COST AND PERFORMANCE REPORT

Soil Vapor Extraction
at the Tyson's Dump Superfund Site
Upper Merion Township, Pennsylvania

September 1998

Prepared by:

EPA

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information

Tyson's Dump Superfund Site, Upper Merion Township, Pennsylvania

CERCLIS ID No: PAD980692024

Record of Decision (ROD) Date:
December 21, 1984
March 31, 1988 (revised ROD)
July 20, 1996 (revised ROD)

Treatment Application

Type of Action: Remedial

Technology: Soil Vapor Extraction

EPA SITE Program Test Associated With Application? No

Period of Operation: November 1988 to September 1996

Quantity of Material Treated During Application: The 1984 ROD indicated that the estimated amount of contaminated soil was 30,000 cubic yards (yd^3). [13]

Background Information [1]

Waste Management Practice That Contributed to Contamination: Spill; surface disposal area; surface impoundment/lagoon.

Site History: Tyson's Dump (Tyson's) Superfund site is a four-acre, abandoned septic waste and chemical waste disposal site reported to have operated from 1960 to 1970 in a sandstone quarry. Franklin P. Tyson and Fast Pollution Treatment, Inc. (FPTI) used lagoons on the eastern and western portions of the site (east lagoon and west lagoon) to store industrial, municipal, and chemical wastes. Various locations throughout the site were also used for the disposal of septic tank wastes and chemical sludges.

In 1973, the Pennsylvania Department of Environmental Resources (PADER) ordered the owners of the site to close the facility. At that time, although some ponded water was removed, the owners did not arrange for removal of contaminated soils.

In January 1983, EPA investigated an anonymous citizen complaint about conditions at the Tyson's site and subsequently determined that immediate removal measures were required. In March 1983, EPA initiated a removal action which included the construction of a leachate collection and air stripping system, installation of drainage controls and a cover on the site, and erection of a fence around the lagoon area.

Between January 1983 and August 1984, EPA conducted a remedial investigation/feasibility study (RI/FS) in the area of the lagoons. Samples of soil from the lagoons indicated the presence of several volatile organic compounds (VOCs) at concentrations that exceeded 50 milligrams per kilogram (mg/kg).

A ROD was issued in 1984, specifying excavation and off-site disposal of contaminated soils. In June 1987, the responsible parties (RPs) submitted the results of a comprehensive feasibility study (CFS) recommending SVE as an alternative remedy. The RPs had performed an SVE pilot study in November 1986 and submitted the results as part of the CFS. According to the RPs, the CFS also indicated that the contaminants in the bedrock underlying the lagoons would be a source of continuing contamination of the backfilled soils after excavation. In addition, the CFS stated that the remedy selected in the 1984 ROD would be of limited effectiveness without the installation of a barrier to limit upward movement of contamination from the underlying bedrock.

In July 1987, the RPs submitted a proposal to EPA for cleanup of the on-site lagoon areas, upgrading of the leachate collection system, and cleanup of the tributary sediments.

EPA negotiated a partial consent decree to implement SVE and issued a revised ROD as discussed below.

SITE INFORMATION (CONT.)

Regulatory Context [1, 2, 7, 13]

In December 1984, EPA issued an initial ROD for the site that specified the following remedial actions:

- Excavation of contaminated soils and disposal at a landfill permitted under the Resource Conservation and Recovery Act (RCRA)
- Upgrading of the existing air-stripping facility, which had been constructed as part of the removal measures, to treat leachate, shallow groundwater, and surface runoff encountered during excavation
- Excavation and off-site disposal of contaminated sediments in the tributary that receives effluent from the existing air stripper

In March 1988, EPA revised the ROD to change the remedy for the lagoons from excavation to SVE. The revised ROD, signed in March 1988, did not alter the remedy with respect to air stripping, leachate treatment, or remediation of contaminated sediments.

EPA subsequently determined that the SVE system was incapable of meeting the cleanup levels that had been specified in the revised ROD in a "timely and cost effective manner." According to EPA, the ability of the SVE system to efficiently remove the remaining contamination had decreased significantly beginning in 1993.

In July 1996, EPA issued a ROD Amendment changing the remedy from SVE to placement of a wet soil cover over the lagoons. According to the amendment, the wet soil cover met the remedial action objectives. In addition, the wet soil cover provided effective long-term control of VOC emissions.

Site Logistics/Contacts

Site Management: RP Lead

Oversight: Federal

PRP Contact:
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MATRIX DESCRIPTION

Matrix Identification [3, 13]

Type of Matrix: Soil

Geology: The natural soils at the site consisted primarily of a less-than-one-foot layer of topsoil, underlain to a depth of six to eight feet by clayey sand to sandy silt. That layer generally was underlain by fine to medium, slightly silty

MATRIX DESCRIPTION (CONT.)

sand with some gravel, extending to 12 feet in depth. Shallow bedrock in the vicinity of the site was highly fractured with outcroppings of bedrock throughout the site.

