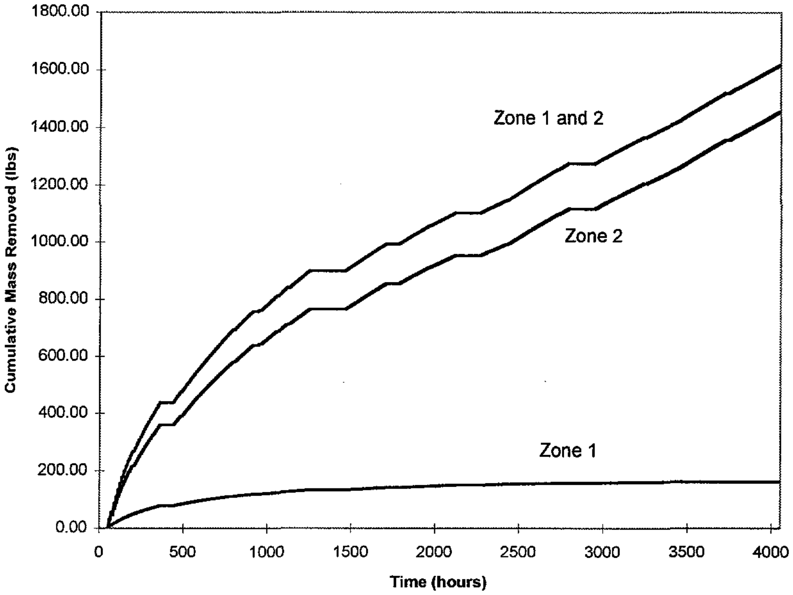

Figure 11. Cumulative Mass of VOC Extracted from Zones 1 and 2

The early time periods in a SVE system provide much more mass removal than in the later periods due, principally, to the diffusion limitation condition in later time periods where VOCs must move from within dead end pore spaces to the locations experiencing active ventilation. The total mass removal rate (Figure 12) has reached a plateau at about 0.04 lb/hr for Zone 1 and 0.4 lb/hr for Zone 2. As of May 31, 1998 the total mass removal was near 10 lbs/day which is considered the deminimis level for air emissions regulations. Future monitoring should provide more information to support a proposal to bypass the carbon treatment system.

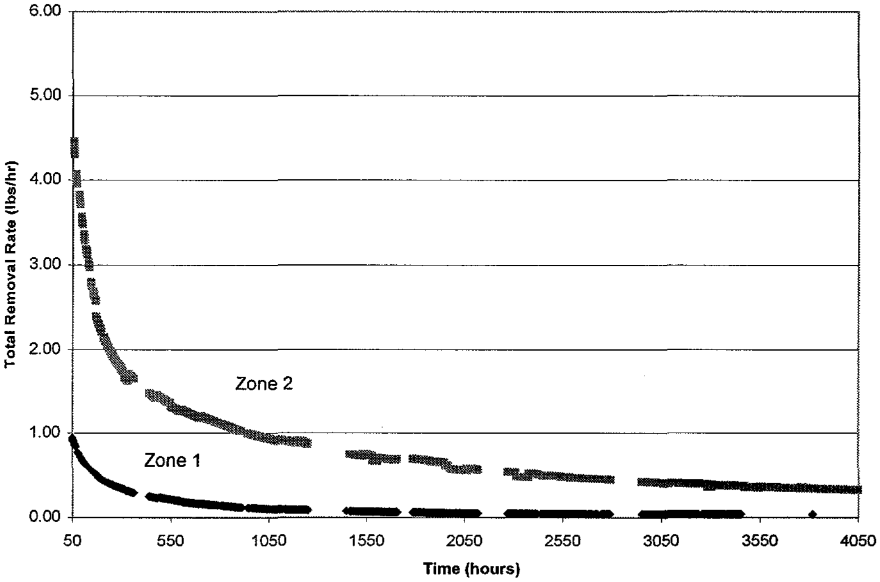

Figure 12. Total VOC Mass Removal Rate over Time

Individual SVE well grab samples were obtained to show proportionate mass removal. Table 3 shows the results for the principal compounds from each sampling location for Time Zero (before starting SVE system) and Time Series #1 (about 5 months after startup).

