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TREATMENT PLAN FOR THE REMOVAL OF TRICHLOROETHYLENE FROM CONTAMINATED SOIL OBTAINED FROM REMEDIATION AREA 3A AND STAGED IN QUONSET HUT NO. 1

SOIL AND DISPOSAL FACILITY PROJECT

FERNALD CLOSURE PROJECT
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CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EM-50	Environmental Management-50
FCP	Fernald Closure Project
ft^3/min	cubic feet per minute
kg/yd^3	kilograms per cubic yard
LAN	Local Area Network
mg/L	milligrams per liter
μg/L	micrograms per liter
OAC	Ohio Administrative Code
OSDF	On-Site Disposal Facility
PCE	tetrachloroethylene
PSP	Project Specific Plan
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
SAE	Supplemental Accident Expense
SCQ	Sitewide CERCLA Quality Assurance Project Plan
SVEU	soil vapor extraction unit
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leachate Procedure
VOC	volatile organic compound
yd^3	cubic yard

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1.0 INTRODUCTION

This treatment plan describes the enhanced soil venting that will be used to remove trichloroethylene (TCE) from contaminated soil staged at Quonset Hut No. 1, which is located northeast of Remediation Area 3A in the former production area of the Fernald site (Figure 1-1). The U.S. Department of Energy (DOE) owns the Fernald site, and its Fernald Closure Project (FCP) is scheduled to complete all restoration activities in 2006. Successful treatment of the TCE-contaminated soil will allow the treated soil to be placed in the On-Site Disposal Facility (OSDF).

1.1 Background Information

Subsurface sediment deposits below Remediation Area 3A have been described in detail in the Operable Unit 5 Remedial Investigation and Feasibility Study (DOE 1995), a geotechnical investigation report (DOE 1998) and the Area 3A/4A Implementation Plan (DOE 2001). Briefly, the stratigraphic column under Area 3A is generally fill, glacial overburden and fluvial sand and gravel deposits of the Great Miami Aquifer, and carbonate bedrock. The emphasis here is on the glacial overburden, as this till contains the impacted materials being addressed by the soil treatment plan.

Glacial overburden is a till that is comprised primarily of a carbonate clay matrix enclosing muddy stream deposits. The stream deposits are primarily silt and sand with minor gravel and are continuous along the channel traces (primarily northeast to southwest), but discontinuous over broad lateral areas. When present, most of the channel deposits lie between a basal gray clay and overlying brown clay. Approximately 30 to 40 percent of Area 3A is underlain by the stream deposits. Most of the deposits are 5 to 7 feet thick and they lie 8 to 14 feet below the surface in the area impacted by the TCE contamination. The brown clay directly overlies the gray clay where the stream deposits are absent.

Soil staged at Quonset Hut No. 1 is comprised of the brown and gray till deposits that were removed from the excavation off the northwest corner of the Maintenance Building (Figure 1-1). During the predesign investigation for Area 3A/4A, the soil was shown to exhibit the toxicity characteristic, per the Resource Conservation and Recovery Act (RCRA). The toxicity characteristic is based on the results of 20 TCE analyses that failed the toxicity characteristic leaching procedure (TCLP). Detailed information on the sampling history of the soil can be found in the Area 3A/4A Implementation Plan and the Project Specific Plan (PSP) for Investigating of Soil Staged in Quonset Hut No. 1 (DOE 2002a).

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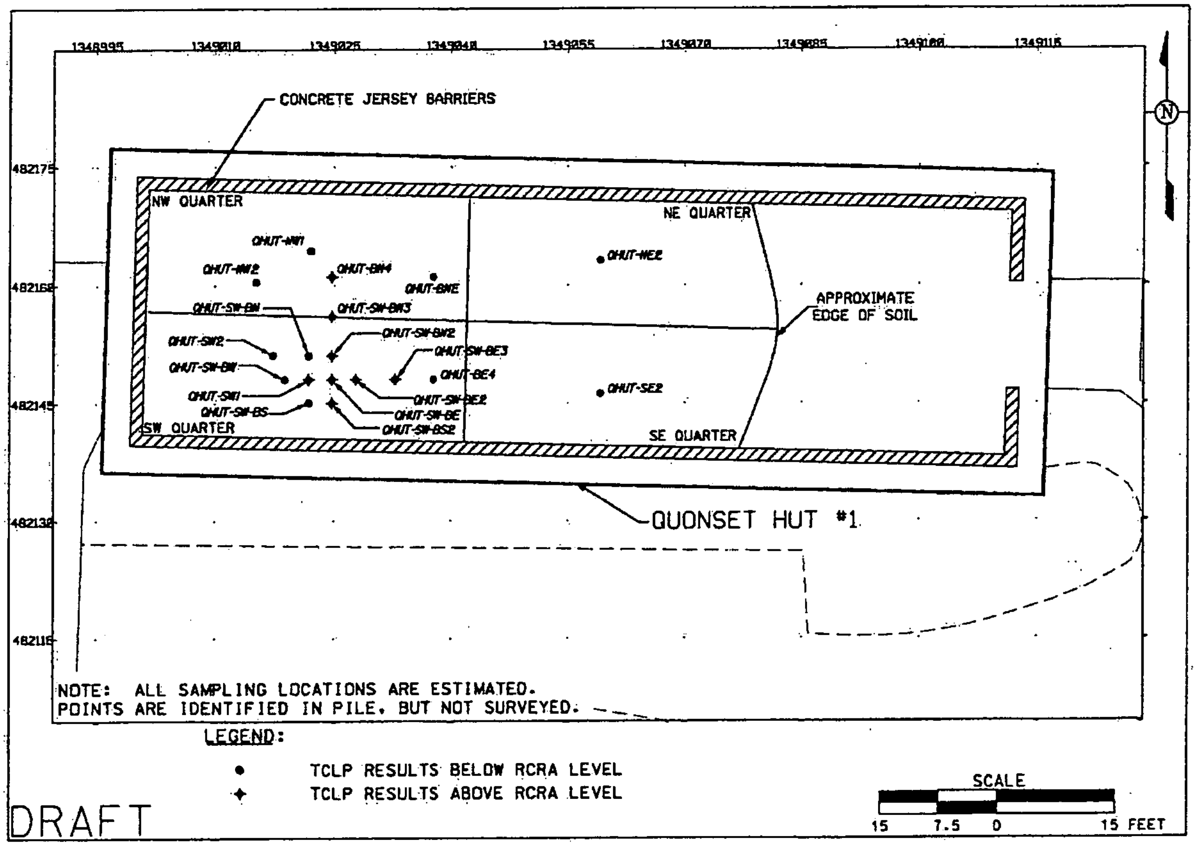


Figure 1-1 TCLP Sample Locations for Soil Pile Staged in Quonset Hut No. 1

In late 2001, approximately 600 cubic yards (yd^3) of soil were excavated from the TCE-impacted soil area northwest of the Maintenance Building and taken directly to Quonset Hut No. 1 for temporary staging. The contaminated soil is stockpiled in a geometry that allows pedestrian access around the entire perimeter of the pile. Prior to placement of the RCRA soil in Quonset Hut No. 1, concrete "jersey" barriers were placed inside of the north, south and west perimeter of the floor, within approximately 4 feet of the walls, to contain the soil pile. Soil was transported through the doors on the east side of the building, and the footprint of the pile initially occupied an approximately 30-foot by 80-foot area, with a maximum height of 8 to 10 feet. As discussed in Section 1.2, TCLP testing shows that approximately one-half of the initial soil pile volume can be removed and placed in the OSDF, with a concomitant reduction in the soil pile footprint.