In 1991, during installation of horizontal wells in the western portion of the east lagoon, a layer of rock was discovered. The layer varied in depth from 7 to 12 feet below the ground surface (bgs). The layer was estimated to be 200 feet wide and approximately one to two feet thick.

Matrix Characteristics That Affected Cost or Performance of Treatment [3, 13]

Limited information on matrix characteristics that affected cost or performance was available for this application. The soil at the site was classified as clayey sand to silt (6 to 8 ft. bgs) and slightly silty sand (8 to 12 ft. bgs). Nonaqueous phase liquid (NAPL) was present at the site.

Contaminant Characterization [1, 7]

Primary Contaminant Groups: VOCs

The 1988 revised ROD identified the following four contaminants of concern (these contaminants were selected to represent the presence of all VOCs at the site): 1,2,3-trichloropropane, benzene, trichloroethene, and tetrachloroethene. Soil sampling was conducted in 1988 to determine the initial mass and distribution of contaminants in the former lagoon areas. Soil samples were collected from 65 well borings, at 5 to 10 feet intervals, for a total of 82 samples from the east lagoon and 63 samples from the west lagoon.

Concentrations in the soil for the four contaminants of concern ranged from non-detect to maximum concentrations exceeding 250,000 mg/kg. Table 2 presents a summary of the range of average concentrations of those contaminants.

Table 2: Summary of the Average Concentration of Contaminants of Concern in the 65 Well Borings - 1988 Sampling [7]

Contaminant of Concern	No. of Well Borings by Concentration			
	Non-Detect	< 50 mg/kg	50 to 500 mg/kg	> 500 mg/kg
1,2,3-Trichloropropane	21	15	9	20
Benzene	55	10	0	0
Trichloroethene	56	8	1	0
Tetrachloroethene	33	19	7	6

MATRIX DESCRIPTION (CONT.)

Figures 1 and 2 show the estimated percentage of organic mass located in each "soil block" in the east and west lagoons. The mass of VOCs in the soil blocks was estimated using the average concentration in a block (based on the average contaminant concentration of the soil borings within that block) (mg/kg), the surface area of the block (ft^2), depth of the block (ft, determined from each boring), and density of the soil (lb/ft^3, assumed to be 110 lb/ft^3). The mass of each organic compound in the soil was determined using a similar formula.

As shown in Figure 1, the VOC contaminant mass was concentrated in the western portion of the east lagoon. Figure 2 shows that the VOC contaminant mass in the west lagoon was concentrated in the eastern portion. An estimate of mass of the individual compounds indicated that 1,2,3-trichloro-propane accounted for 84 percent of the total mass of VOCs.

DESCRIPTION OF TREATMENT SYSTEM

Primary Treatment Technology

Soil vapor extraction

Supplemental Treatment Technology

Carbon adsorption of off-gas

System Description and Operation

Pilot Study [1, 2]

In November 1986, Ciba-Geigy Corporation, the primary RP for the site, performed a pilot study of an on-site soil vapor extraction (SVE) process. The pilot study initially operated for fewer than 10 days. The pilot study resumed operation in May, 1987 and operated for three weeks.

Description and Operation of System [2, 8, 12, 14]

The initial design of the SVE system at Tyson's included approximately 80 vapor extraction wells, 9 dual extraction (RD) wells, and 7 bedrock extraction wells connected to a manifold that led to a central processing plant. Figures 3 and 4 show the locations of the wells at the east and west lagoons at Tyson's. Most of the VE wells were drilled to a depth of less than 10 feet (approximate depth to bedrock).

The processing plant contained two 700-horsepower (hp) vacuum units and two 250-hp vacuum units. Extracted vapors were treated by activated carbon adsorption, with regeneration and solvent recovery on site. Recovered solvent was sent off site for destruction.

Support equipment for the system included two air coolers, boilers, a chemical feed system, a fuel oil system, on-line automatic gas chromatograph (GC) analyzers, and an electrical distribution system. The system also was equipped with automated ambient air monitoring, explosive vapor monitoring, and fire suppression systems.

The design air flow rate was approximately 15,000 standard cubic feet per minute (scfm) at 13 inches of mercury (Hg) vacuum. At the blowers, the vapors were pressurized to two pounds per square inch (psi), cooled to 100 degrees Fahrenheit (°F), and passed through a series of 7,000-pound carbon vessels prior to release to the atmosphere. Water extracted using the RD wells was treated by air stripping and carbon polishing.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Figure 1. Percentage of Organic Mass by Soil Block Area for Tyson's Dump Superfund Site - East Lagoon, 1988 Data [Modified from 17]