Table 3. Sampling Results for Time Zero and Time Series #1

SAMPLE	ANALYTE									
	DCM		cisDCE		BEN		TCE		TOL	
	(ppmv)		(ppmv)		(ppmv)		(ppmv)		(ppmv)	
	Time Zero	Time Series #1	Time Zero	Time Series #1	Time Zero	Time Series #1	Time Zero	Time Series #1	Time Zero	Time Series #1
	11/12/97	04/15/98	11/12/97	04/15/98	11/12/97	04/15/98	11/12/97	04/15/98	11/12/97	04/15/98
tedlar blank		nd		nd		nd		nd		nd
tedlar blank		nd		nd		nd		nd		nd
tedlar blank		nd		nd		nd		nd		nd
VPMP-2	0.005	nd	0.460	nd	0.030	nd	0.260	nd	0.007	nd
VPMP-3S		nd		3.2		nd		nd		nd
EW-N1	0.001	nd	nd	nd	nd	nd	nd	nd	nd	nd
EW-N2	Nd	nd	0.760	nd	nd	1.4	5.100	nd	0.066	nd
EW-N3	0.001	nd	nd	nd	0.002	nd	0.001	nd	0.003	nd
EW-N4	0.008	nd	0.220	4.9	nd	nd	0.920	nd	0.007	nd
EW-N5	0.120	nd	16.000	5.9	0.180	nd	0.780	4.1	nd	nd
EW-N6	0.014	nd	0.290	nd	0.024	nd	2.800	nd	nd	nd
EW-N7	28.000	nd	3700.000	4.9	16.000	nd	2800.000	8.0	2000.000	9.1
EW-N8	0.024	nd	1.300	8.6	6.000	nd	2.500	7.2	4.400	5.0
EW-N9	0.120	nd	4.400	28.8	nd	nd	8.500	24.0	13.000	4.7
EW-N10	0.026	nd	1.900	9.7	nd	nd	2.700	1.5	2.900	nd
ED-N1	Nd	nd	0.150	nd	nd	nd	0.033	nd	nd	nd
ED-N2	0.001	nd	0.190	nd		nd	0.008	nd	nd	nd
ED-N3	0.002	nd	0.096	nd	0.003	nd	0.041	nd	nd	nd
ED-N4	0.002	nd	0.015	nd	nd	nd	0.003	nd	nd	5.0
ED-N5	0.003	nd	0.012	nd	0.003	nd	0.005	nd	0.002	nd
EW –ITRD-N7	0.140	nd	19.000	20.1	0.080	nd	16.000	2.8	5.000	nd
EW-ITRD-N9	Nd	nd	1.900	nd	0.010	nd	1.900	8.864	3.000	nd
tedlar blank		nd		nd		nd		nd		nd

nd – not detected
DCM – Dichloromethane (methylene chloride)
cisDCE – cis-1,2-Dichloroethene
BEN – Benzene
TCE – Trichloroethene
TOL - Toluene

Table 3 does not show tetrachloroethene, ethylbenzene and xylenes because the results for these compounds were not above the practical quantitation limit of 1 ppmv for the Sentex system operating in the loop mode. For Zone 2, wells EW-N1 and EW-N3 are short-screened wells located in the glacial till. These wells have non-detectable (<1 ppmv) quantities of VOCs indicating that the value of these wells for mass removal is very limited. EW-N2 showed a slight increase in benzene and a disappearance of cis-1,2-dichloroethene and toluene. All the trace quantities in EW-N4 dropped, except cis-1,2-dichloroethene, which increased. EW-N5 had mixed results with cis-1,2-dichloroethene decreasing and trichloroethene increasing. EW-N6 showed only trace VOCs at time zero which have dropped to non-detectable levels at time series #1.

For Zone 2, the Time Zero report showed a significant amount of VOCs present in EW-N7 and much less in the rest of the extraction wells. The current samples show that these high concentrations have dropped substantially. EW-ITRD-N7 showed a stable but high level of cis-1,2-dichloroethene and a significant drop in the trichloroethene concentration. EW-N8 showed increased concentrations for cis-1,2-dichloroethene, trichloroethene and toluene. EW-N9 showed a significant increase in cis-1,2-dichloroethene and trichloroethene. The EW-ITRD-N9, which is adjacent to EW-N9, also showed a significant increase in trichloroethene but not for cis-1,2-dichloroethene. EW-N10 also showed a significant increase in cis-1,2-dichloroethene and little change in trichloroethene. The French drains all showed less than 1 ppmv for all compounds in the time zero sample event and, except for ED-N4, all time series #1 values were non-detectable (< 1 ppmv). ED-N4 showed a significant increase for toluene.

The results from the dynamic soil vapor extraction monitoring indicate that the three most prevalent compounds are cis-1,2-dichlorethene, trichloroethene and toluene. These compounds are also most prevalent in the static soil gas results noted above. The active subsurface ventilation acts to remove and redistribute the VOCs. This may be an explanation for why some of the locations had increased vapor concentrations and others showed decreased concentrations. The data from the low permeability till screened wells (EW-N1 and EW-N3) show that there is very little VOC present in these locations. There still appears to be relatively high concentrations around EW-N7 and up near the overflow pond at EW-N9.

Acknowledgements

This work was performed with funds from the U.S. Department of Energy, Office of Environmental Restoration, through the Innovative Treatment Remediation Demonstration Program. Sandia National Laboratories is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.