1.2 Contamination Levels

Prior to excavating the soil, over 150 samples were collected and submitted for TCLP testing to bound the vertical and lateral extent of the contamination, and TCE results that failed the TCLP test [>0.5 milligrams per liter (mg/L)] ranged from 0.53 to 3.5 mg/L (Table 2-4 of the Area 3A/4A Implementation Plan). Approximately one year after the soil was excavated and placed in Quonset Hut No. 1, 32 soil samples were collected from 18 locations (Figure 1-1) under the PSP for Investigation of Soil Staged in Quonset Hut No. 1. Tetrachloroethylene (PCE) and TCE results for the TCLP test indicate 9 samples failed the TCLP test for TCE (Table 1-1), while all of the PCE results passed the TCLP test (<0.7 mg/L). Based on the results in Table 1-1, the northeast and southeast quadrants of the soil pile (Figure 1-1) do not exhibit the toxicity characteristic, and this soil can be removed and placed in the OSDF.

The ranges for TCE and PCE concentrations in the western half of the soil pile (about 300 yd^3) are 0.026 to 1.9 mg/L and 0.005 to 0.39 mg/L, respectively (Table 1-1). Assuming the TCLP results represent the range of TCE and PCE concentrations in the western half of the soil pile (i.e., all the TCE and PCE are released from the soil sample during the TCLP test), the total mass of each constituent that is likely to be in the off gas generated from treating the 300 yd^3 of soil is estimated to range from approximately 200 to 14,000 grams and 38 to 2,900 grams, respectively. This estimate is based upon 0.05 kg of soil in the TCLP test and a soil density of 1,227 kilograms per cubic yard (kg/yd^3) (e.g., 0.026 mg TCE/L * L/0.05 kg * 1,227 kg/yd^3 * 300 yd^3 = 191,412 mg = 191 g of TCE in 300 yd^3 of soil).

1.3 Evaluation of Treatment Technologies

In May of 2002, DOE's Environmental Management-50 (EM-50) organization assembled a technical team to assist in the screening of viable treatment technologies. The EM-50 team evaluated passive soil venting, enhanced soil venting, zero-valent iron, thermal desorption, anaerobic bioremediation, aerobic bioremediation, vacuum desorption, incineration, and chemical oxidation (DOE 2002b). Based on cost, ease of implementation, schedule and the current location of the RCRA soil, the EM-50 team recommended, and Fluor Fernald concurred, that enhanced soil venting is the best option.

Table 1-1
TCLP Results for Soil Samples Collected in Quonset Hut No. 1

Collection Date	Sample ID	TCE (mg/L)	PCE (mg/L)
11-5-02	QHUT-NE2-B-L	0.18	0.040
11-5-02	QHUT-NE2-M-L	0.041	0.040
11-5-02	QHUT-NE2-T-L	0.021	0.040
11-5-02	QHUT-NW1-10-L	0.14	0.39
11-5-02	QHUT-NW1-12-L	0.095	0.21
11-5-02	QHUT-NW2-B-L	0.35	0.040
11-5-02	QHUT-NW2-M-L	0.33	0.011
11-5-02	QHUT-NW2-T-L	0.026	0.014
11-5-02	QHUT-SE2-B-L	0.025	0.040
11-5-02	QHUT-SE2-M-L	0.060	0.040
11-5-02	QHUT-SE2-T-L	0.040	0.040
11-5-02	QHUT-SW1-11-L	0.13	0.091
11-5-02	QHUT-SW1-13-L	0.076	0.050
11-5-02	QHUT-SW1-6-L	**0.79**	0.014
11-5-02	QHUT-SW1-6-L reanalysis	**0.93**	0.018
11-5-02	QHUT-SW2-B-L	0.10	0.072
11-5-02	QHUT-SW2-M-L	0.030	0.057
11-5-02	QHUT-SW2-T-L	0.017	0.051
12-11-02	QHUT-SW-BE-6-L	0.12	0.050
12-11-02	QHUT-SW-BE-13-L	**0.91**	0.050
12-11-02	QHUT-SW-BS-6-L	0.13	0.050
12-11-02	QHUT-SW-BW-6-L	0.091	0.050
12-11-02	QHUT-SW-BN-6-L	0.39	0.050
1-13-03	QHUT-SW-BS2-8-L	**0.51**	0.025
1-13-03	QHUT-SW-BE2-12-L	**1.1**	0.012
1-13-03	QHUT-SW-BN2-13-L	**1.5**	0.025
2-5-03	QHUT-SW-BE3-11-L	0.45	0.005
2-5-03	QHUT-SW-BN3-15-L	**1.9**	0.11
2-5-03	QHUT-SW-BN3-8-L	**0.85**	0.025
2-26-03	QHUT-SW-BE4-12-L	0.33	0.035
2-26-03	QHUT-SW-BN4-14-L	**3.0**	0.027
2-26-03	QHUT-SW-BNE-16-L	0.18	0.010

Note: Bold numbers indicate TCE exceeds the TCLP limit of 0.5 mg/L.

Enhanced soil venting removes TCE from soil by pulling the pore air and water out of the soil. This is achieved by placing perforated pipe in the soil and attaching the pipes to a vacuum blower (Section 2.1). This simple technology is well suited for the soil pile in Quonset Hut No. 1 because access to the pile is good, solar heating can be enhanced by painting the building black, and minimal energy needs are required to run the blower. By installing a sufficient number of pipes and a large vacuum blower, large air volumes can be removed from the soil pile and volatile organic compound (VOC) air concentrations can be maintained below regulatory limits. The simplicity of the system allows for monitoring of air samples prior to and after they pass through the blower. Air samples will be collected to monitor the decreasing levels of TCE in the soil pile and ensure that the off gas complies with regulatory requirements.

1.4 Regulatory Drivers

Successful treatment of the soil requires that post-treatment soil samples put through the TCLP test release less than 0.7 and 0.5 mg/L of PCE and TCE, respectively [40 Code of Federal Regulations (CFR) 261.24]. By pulling large air volumes through the soil pile, organic compounds in the off-gas emissions will be maintained below the 15 pounds per day permit-exemption requirement [Ohio Administrative Code (OAC) 3745-31-03, Paragraph D]. For example, the maximum estimated mass of TCE in the soil (14 kg or 31 pounds; Section 1.2) would need to be released in two days to exceed the permit-exemption requirement, which is unlikely based on the physicochemical mechanisms involved in the passive soil venting process.

2.0 SYSTEM DESIGN OVERVIEW

2.1 Conceptual Design of Enhanced Soil Venting

Implementation of enhanced soil venting for the excavated soils from Area 3A could be successfully performed using any of a number of configurations. The selected configuration approach and design was developed and finalized to provide for effective treatment and efficient use of resources. The implementation can be roughly divided into three activities:

- Installation of venting pipe(s) into soil pile(s)
- Installation and operation of the venting system(s)
- Monitoring and documenting performance

Figure 2-1 shows a schematic diagram to assist in describing these steps. In this diagram, the horizontal venting pipe is installed near the bottom interior of the pile so that air must pass relatively evenly and completely through the contaminated soil prior to collection. The diagram documents the thermal enhancement from solar energy and the general configuration of the equipment for air extraction and monitoring. Each of the implementation phases is described in more detail herein.