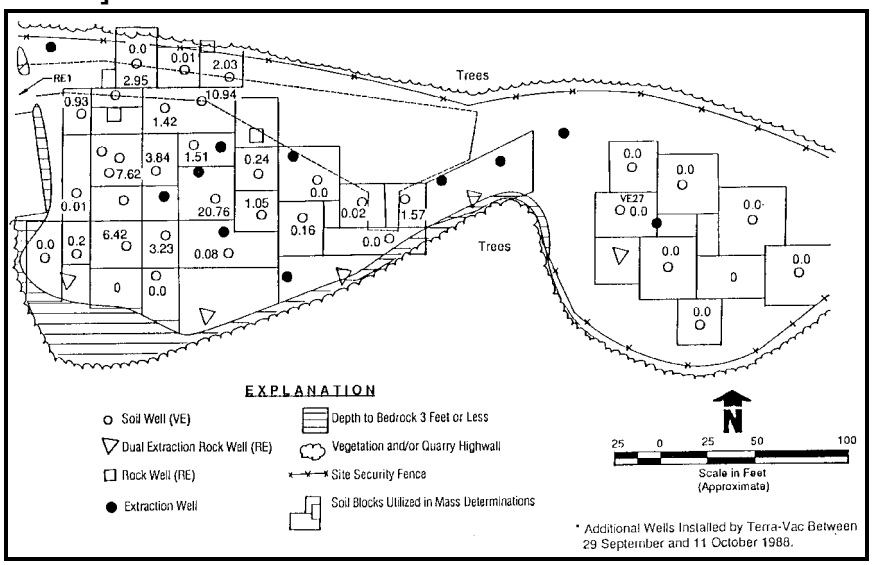
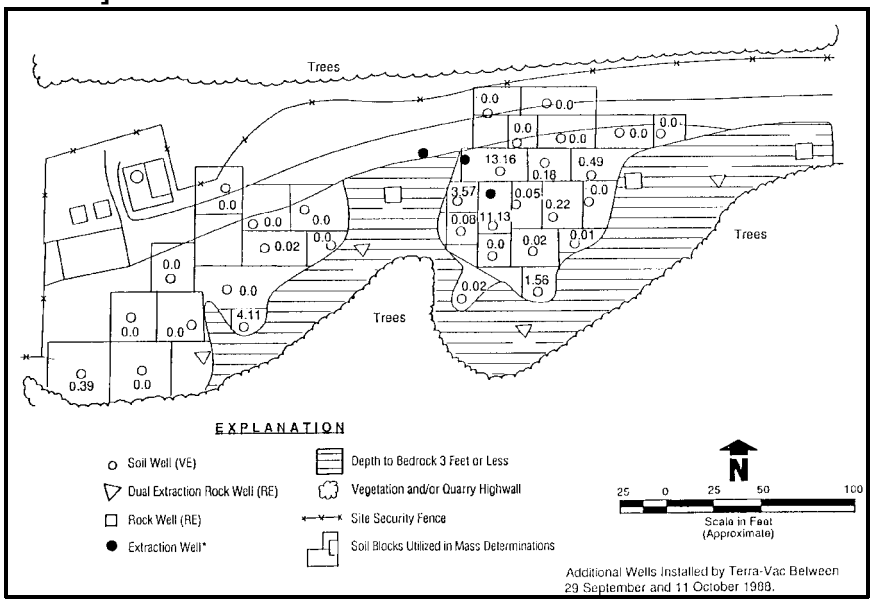


Figure 2. Percentage of Organic Mass by Soil Block Area for Tyson's Dump Superfund Site - West Lagoon, 1988 Data [Modified from 17]



DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Figure 3. Location of Wells in East Lagoon at the Tyson's Dump Superfund Site, Initial Design [Modified from 17]

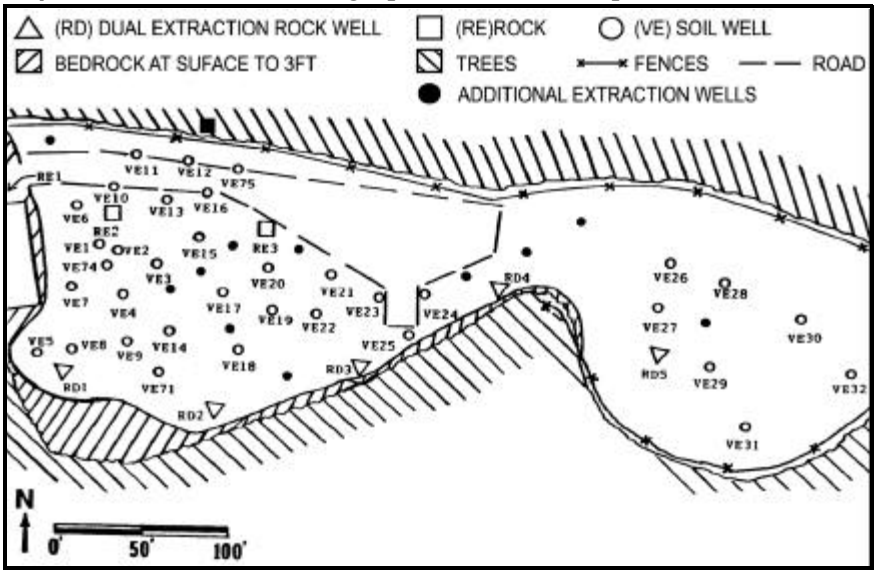
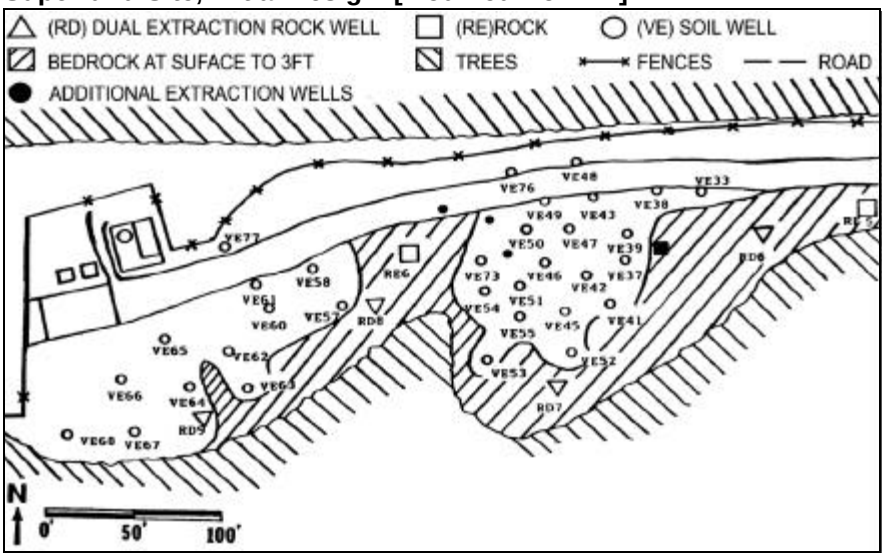