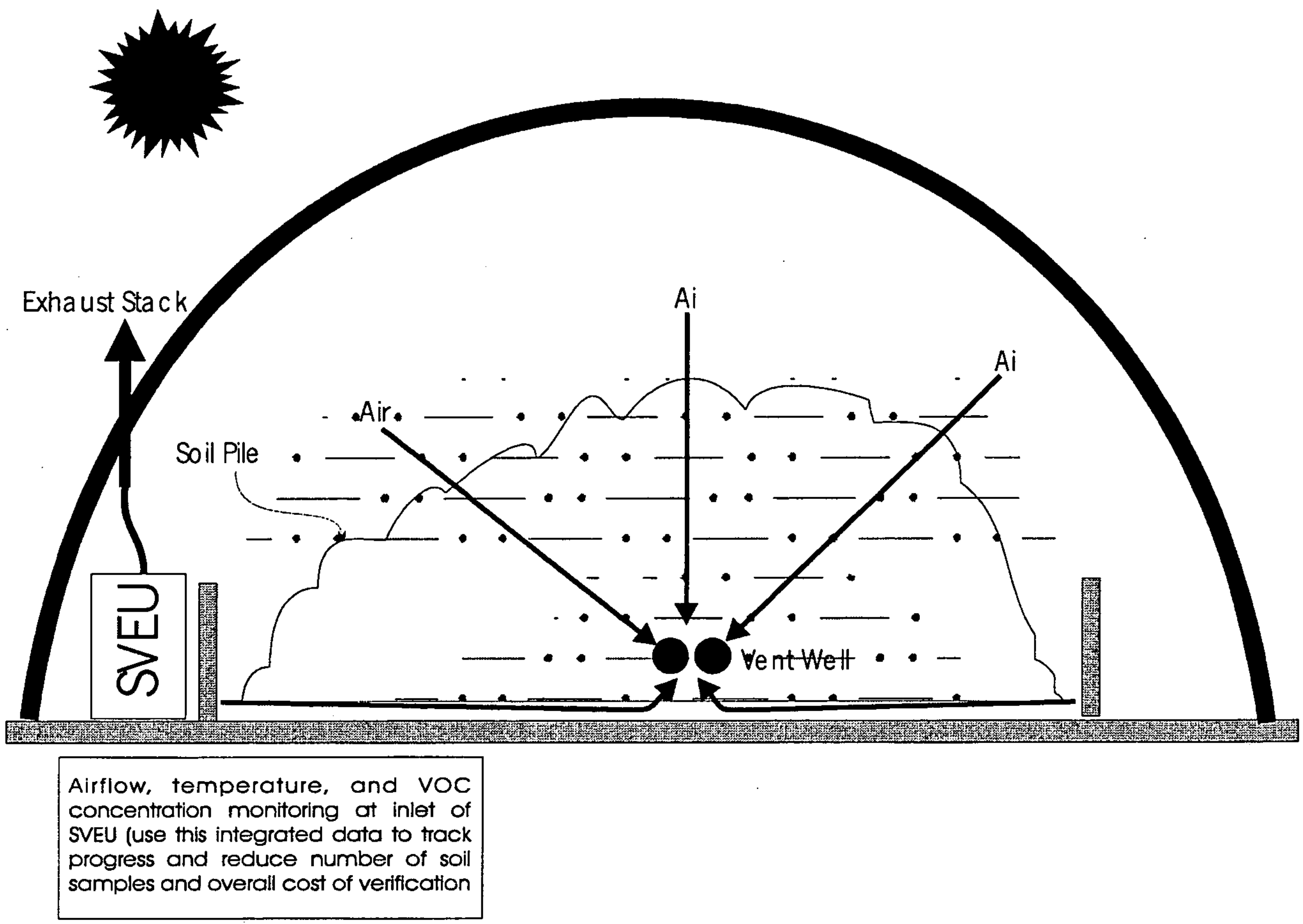


Figure 2-1 Schematic Representation of SVE Treatment System for Soil Pile in Quonset Hut No. 1

2.2 Vent System Geometry

The effectiveness of a typical soil vapor extraction system is dependent in part on the proper placement of the vent wells in relation to the contamination (i.e. placement and screened interval). The geometry of the venting system must be optimized in order to maximize the effectiveness of the treatment system. The soil stored in Quonset Hut No. 1 is in the form of a long pile (circa 30 by 80 feet) about 10 feet in height, which will be reduced to approximately 30 by 40 feet when the eastern half of the pile is removed and placed in the OSDF. These excavated soils are loosely compacted and suitable to soil vapor extraction. A horizontal vent well configuration is the most appropriate design to take full advantage of the soil permeability and to maximize the volume of soil treated by the extraction system. Due to pressure drop along the screened interval, the flow rate entering the well will be highest near the end closest to the vacuum source. To minimize this effect and to insure that the system can effectively treat the entire length of the pile in a reasonable time period, two horizontal vent wells will be installed. These vent wells will be located in the center of the soil pile and near the bottom of the pile to ensure that air passes evenly through the contaminated soil prior to entering the collection system. Both wells will extend the entire length of the pile; however, the screened interval for each well will be half the length of the pile, with each screened interval starting at opposite ends of the pile (Figure 2-2). By extending the well casing for each well completely through the pile, the soil vapor extraction unit (SVEU) can be connected to either end. This allows for some flexibility in the positioning of the unit and provides the advantage of being able to pump from either end (or both ends) of each well screen. The vent wells will be constructed of 2-inch diameter Schedule 40 polyvinyl chloride (PVC) pipe and the ends of each well will be fitted with a 2-inch diameter threaded coupling (NPT) to facilitate connection to the SVEU.

2.3 Venting System

Many choices for pump types are available for use on soil vapor extraction systems. These pumps include regenerative blowers, rotary type blowers, liquid ring pumps, and centrifugal pumps. The two most commonly used pumps in soil vapor extraction systems are the rotary lobe blower and the regenerative blower. Both blowers are simple, inexpensive, and have minimal maintenance requirements. The rotary lobe blower is capable of producing significant airflow at moderate vacuums (up to 14 inches Hg). It is particularly suited for soils and sediments with moderate permeability. The regenerative blower is also capable of producing significant airflow, but operates at lower vacuums than the rotary blower. Based on the fact that the soil has been reworked and stacked, either type pump represents an acceptable alternative for this treatment project.

The size of the vacuum blower is dictated by the flow rate requirements for the system. Section 3.4 presents simplified calculations using hypothetical contaminant concentrations to determine the number of pore volumes that need to be removed over the course of the remediation effort to clean the contaminated soils to the TCLP based goal concentrations. The actual number of pore volumes required to clean the soil pile to the goal concentrations will be determined using the method in Section 3.4 following the startup of vapor extraction. The number of pore volumes required to attain successful treatment will be a function of the actual behavior of the TCE concentration in the offgas from the pile. To size the unit, the assumption was made that the unit would need to remove approximately two pore volumes per day to clean the soil pile. If we assume 300 yd^3 of soil with a porosity of 0.4, one pore volume would be about 3,240 cubic feet (ft^3). Removal of one pore volume per day equates to a flow rate