Figure 4. Location of Wells in West Lagoon at the Tyson's Dump Superfund Site, Initial Design [Modified from 17]



DESCRIPTION OF TREATMENT SYSTEM (CONT.)

The system began full-scale operation on November 14, 1988. For the first ten months of operation, the extraction rate for VOCs ranged from 2,000 lbs/month to over 10,000 lbs/month (September 1989). However, between September and December 1989, the extraction rate decreased to about 2,000 lbs/month. The results of additional investigations performed by Terra Vac identified several conditions at the site that were limiting the diffusion rate of VOCs and adversely impacting the performance of the SVE systems. These conditions included greater variation in the permeability, porosity, particle size, and moisture content of the soils than identified during previous investigations; the presence of DNAPL over a larger area of the site; the presence of tar in 22 wells at the site and perched water at various locations at the site.

As described below, Terra Vac performed a number of modifications to the SVE system in an effort to enhance system performance. These included varying the number and types of wells in the system, heating the soil, destroying contaminants in situ, and physically creating new flow paths as a means to improve the diffusion rate.

Enhancements to Mitigate the Effects of Newly-Discovered Site Conditions [8]

The following enhancements were made to the SVE system:

- Installation of additional wells
- Steam injection
- Installation of slurp wells
- Decane treatment
- Cover over east lagoon
- Hot air injection
- Increased vacuum pressure
- Use of selectively screened wells
- Pressurized air injection
- Installation of horizontal wells
- Electrical soil heating-Electrovac™
- Removal of ineffective wells
- Geomixing
- In situ contaminant destruction-OxyVac™

Table 3 summarizes the enhancements made in the SVE system, the time frame over which each enhancement was made, and the purpose and results of each enhancement. Additional detail on the Electrovac™ and pressurized air injection enhancements is presented below.

Electrical Soil Heating - Electrovac™

During May 1991, a pilot test of electrical soil heating was conducted at the site. This test resulted in a small increase in soil temperature and had no significant effect on VOC extraction rates. According to Terra Vac, the limited effectiveness was attributed to the low electrical conductivity of soils and the presence of DNAPL.

Pressurized Air Injection

During October 1990, tests involving the injection of pressurized air into the soils at the Tyson's site were conducted in the west and east lagoons. Hollow steel rods, ½ inch in diameter, were driven down to about one foot above the bottom of known DNAPL layers. The rods then were connected to an air compressor. Air was injected at a pressure of approximately 15 pounds per square inch in gauge (psig) and at a flow rate of approximately 75 scfm.

After testing, air was injected through pressure injection probes (PIP) for two to four hours. The compressor was then shut down for the same period of time. VOC extraction rates for wells in the east and west lagoons increased in some areas in response to air injection. Therefore, the use of air injection was expanded to more than 100 PIPs that were installed in the east and west lagoons. VOC extraction rates from both lagoons increased during the second quarter of 1991; however, the VOC extraction rate diminished with time.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Table 3: Summary of SVE Enhancements at the Tyson's Dump Superfund Site [4, 6, 8, 10]

Enhancement	Dates Implemented	Purpose	Results
Installation of 40 additional wells	11/15/88 to 12/15/88	To ensure the zone of influence for each well would overlap sufficiently to eliminate preferential flow pathways created by subsurface heterogeneities and remedy the incomplete coverage of the site by the existing wells	Terra Vac indicated that new preferential pathways were formed and the VOC extraction rate increased temporarily. However, within one to two weeks the extraction rate returned to the initial level.
Steam injection	4/89	To remove the tar that had accumulated on the well screens and increase the VOC extraction rates	Increased the VOC extraction rate because of the increase in subsurface temperature. However, tar was not removed and steam quickly condensed in the well inhibiting subsurface air flow.
Conversion of 41 extraction wells to slurp wells - To convert the wells to slurp wells, Terra Vac inserted a flexible hose into the well to a depth just above the total depth. Water was then extracted from the well by applying a vacuum to the hose.	6/89	Wells were converted to slurp wells to remove perched groundwater	Slurp wells were effective in removing excess water but required constant monitoring because wells tended to fill up with water.
Decane treatment - Two to five gallons of decane were added to several wells, agitated with a plunger and allowed to sit for 45 minutes or until the decane seeped into the well packing. The remaining decane was then removed from the well.	6/89	The decane was supposed to dissolve the tar that had plugged the well screens of 22 wells	In July 1990, 6 of 22 wells showed evidence of tar still remaining.
Installation of a nylon-reinforced plastic cover over east lagoon	7/89	Prevent infiltration of precipitation and short circuiting of air through the surface	No data are available on the results of this enhancement.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Table 3 (continued): Summary of SVE Enhancements at the Tyson's Dump Superfund Site [4, 6, 8, 10]

Enhancement	Dates Implemented	Purpose	Results
Hot air injection. Hot air (200°F) was injected through injection wells	8/89	To increase the VOC extraction rate by increasing subsurface temperature and eliminating accumulation of water that resulted from condensation of steam from the steam injection enhancement	Terra Vac noted that this enhancement did improve the extraction rate but not as much as anticipated. Terra Vac indicated that the shallow depth of the injection wells limited injection pressures and significant heat losses were experienced.
Increased vacuum pressure [29 inches Hg]	11/20/89 - 2/20/90	Increase VOC extraction rate	Terra Vac indicated the high vacuum increased the extraction rate for extraction wells which had exhibited low flow rates coupled with high VOC concentrations. However, the increase was temporary and the extraction rate became diffusion-limited.
Installation of 166 selectively screened wells in areas where permeability was low and the concentration of contaminants was higher than at other areas	5/90 to 6/91	The selectively screened wells were intended to focus air flow through areas of low permeability and high contaminant concentration, thus increasing the VOC extraction rate	Terra Vac indicated that the VOC extraction rate increased temporarily. Extraction rates became diffusion-limited after the area immediately around the well was treated.
Pressurized Air Injection - Air was injected at 15 psig and a flow rate of 75 scfm	10/90	Develop additional air flow pathways to increase the VOC extraction rate	VOC extraction rates increased temporarily; however; the extraction rate became diffusion-limited.
Installation of 135 horizontal wells	3/91 to 6/92	To provide removal of perched groundwater and enhance extraction rate of VOCs	Some of the highest VOC extraction rates resulted from this enhancement. However, extraction rates eventually became diffusion-limited. No data are available on how effective the horizontal wells were in removing perched groundwater.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Table 3 (continued): Summary of SVE Enhancements at the Tyson's Dump Superfund Site [4, 6, 8, 10]

Enhancement	Dates Implemented	Purpose	Results
Electrical Soil Heating - Terra Vac's ElectroVac™ process was used to raise the temperature of the subsurface soil	5/91	Raise the soil temperature to increase the VOC extraction rate.	Terra Vac indicated that the ElectroVac™ process resulted in a very limited increase in the soil temperature and had no significant effect on the VOC extraction rates.
Removal of 94 ineffective wells	12/15/91 to 12/20/91	To remove ineffective wells and reduce the number of wells so that the capacity of the SVE system was not exceeded.	A total of 94 wells were taken off-line. As the number of extraction wells in a given area increased, the competition for subsurface air flow increased among individual wells as their zones of influence began to overlap. Consequently, several wells were taken off-line because their performance was less than that of other wells and because the vapor extraction system did not have the capacity to support all the wells.
Geomixing - Soils were physically mixed with augers and backhoes	1/92 - 10/92	Break up soil heterogeneities and increase the VOC extraction rate.	Geomixing appeared to break up the soil heterogeneities because VOC extraction rates generally increased immediately after mixing but decreased within a week after. In one case the VOC extraction rate increased from 5 to 70 pounds per day. However, it decreased to 10 pounds per day within a week.
OxyVac™ - Adding hydrogen peroxide (H_2O_2) to oxidize contaminated soils and recover the vapor phase oxidation products	10/92	H_2O_2 would oxidize contaminants and the resulting oxidized product could be recovered by the vapor extraction system.	Pilot results indicated that concentrations of 1,2,3-trichloropropane were reduced by 45 percent. However, the effectiveness of the H_2O_2 was limited only to those soils that had direct contact with the H_2O_2.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Operating Parameters That Affected Cost or Performance of Treatment

Table 4 shows the operating parameters that affected cost or performance of this technology and the values measured for each.