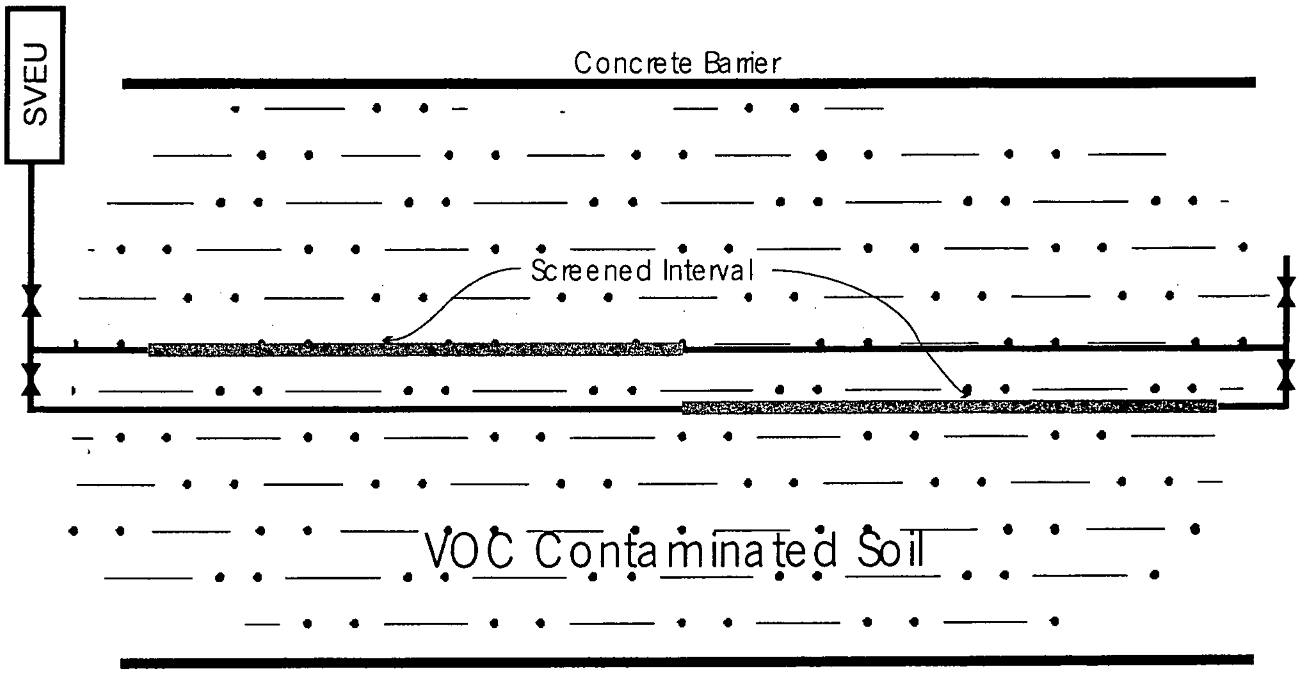


Figure 2-2 Plan View of SVE System and Horizontal Vent Wells Showing the Screened Interval for Each Well. The SVEU can be connected to either end of the vent wells.

of about 2.25 ft^3/min. Therefore, the required flow rate will be greater than 4 ft^3/min but less than 30 ft^3/min (equipment limit). The actual operating flow rate will be a function of the permeability of the soil pile and permit requirements. The treatment system is currently limited to 15 pounds of VOC emissions per day (OAC 3745-31-03, Paragraph D). VOC samples will be routinely collected and analyzed to insure that the system operates within the permitted limits. Offgas TCE concentrations will be highest at startup (Section 3.4, Figure 3-4) and samples will be collected more frequently during this period to insure compliance.

Several types of commercially available vacuum blowers are capable of producing the flow rate required for this remediation effort. A small blower such as the Roots-Dresser™ Frame 22 universal rotary lobe blower or a small regenerative blower such as the Gast™ R4P155N-50 are acceptable units for this project. These blowers have the capacity to operate at flow rates in excess of 4 ft^3/min, if needed. Total flow through each unit is controlled by a make-up air valve that allows ambient air to enter the system. Both units have silencers for noise reduction and a moisture separator to collect condensate that may form during the extraction process. Condensate may be generated during the course of the remediation effort; however, quantities are expected to be small because there should only be a small temperature difference between the ambient conditions in the shed and the soil gas in the pile. Any condensate collected in the knockout will be analyzed for TCE and disposed of as described in Section 3.6 (Waste Streams).

The SVEU will be connected to the well heads via a manifold constructed of 2-inch diameter Schedule 40 PVC pipe. The manifold will consist of an appropriate combination of valves, vacuum gauges, and sampling ports to allow for independent operation of each vent well as shown in Figure 2-3. Vacuum will be monitored using direct reading vacuum gauges. Flow rates will be monitored with a mass insertion type flow meter up-stream of the SVEU. The flow meter is capable of outputting a 4-20 ma signal, which will be logged using a standard data logger. Temperature of the inlet and outlet air stream will be monitored using Type T thermocouples connected to the data logger.

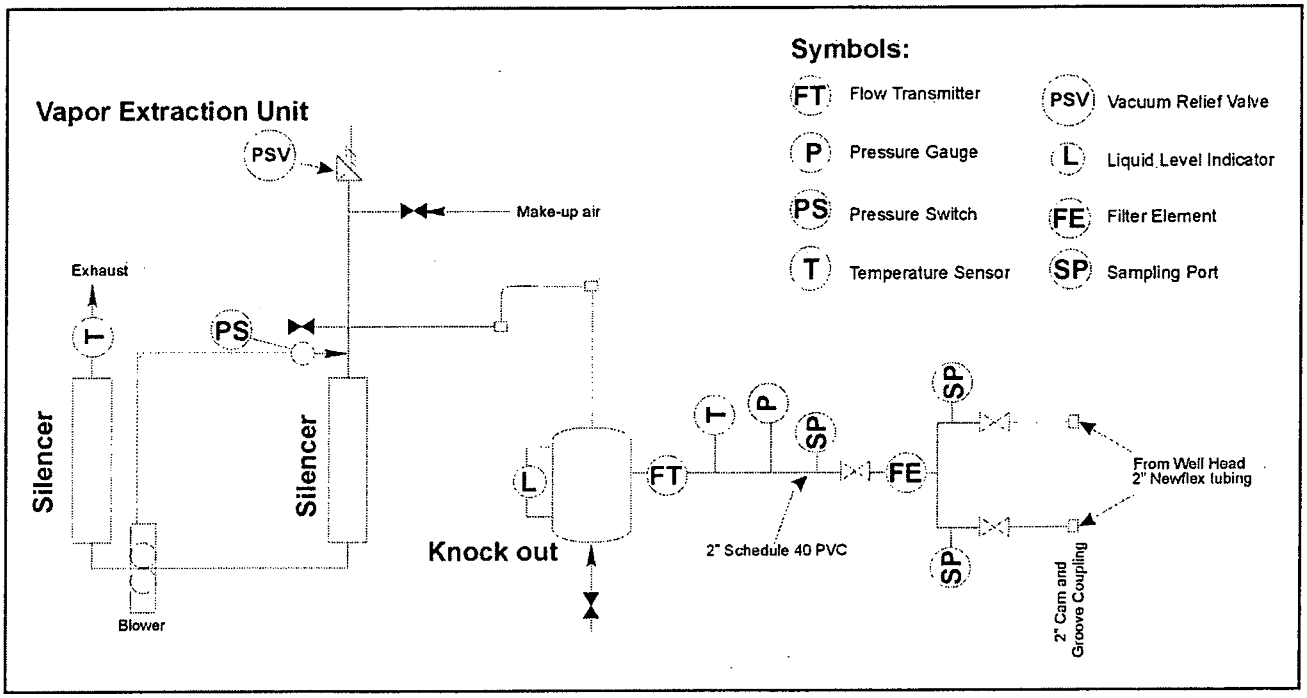


Figure 2-3 Schematic Representation of the Vacuum Extraction Unit and Manifold Configuration for the Quonset Hut No. 1 Soil Pile

The manifold configuration also consists of a polyethylene filter element upstream of the manifold to filter out any sediments and particulates from the air stream prior to entering the SVEU. The vent wells will be connected to the manifold using heavy duty Newflex® spiral reinforced PVC flexible tubing manufactured by NewAge Industries, Inc. The heavy duty Newflex® tubing has a vacuum rating of 28 inches of Hg, which is double the maximum operational vacuum of the SVEU (14 inches of Hg). The Newflex® tubing will be connected to each well using a wellhead assembly constructed of Schedule 40

PVC pipe. All connections will be made using standard hose clamps and cam and groove hose couplings. Teflon tape and standard silicone sealant will be used as necessary to seal connections on the well assembly and manifold.