Table 4: Operating Parameters That Affected Cost or Performance [14]

Parameter	Value
Air flow rate	15,000 scfm
Operating pressure/vacuum	13 inches of mercury vacuum

Timeline

Table 5: Timeline [1, 4, 6, 8, 12, 13]

Start Date	End Date	Activity
January 1983	August 1984	EPA and its contractors conducted a series of investigations of the site.
December 1984	-	EPA issued ROD for the on-site area (east and west lagoons).
November 1986	-	Ciba-Geigy Corporation initiated a pilot study of an innovative vacuum extraction technology.
June 1987	July 1987	The four responsible parties submitted a proposal to EPA for cleanup of the lagoon areas, upgrading of the leachate collection systems, and cleanup of the tributary systems.
March 31, 1988	-	EPA issued a revised ROD changing the remedy to soil vapor extraction
November 1988	September 1996	SVE system operation performed
July 1989	-	Terra Vac covered the surface of the east lagoon with a nylon-reinforced plastic cover. Terra Vac initiated a plan to remedy clogged wells through the use of a combination of steam injection and decane treatment. Terra Vac also converted 41 wells to slurp wells.
August 1989	October 1992	Terra Vac added enhancements described in Table 3.
October 1, 1995	April 30, 1996	The SVE system was off line for a seasonal shutdown approved by EPA.
July 20, 1996	-	EPA issued a ROD amendment changing the remedy for the soils in the lagoons to placement of a wet soil cover over the lagoon area soils.

Cleanup Goals and Standards [1]

Table 6 shows the cleanup standards specified in the 1988 revised ROD for the four contaminants of concern (indicator parameters) in the lagoon soils at the Tyson's site. EPA also specified cleanup goals for 41 other organic compounds in the lagoon soils, as shown in Appendix A.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Table 6: Cleanup Standards for Four Constituents of Concern in the Lagoon Soils [1]

Compound	Concentration (mg/kg)
Benzene	0.05
Trichloroethene	0.05
Tetrachloroethene	0.05
1,2,3-Trichloropropane	0.05

Additional Information on Goals [1]

The 1988 revised ROD required the cleanup goals to be achieved within 26 months after startup of the SVE system. It also specified that, if cleanup goals had not been met within the first year of operation of the SVE system, supplemental measures would be implemented to improve the vacuum extraction process. The revised ROD did not provide specific information indicating which supplemental measures were to be implemented or what action would be taken if the cleanup goals were not attained within the 26-month time frame.

Treatment Performance Data

Terra Vac conducted a limited soil sampling program during August 1991, approximately 32 months after the SVE system began operation. Soil samples were taken from areas adjacent to eight wells. The areas were defined by three soil borings which were drilled in a triangular array about three to five feet from each well (24 borings total). Samples were taken using a continuous split spoon from the surface to auger refusal, with samples taken from the split spoon at intervals of every 4 inches whenever possible and composited into the soil sample per boring.

Table 7 presents the results from the August 1991 sampling event and the August 1988 sampling event (two months before the system began operating). As shown in the table and described below, the concentrations of the four constituents of concern remained above the cleanup goals after 32 months of operation. In a number of cases, the constituent concentrations reported in 1991 were higher than reported in 1988.

The results for 1, 2, 3-trichloropropane showed that concentrations had been reduced to below detection limits in seven of the 24 soil borings. However, the concentrations in the remaining soil borings were above the cleanup goal, and ranged from 16 mg/kg to 32,752 mg/kg. Between 1988 and 1991, concentrations of this constituent decreased in three of the eight soil borings sampled, but increased in the remaining soil borings.

The results for benzene showed that concentrations had been reduced to below detection limits in 18 of the 24 soil borings. The concentrations in the remaining soil borings were above the cleanup goal and ranged from 11 mg/kg to 158 mg/kg. Between 1988 and 1991, benzene concentrations decreased in three of the eight soil borings, but increased in the remaining five. Likewise, concentrations for trichloroethene were reported below detected limits in 17 of 24 soil borings, with concentrations above the cleanup goal (21 mg/kg to 116 mg/kg) reported in the remaining soil borings. Between 1988 and 1991, trichloroethene concentrations decreased in five of the soil borings, but increased in the remaining three.

For tetrachloroethene, 17 of the 24 soil borings showed concentrations below the detection limit. The remaining soil borings showed concentrations above the cleanup goal (21 mg/kg to 3,951 mg/kg). Between 1988 and 1991, concentrations decreased in six soil borings, but increased in the remaining two.