The exhaust stack for the SVEU will be vented through the roof of the Quonset Hut. To accommodate this, a standard 4-inch diameter dryer vent will be inserted through the roof of the hut in a manner similar to that shown schematically in Figure 2-1. The unit will be connected to the vent using flexible hose. This configuration will make placement of the unit simple since it will not need to be hard plumbed into an existing stack.

3.0 TREATMENT PROCESS

3.1 Site Preparation and Installation

The vacuum units proposed for the treatment process are small and do not have any special mounting requirements other than being level. Since the SVEU will be located inside the Quonset Hut, weather protection will not be an issue. The Roots-Dresser™ Frame 22 rotary blower is driven by a 1.5-HP 240/480 VAC 3ϕ motor. The motor draws 2.5 amps at 480 VAC under normal operating conditions, which is 2.1KW. Since the unit will only operate for a short duration, a diesel generator is the most appropriate means by which to supply power to the unit. Power requirements will be at a maximum when the unit is initially started and should not exceed 10KW. A commercially available diesel generator capable of supplying a minimum of 10KW will be used for project. A diesel generator is preferred over gasoline because it can be safely fueled while the unit is operating.

The Gast™ regenerative blower is driven by a 240 VAC 1ϕ motor that draws 11.2 amps under full load (2.7 KW). Therefore, as with the rotary blower, the regenerative blower will require a diesel generator capable of supplying a minimum of 10KW.

3.2 Startup Testing

Prior to connection of the unit to the generator, the vacuum pump will be turned over by hand to insure all components rotate freely. Once the unit is connected to the generator and prior to connection to the wellhead assemblies, the blower will be bumped a few revolutions to verify proper rotation direction. Once this verification process is complete, the unit should be operated under "no-load" conditions for a couple of minutes to check for vibrations and abnormal noises. Afterwards, the unit can be connected to the wellhead assemblies and prepared for startup. Once the valve configuration has been set to pump the desired well, the unit may be started. The unit should initially be started under "no-load" conditions with the make-up air valve open. Vacuum should then be applied slowly to the wellhead by decreasing the amount of make-up air supplied to the unit until the desired flow rate is achieved.

3.3 System Maintenance

Maintenance requirements for both the rotary and the regenerative SVE units are minimal. The regenerative blower is essentially maintenance free. The motor and pump are directly connected and are factory sealed. The pump is oil less. Therefore, there are no periodic maintenance requirements for this unit. For the rotary unit, maintenance will consist of changing the oil and lubricating the shaft bearings periodically.

If a rotary unit is used, maintenance will be conducted on the unit prior to initial startup. This will include changing the oil, lubricating the shaft bearings, and verifying belt tightness. Selection of the appropriate oil is important since the unit will be operating inside the Quonset Hut where temperatures will be greater than ambient outdoor temperatures. The recommended oil for operating temperatures in excess of 90°F is Supplemental Accident Expense (SAE) No. 50. The rotary unit requires 6.1 ounces of oil for proper lubrication. The unit should be filled through the breather plug until oil drains from the overflow plug. The manufacturer's recommendation for complete oil change is every 1000 operating hours. The shaft bearings should be greased weekly with NLGI # 2 premium grade, petroleum based, high temperature grease.

3.4 Proposed Monitoring Approach

3.4.1 Overview

TCE-contaminated soils from Area 3A will be treated using enhanced venting – a form of active soil vapor extraction. Solvents are removed by placing horizontal vent wells into the soil pile and extracting air using a standard vacuum blower. A secondary, but significant, advantage of this approach is that active air extraction from the interior of the pile serves as a collection system for low cost monitoring of the progress of cleanup – the system itself provides an integrated measurement of the presence and concentration of VOCs in the pile. Because of the fixed size of the pile, the simple boundary conditions, and high degree of process control, theoretically based criteria can be developed for offgas concentrations and rebound to indicate when the process is relatively complete. This should reduce and optimize the number of confirmatory point soil samples for TCLP analysis.

The primary measure of progress in this approach is offgas concentration. This primary measure, combined with related measures (flow and temperature), and supporting gas concentration measurements (e.g., to test the concentrations in the various laterals to determine progress in different portions of the pile), support a robust monitoring paradigm. Composite offgas samples and process control samples will be collected in TEDLAR® bags from sample ports upstream of the blower as shown on Figure 2-3. A small vacuum pump will be used to fill the sample bag. Concentrations will be determined using a portable gas-chromatograph analyzer that will be calibrated with known concentration gas mixtures and check samples.

The general behavior of the composite offgas concentration profile from a simple soil pile venting operation is relatively straightforward. At startup, the concentrations in the offgas are low as the clean air in the lines is removed. Offgas concentrations rapidly increase as the high concentration pore gases (in equilibrium with the original contaminated soil) reach the vacuum pump. The high initial "static" concentrations then decrease and stabilize at lower "pumping" concentration levels because of preferential flow (i.e., relatively clean air reaching the extraction well in some areas) and associated mass transfer limitations. Concentrations then slowly decline as the source solvent is removed from the pile. If the pumping is stopped and the pile returns to a static condition, concentrations rise as the pore gases and the soil throughout the pile re-equilibrate.

These various concentration behaviors are depicted on Figure 3-1. The figure also shows that measurements at key points in time and simplified calculations provide valuable information about the progress of the cleanup. The method suggests pumping concentrations that correspond to the time when confirmation sampling would likely meet the clean up criteria. This is then further confirmed by the static concentrations observed after "rebound" from pumping. A more quantitative description of the features observed in the typical composite offgas profile and the calculation of target concentrations follows.

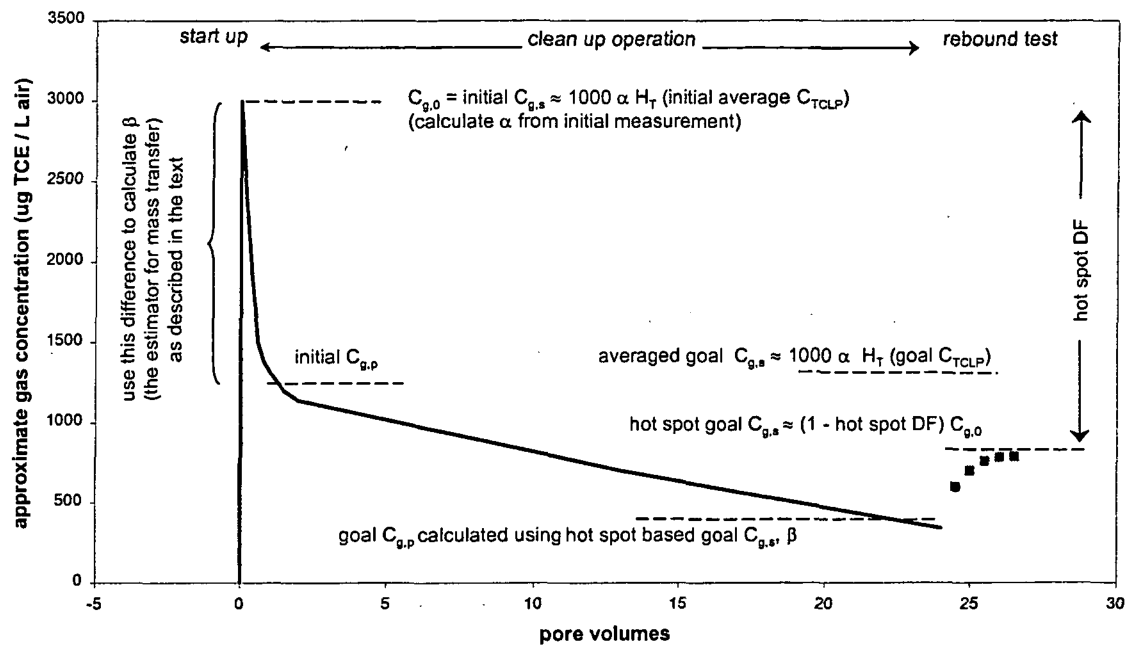


Figure 3-1 Hypothetical VOC Off Gas Concentration vs. Time Profile Showing Various Operational Stages and Calculations for a Simple Soil Pile Venting Operation. Solid line represents measured concentrations during continuous operation and data points represent intermittent measurements during rebound. The graph also notes key concentration measurements and calculations (discussed in text) that relate measured gas concentrations to soil TCLP.

3.5 Simplified Monitoring Calculations

For a soil that is contaminated by volatile solvents but that does not contain large volumes of nonaqueous phase liquids (soils such as those excavated from Area 3A and stored in the Quonset Hut) the solvent removal and mass transfer can be estimated using simple approximations. Example calculations illustrated on Figure 3-1 and discussed below appear in Attachment I. The "flux" or removal of solvents from the soil at any point in time is directly measured using flow and concentration:

$$\text{Flux} = 40780\, Q\, C_{g,p}$$

where:
Flux = extraction rate of solvent {μg/day}
Q = gas pumping flow rate {scfm}
$C_{g,p}$ = concentration in the gas phase under pumping conditions {μg/L}
40780 = {L/day per scfm}

The flux can also be estimated based on mass transfer. To simplify the analysis we have written the mass transfer equations in terms of the static gas concentration and the pumping gas concentration. The static gas concentration is the high concentration that is in equilibrium with source solvents in the soil matrix and the soil moisture when the system is not being vented. The active extraction process and the drawing of fresh air through the pile are the dominant removal mechanisms. Thus, if static soil gas concentration equals the pumping gas concentration at any time then the flux is zero. If the static concentration is higher than the pumping concentration then solvents are being removed from the pile. The difference in the static and pumping concentrations is the driving force and the flux is estimated using:

$$\text{Flux} \approx 1000\,k\,A\,(C_{g,s} - C_{g,p})$$

where:
Flux = extraction rate of solvent {μg/day}
k = mass transfer coefficient from soil into the flowing gas {m/day}
A = surface area of soil {m^2}
$C_{g,s}$ = concentration in the gas phase under static conditions (with no pumping) {μg/L}
1000 = {L / m^3}

After a short period of pumping, the fluxes will roughly balance and can be assumed to be at a pseudo steady state:

$$40780\,Q\,C_{g,p} \approx 1000\,k\,A\,(C_{g,s} - C_{g,p})$$

or,

$$C_{g,p} \approx ((1000\,k\,A)/(40780\,Q))\,(C_{g,s} - C_{g,p}) \approx \beta\,(C_{g,s} - C_{g,p})$$

where:
β = site specific conditional concentration calculation factor

Explicit estimation of the mass transfer coefficient, the surface area of the soil particles and other site-specific factors is complex and expensive. The lumped conditional calculation factor, however, can be directly estimated using the concentrations measured at startup and at the point when the offgas profile levels off. This factor is relatively insensitive to expected changes in condition during cleanup and, therefore, can be used throughout the test.

Finally, a relationship is needed to specifically relate cleanup goals to measured gas concentrations (both static and pumped). In the case of Fernald, the cleanup criteria for the Quonset Hut soils are in terms of TCLP. Based on Henry's Law, the following relationships can be used in the evaluation:

$$C_{g,s} = 1000\ H_T C_w \approx 1000\ H_T\ \alpha\ C_{TCLP}$$

where:
C_w = aqueous concentration in soil moisture in pile {mg/L}
C_{TCLP} = TCLP leach concentration result {mg/L}
H_T = Temperature dependant Henry's Law
concentration ratio {(mg VOC / L gas) / {(mg VOC / L water)}
α = site specific scaling factor relating C_{TCLP} to Cw
1000 = {µg/mg}

The scaling factor α, similar to β above, can be estimated based on the behavior of the offgas concentration profile. An initial estimate for α can be made based on the startup concentration and the initial TCLP levels in the soil. While α will vary slightly as conditions change (e.g., as some of the moisture is removed from the soil), it is expected to be sufficiently constant to support monitoring the general progress of cleanup. For this particular site, passive solar heating is proposed to enhance the venting process. Because of this, and the fact that Henry's Law partitioning ratio is a strong function of temperature (Figure 3-2), H_T is retained in the final equation (i.e., not lumped into α) and it should be adjusted for changing conditions. Also, we retained the conversion factor separate from α to emphasize that different concentration units are being used to help distinguish gas concentrations (µg/L) from water concentration (mg/L). If concentrations are measured in other units (e.g., ppmv for gas) then they should be converted to the listed units for use with these equations. Note that any partitioning relationship can be used and substituted for the one shown depending on how the cleanup criteria are defined (e.g., if target goals are in terms of soil concentrations, then equations relating soil concentrations to gas concentrations could be used). Gas concentrations during pumping are related to cleanup goals by combining the above two equations.

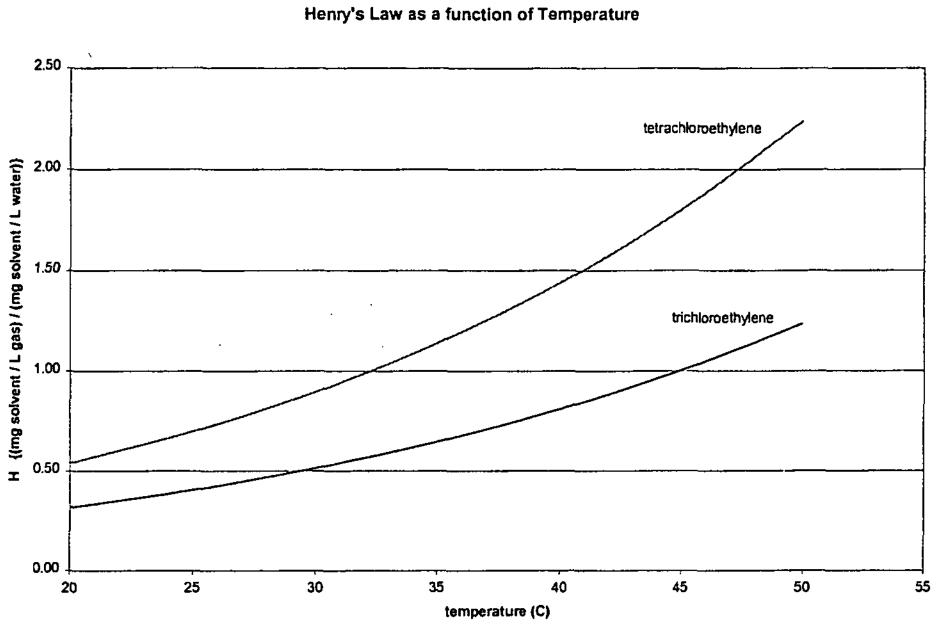


Figure 3-2 Henry's Law as a function of temperature for trichloroethylene and tetrachloroethylene