Figure 5 shows the cumulative mass of VOCs removed, the monthly mass extraction rate, and the average extracted air flow per month from 1988 through 1993. Between November 1988 and November 1993, approximately 200,000 pounds of VOCs had been recovered from the

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Table 7: Comparison of Maximum Concentrations Detected in Soil Boring Samples Collected Near Eight Wells at Tyson's Dump Superfund Site from 1988 to 1991 [11]

Well Number	1,2,3-Trichloropropane (mg/kg)		Benzene (mg/kg)		Trichloroethene (mg/kg)		Tetrachloroethene (mg/kg)	
	1988	1991*	1988	1991*	1988	1991*	1988	1991*
Cleanup Goal	0.05		0.05		0.05		0.05	
VE-06	166	43 63 63	5.10	14 ND ND	0.12	ND ND ND	135	33 ND ND
VE-18	5,660	16 221 435	120	ND ND ND	24.4	ND ND ND	366	ND ND 50
VE-23	0	185 ND ND	0.04	38 29 ND	0.13	46 72 ND	0.43	25 ND 55
VE-26	14	29 ND ND	0	ND ND 71	0	35 22 40	0	ND ND ND
VE-41	249	3,872 ND 86	0.14	ND ND ND	0.80	ND ND ND	6.64	ND ND ND
VE-42	250	102 69 ND	3.03	ND 158 ND	10.60	ND ND 21	12.9	ND ND ND
VE-52	17,200	13,946 286 32,752	34.2	ND ND ND	141	ND ND 116	4,730	898 21 3,951
VE-66	403	22 2,079 ND	0.04	ND 11 ND	0.39	ND ND ND	0.21	ND ND ND

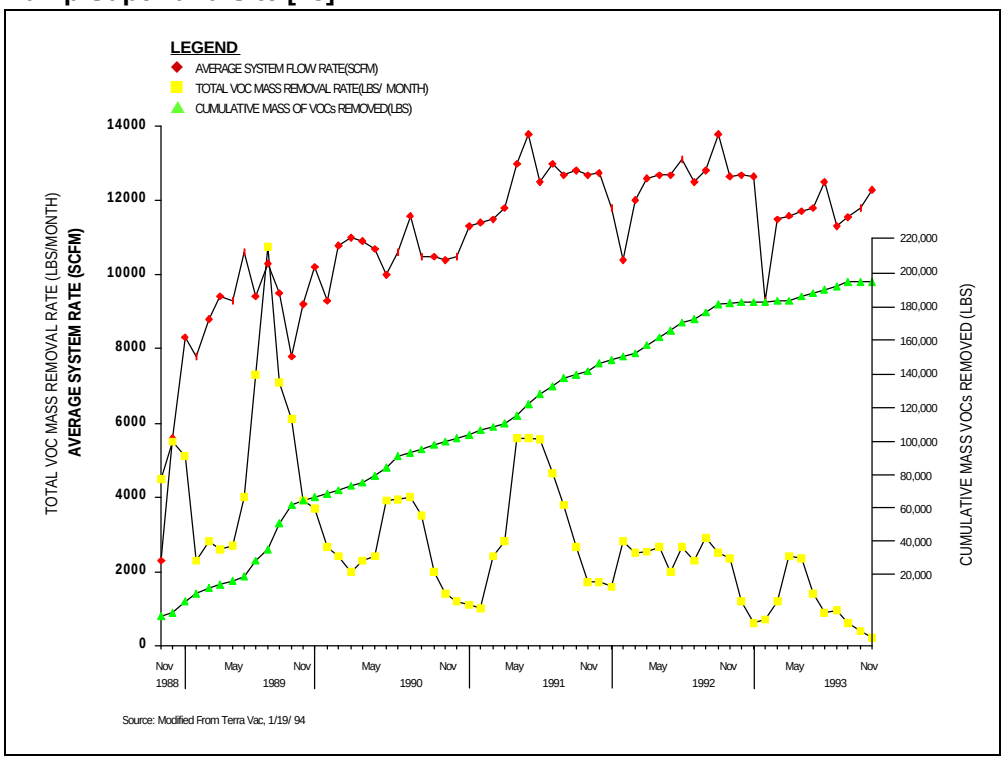
* Results are provided for three soil borings which were drilled in a triangular array about 3 - 5 feet from each well.

site by the SVE system. There were no data available to indicate which specific contaminants were included as VOCs. Based on the estimate of the mass of VOCs present (434,000 pounds), the vapor extraction system had removed less than 50 percent of the mass of contamination at the site by November 1993. As shown in Figure 5, the VOC extraction rate was lowest during the winter months.

According to EPA, in 1993, concentrations of VOCs ranged from 10 mg/kg in the upper two feet of soil to 10,000 mg/kg in the deeper soils. The VOC extraction rate reached a maximum of about 10,000 lbs/month in September 1989. The VOC extraction rate then decreased to below 2,000 lbs/month between September and December 1989. As described above, Terra Vac attributed the decrease to site conditions, including soil heterogeneity, soil moisture, and the presence of DNAPLs. Terra Vac installed a number of enhancements to the system (see Table 3) in an attempt to improve performance.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Figure 5. VOC Mass Removal and Air Flow for the SVE System at Tyson's Dump Superfund Site [15]



Many of the enhancements resulted in short-term improvements in the extraction rates. However, as described by Terra Vac, once the new flow paths created by the enhancements had been stripped of VOCs, the extraction rate for the system became limited by the diffusion rate.

In October 1995, EPA approved a seasonal shut-down of the SVE system based on the low VOC extraction rates obtained during the winter months.