As outlined above and described below, measurements of offgas concentration, temperature and flow during operation combined with concentration rebound monitoring (total rebound and rate) can all be related to residual VOC levels in the soil and help determine when the process is complete. Because the measure is integrated it is unlikely to completely miss a "hot spot" of VOC. This integrated measure would be confirmed by limited soil sampling once the concentration/rebound criteria are met. The following tabulation provides a step-by-step description of the proposed monitoring.

Step 1: Start up system and measure TCE concentration and soil gas temperature after system lines have purged. Use this high initial TCE concentration and average TCLP result to back calculate α.

Step 2: Monitor TCE concentration every few hours until the TCE concentration begins to stabilize. Calculate β using the following equation (derived from above):

$$\beta \approx \{(\text{initial } C_{g,s} / \text{initial } C_{g,p}) - 1\}^{-1}$$

Step 3: Calculate target off gas (pumping) concentration and target static soil gas concentration based on TCLP goal for the soil. Two endpoints are proposed:

a) estimate off gas TCE concentration and static soil gas TCE concentration for the average soil TCE concentration that will pass TCLP,

$$\text{averaged goal } C_{g,s} \approx 1000\,\alpha\, H_T\,(\text{goal } C_{TCLP})$$

$$\text{averaged goal } C_{g,p} \approx (\beta/(1+\beta))\text{ averaged goal } C_{g,s}$$

b) estimate off gas TCE concentration to indicate when the soil hot spots (i.e., soil represented by the highest TCLP values) meet TCLP.

$$\text{hot spot DF} = (\text{initial maximum TCLP} - \text{goal TCLP}) / \text{initial maximum TCLP}$$

$$\text{hot spot goal } C_{g,s} \approx (\text{final } H_T / \text{initial } H_T)\,(1 - \text{hot spot DF})\text{ initial } C_{g,s}$$

$$\text{hot spot goal } C_{g,p} \approx (\beta/(1+\beta))\text{ hot spot goal } C_{g,s}$$

NOTE: DF indicates the hot spot is calculated as a decimal fraction of the initial $C_{g,s}$ value as follows: hot spot DF = (initial $C_{g,s}$ - goal $C_{g,s}$)/initial $C_{g,s}$. The relationship with TCLP results is then derived using the Henry's Law equation. Also, final H_T/initial H_T provides a correction factor between initial and final treatment temperature.

<u>Step 4</u>: Operate system and analyze offgas every few days. Continue operations until offgas concentrations reach goals to clean hot spots to target levels (until off gas $\le$ hot spot goal $C_{g,p}$).

<u>Step 5</u>: Turn off system and perform rebound test by collecting samples while pumping for short periods and show that the maximum rebound static gas concentration is less than the hot spot goal. If the rebound test fails, use data to recalculate β and go to Step 4.

<u>Step 6</u>: Collect approximately three soil samples from each quadrant of the soil pile that are expected to have the highest TCE levels, based on the November 2002 to February 2003 TCLP data. Confirm residual levels are below TCLP targets. If not, recalculate α and go to Step 4.

3.6 Waste Streams

Waste streams generated from the treatment process consist of the off gas, condensate collected in the moisture separator, and the treated soil. Off gas will be directly discharged to the atmosphere, as the organic compounds in the off-gas emissions will be maintained below the 15 pounds per day permit-exemption requirement (OAC 3745-31-03, Paragraph D). Compliance with the exemption requirement will be demonstrated through the collection of air samples at the sample port indicated on Figure 2-3. The precise number of air samples that will be collected is unknown, but this has no effect on the outcome of the treatment process, as TCLP samples must be taken to verify successful treatment. Condensate collected in the moisture separator will be sent to Phase II treatment at the Advanced Wastewater Treatment Facility. As discussed in Section 3.5, the treated soil will be sampled for TCLP analysis when monitoring parameters indicate that TCE levels have decreased to a level that results in a high probability of the soil samples passing the TCLP test. If the soil samples should fail the TCLP test, then treatment will continue and another batch of TCLP samples will be collected to verify successful treatment. After demonstrating successful treatment of the soil, the soil will be hauled to the OSDF for disposal.

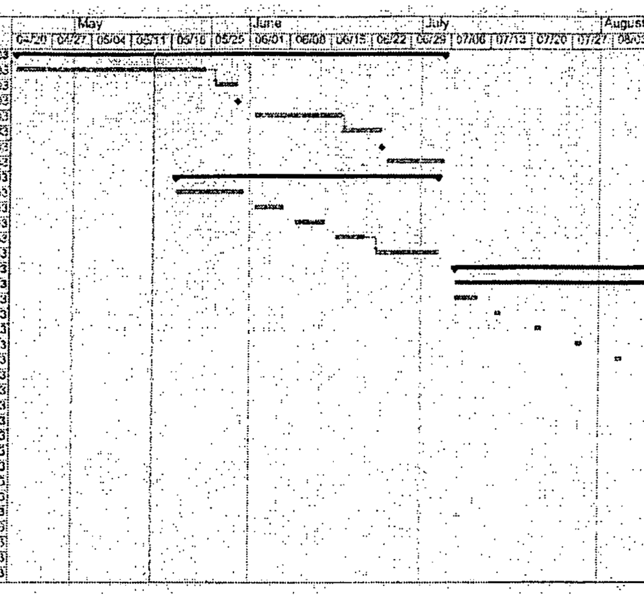
3.7 Verification Samples

The composite off-gas monitoring approach described above provides a powerful tool to track cleanup. Thus, the goal of verification sampling is to confirm that the initial hot spots meet TCLP levels. Three sampling locations will be identified in each quadrant of the soil pile (12 total) where the highest initial TCLP level was measured (Figure 1-1 and Table 1-1). Samples from the pile will be collected and analyzed using TCLP methods to confirm that the toxicity hazard has been removed from the soil prior to its disposition to the OSDF. If one or more samples fail TCLP, the vapor monitoring factors α and β will be re-estimated and SVE will be continued on the entire pile, or a segregated portion of the pile, until the acceptable off-gas TCE concentration is measured. Once again, samples from the pile will be collected (three per quadrant) and analyzed using TCLP methods to confirm that the toxicity hazard has been removed from the soil prior to its disposition to the OSDF.

4.0 SCHEDULE

Figure 4-1 summarizes the schedule for the treatment process. In parallel to the submittal and review of this plan by the regulatory agencies, site preparation activities will commence with the removal of the eastern half of the soil pile in late May of 2003. Review and approval of the plan, and completion of site preparation and set-up activities, are anticipated to be completed by July 1, 2003. Phase I of the treatment process is scheduled to begin on July 7, 2003 with the collection of initial samples to establish the site specific factors that relate TCE TCLP concentrations to TCE water concentrations (α) and the conditional concentration factor (β). If the TCE concentration in the static gas samples collected during the rebound test do not fall below the hot-spot goal (Section 3-5), then Phase II of the treatment will commence. When air samples collected during the rebound test show that the TCE concentration in the gas is below the hot spot goal, soil samples will be collected and analyzed by the TCLP test to verify the success of the treatment. In the event that the soil samples fail the TCLP test, another phase of treatment will be initiated and followed by the collection of additional soil samples and further TCLP tests until the treatment is successful; at which time a verification report will be prepared and issued to the regulatory agencies.

ID	Task Name	Duration	Start	Finish
1	**Prepare Treatment Plan**	**55 days**	**Mon 04/21/03**	**Fri 07/04/03**
2	Preapre draft	25 days	Mon 04/21/03	Fri 05/23/03
3	Internal review	4 days	Mon 05/26/03	Thu 05/29/03
4	Submit OEPA draft	1 day	Fri 05/30/03	Fri 05/30/03
5	OEPA review	11 days	Mon 06/02/03	Mon 06/16/03
6	Revise OEPA draft	5 days	Tue 06/17/03	Mon 06/23/03
7	Submit final plan to OEPA	1 day	Tue 06/24/03	Tue 06/24/03
8	OEPA review and approval	8 days	Wed 06/25/03	Fri 07/04/03
9	**Prepare Treatment Site**	**34 days**	**Mon 05/19/03**	**Thu 07/03/03**
10	Remove eastern half of soil pile	10 days	Mon 05/19/03	Fri 05/30/03
11	Install collar for roof vent	5 days	Mon 06/02/03	Fri 06/06/03
12	Install perforated pipes in soil pile	5 days	Mon 06/09/03	Fri 06/13/03
13	Assemble system components	5 days	Mon 06/16/03	Fri 06/20/03
14	Perform start-up review and checks	9 days	Mon 06/23/03	Thu 07/03/03
15	**Perform Treatment Operations**	**64 days**	**Mon 07/07/03**	**Thu 10/02/03**
16	**Phase I**	**40 days**	**Mon 07/07/03**	**Fri 08/29/03**
17	Collect initial air samples: week 1	4 days	Mon 07/07/03	Thu 07/10/03
18	Collect air samples: week 2	1 day	Mon 07/14/03	Mon 07/14/03
19	Collect air samples: week 3	1 day	Mon 07/21/03	Mon 07/21/03
20	Collect air samples: week 4	1 day	Mon 07/28/03	Mon 07/28/03
21	Collect air samples: week 5	1 day	Mon 08/04/03	Mon 08/04/03
22	Collect air samples: week 6	1 day	Mon 08/11/03	Mon 08/11/03
23	Collect air samples: week 7	1 day	Mon 08/18/03	Mon 08/18/03
24	Collect rebound samples: week 8	5 days	Mon 08/25/03	Fri 08/29/03
25	**Phase II (If needed)**	**24 days**	**Mon 09/01/03**	**Thu 10/02/03**
26	Collect initial air samples: week 1	4 days	Mon 09/01/03	Thu 09/04/03
27	Collect air samples: week 2	1 day	Mon 09/08/03	Mon 09/08/03
28	Collect air samples: week 3	1 day	Mon 09/15/03	Mon 09/15/03
29	Collect air samples: week 4	1 day	Mon 09/22/03	Mon 09/22/03
30	Collect rebound samples: week 5	4 days	Mon 09/29/03	Thu 10/02/03
31	**Verify Treatment Process**	**24 days**	**Tue 09/30/03**	**Fri 10/31/03**
32	Collect TCLP samples	1 day	Tue 09/30/03	Tue 09/30/03
33	Offsite TCLP analysis	11 days	Wed 10/01/03	Wed 10/15/03
34	Prepare verification report	11 days	Thu 10/16/03	Thu 10/30/03
35	Submit verification report to OEPA	1 day	Fri 10/31/03	Fri 10/31/03



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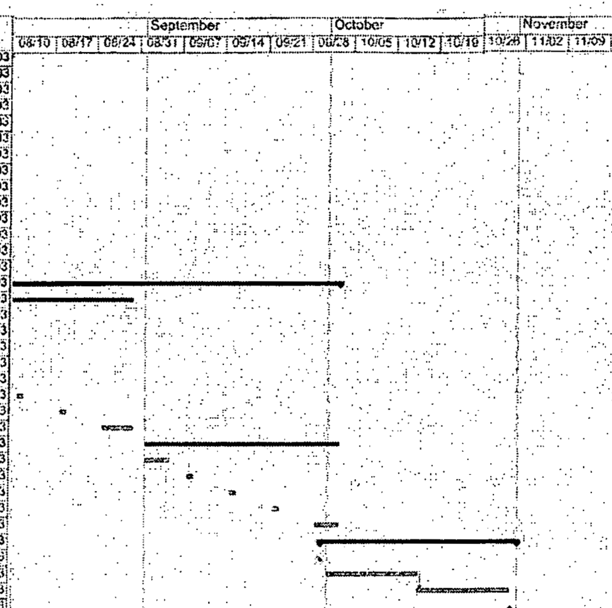

Figure 4-1 Proposed Schedule for Treatment of TCE-Contaminated Soil Staged in Quonset Hut No. 1

5.0 References

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ATTACHMENT I

EXAMPLE CALCULATIONS FOR TCE GAS CONCENTRATIONS

TCE gas concentrations needed to meet the TCLP clean-up goal

Flux = 40780*Q*$C_{g,p}$

Flux	ug/day
40780	L/day/scfm
Q = flow rate	scfm
$C_{g,p}$ = conc of gas phase when pumping	ug/L

Flux ~ 1000*k*A*($C_{g,s}$ - $C_{g,p}$)

Flux	ug/day
1000	L/m^3
k = soil to water coefficient	m/day
A = surface area	m^2
$C_{g,s}$ = conc of gas phase when static	ug/L

Assume fluxes reach steady state soon after pumping begins

40780*Q*$C_{g,p}$ = 1000*k*A*($C_{g,s}$ - $C_{g,p}$)

$C_{g,p}$ = (1000*k*A)/(40780*Q)*($C_{g,s}$ - $C_{g,p}$) ~ B($C_{g,s}$ - $C_{g,p}$)

B = site specific conditional concentration factor = 1/(($C_{g,s}$/$C_{g,p}$)-1)

Relate gas concentration to TCLP clean-up goal via Henry's Law

$C_{g,s}$ = 1000*H_T*C_w ~ 1000*H_T*a*C_{TCLP}

1000	ug/mg
H_T = Henry's law coefficient	$(mg_{TCE}/L_{gas})/(mg_{TCE}/L_{water})$
C_w = aqueous TCE concentration in soil moisture	mg/L
a = site specific factor relating C_{TCLP} to C_w	
C_{TCLP} = TCE concentration in TCLP test	mg/L

Example calculations for TCE at 30C

$C_{g,s}$	$C_{g,p}$	$^{avg}C_{TCLP}$	H_T	a	B	$^{goal}C_{TCLP}$	$^{goal}C_{g,s}$	$^{goal}C_{g,p}$	$^{max}C_{TCLP}$	HS_{DF}	$^{HS}C_{g,s}$	$^{HS}C_{g,p}$
ug/L	ug/L	mg/L				mg/L	ug/L	ug/L	mg/L		ug/L	ug/L
3000	1250	0.644	0.55	8.47	0.714	0.5	2329	970	3.0	0.833	500	208

4891