EPA subsequently determined that, beginning in 1993, the ability of the SVE system to efficiently remove the remaining contaminants had decreased significantly. EPA concluded that the SVE system was incapable of meeting the cleanup levels specified in the 1988 revised ROD. As a result, in a 1996 ROD amendment, the remedy was changed from SVE to installation of a wet cover over the site.

Performance Data Completeness [7, 11, 15]

Performance data for the SVE application at the Tyson's site included initial soil sample data from 1988, and soil sample data from 1991 for the four constituents of concern. No data were provided on any of the 41 constituents listed in Appendix A. Mass extraction data was available from 1988 through 1993. No data were provided after 1993. Data on concentrations of contaminants in the soil after startup (November 1988) of the SVE system were available for only 8 VE wells at the site. Data on concentrations of contaminants in the soil at over 80 other wells at the site was not provided.

DESCRIPTION OF TREATMENT SYSTEM (CONT.)

Quality of Performance Data [11]

Terra Vac indicated that split-spoon samples were collected to obtain soil samples. The methanol extraction method was used to prepare samples. Duplicate samples were collected at a frequency of at least 10 percent. Field and trip blanks were analyzed for each boring. No discrepancies from established QA/QC procedures were noted by Terra Vac.

COST OF THE TREATMENT SYSTEM

Procurement Process

In February 1988, Terra Vac was contracted by the RPs to provide the technology and operate a vacuum extraction system of sufficient size to remediate the Tyson's site within two years. The construction phase of the project was procured through a fixed price contract. The operation and maintenance phase of the project was procured through a time and materials contract.

Cost Analysis [9, 16]

The total actual cost for the SVE system was reported by the RPs as $43.4 million. Approximately $3.5 million was incurred for design and pilot studies. Treatment costs were $39.9 million and consisted of construction and operation and maintenance costs. Construction costs were $18.5 million. Operation and maintenance costs, which included all enhancements, were $21.4 million. No other cost data were available.

OBSERVATION AND LESSONS LEARNED

Performance Observations and Lessons Learned

After 32 months of system operation, a total of about 200,000 lbs of VOCs had been removed from the soil. However, the cleanup goals had not been achieved. EPA subsequently determined that the SVE system was incapable of meeting the cleanup goals in a timely and cost effective manner, and amended the ROD by changing the remedy to a wet soil cover.

Tetra Vac attributed the SVE system's performance problems to the presence of a number of conditions at the site that had not been identified or fully characterized during previous investigations. These conditions included greater variation in soil conditions (porosity, permeability, moisture), greater occurrence of DNAPLs, and the presence of perched water at the site.

Enhancements that were made to the system in an effort to improve performance included varying the number and types of wells, heating the soil using several techniques, destroying contaminants in situ, and physically creating new flow paths. In a number of cases, an enhancement was operated for a short period of time only to evaluate its performance and effect on extraction rate. According to Terra Vac, there was no significant difference in performance between the different types of enhancements. In all cases, only temporary increases in extraction rate were observed.

OBSERVATION AND LESSONS LEARNED (CONT.)

Cost Observations and Lessons Learned

The total cost for treatment was $39.9 million or $1,330 per cubic yard of soil treated (based on 30,000 cubic yards). This cost includes costs for construction, operation, and maintenance of the SVE system including modifications and enhancements. Because these costs include the 14 enhancements, the costs may be high when compared to other SVE applications.

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Preparation of Analysis

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APPENDIX A

Table A-1: Cleanup Levels for Lagoon Soils (in addition to those shown in Table 6) [1]

Compound	Concentration (mg/kg)
Aniline	1.4
Anthracene	12,400
Benzoic Acid	6.95
Bis (2-ethylhexyl) phthalate	83,100
2-Butanone	36.8
Chlorobenzene	11.5
2-Chloronaphthalene	170
2-Chlorophenol	3.80
Chrysene	0.06
Cycloheptatriene	0.21
Cyclohexanone	262
Di-n-Butyl Phthalate	894
Di-Octyl Phthalate	16,400
Dichlorobenzenes	60
2,4-Dimethylphenol	10.8
Dodecane	490,000
Ethylbenzene	599
1-Ethyl-2-Methylbenzene	107
Fluoranthene	408
Hexadecane	2,900,000
Hexadecanoic Acid	0.197
2-Methyl Phenol/4-Methyl Phenol	33.5
2-Methyl-2-Pentanone	18.7
2-Methylnaphthalene	478
Methylene Chloride	5.84
N-Nitrosodiphenylamine	4.80
Naphthalene	3.03
Nitrobenzene	0.300
N,N-Dimethyl-1,3-Propanediamine	6.50
1,1-Oxybis-(2-ethoxyethane)	9.22
Phenanthrene	7.09
Phenol	4.19
Pyrene	3,890
Tetramethylurea	7.50
Toluene	588
1,2,4-Trichlorobenzene	479
1,2,4-Trimethylbenzene	1,230
1,3,5-Trichlorobenzene	479
Tridecane	54,000
Undecane	23,000
o-xylene	6.28