Sandia National Laboratories

Environmental Program

# Thermal Enhanced Vapor Extraction System

## Technology Need

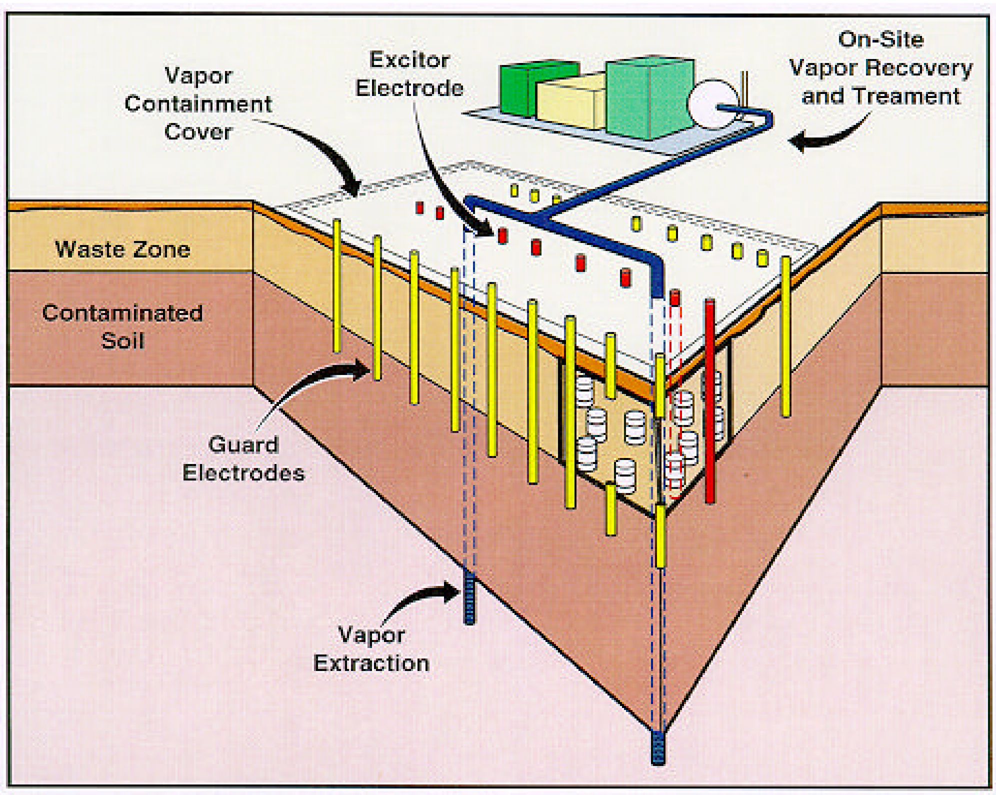
Low mass removal rates by traditional vacuum vapor extraction technology indicate a difficult remediation condition caused by low soil permeability conditions and/or low volatility contaminants. Innovative technologies that increase the mass removal rates of in-situ extraction technologies are needed to reduce the long-term cost of vacuum vapor extraction methods and offer an alternative to excavate and treatment methods for near surface contamination.

## Objective

The objective of this technology demonstration is to evaluate the effectiveness of two soil heating methods (resistive and dielectric) combined with a vacuum vapor extraction system. The added heat will increase the mass removal rate of the soil contamination and decrease the time needed to remediate contaminated soils.

## Project Description

In the Thermal Enhanced Vapor Extraction System (TEVES), three rows of electrodes are placed through an organic waste disposal cell (tri-plate array configuration) down to a depth of 25 feet. The center row electrodes are connected as the excitor (energy input) source and the two exterior rows are used as ground/guard electrodes to help contain the input energy to the treatment zone. Surface hardware



connecting the electrodes are then installed. Two dual-purpose vacuum vapor extraction wells/electrodes are installed as part of the excitor array. A vacuum blower and off-gas treatment system is provided for the removal of the heated soil contaminants.

Resistive heating technology passes powerline frequency (60 Hz) energy through the soil using the conductive path of the residual soil water. Powerline frequency energy input is controlled through a multi-tap transformer to allow for the changing impedance of the soil as soil water is removed. Voltages begin as ~200V and can be increased in steps up to 1600V. Water addition to the excitor electrodes moderates the increased soil resistance caused by removal of the soil water adjacent to the electrodes. The soil heating technology vaporizes the soil water into steam which provides another mechanism for enhancing contaminant removal. When the temperature nears 100°C and the soil water is being removed, the resistive heating energy input becomes constrained by the increased soil resistance. At this point, if higher soil temperatures are needed, radiofrequency (RF) heating is needed.

RF heating uses high-frequency microwaves (2-20 MHz) to hear the soil by dielectric heating. The RF energy is transmitted through the soils without using residual soil water as the conductive path. Energy deposition is a function of the frequency applied and the dielectric properties of the soil. Frequency selection is based on trade-offs of wave penetration depth and the dielectric constant of the soil profile. Typical frequencies used are 3.39 and 6.78 MHz. The energy output from the RF transmitted is passed through a network of capacitors to match the impedance of the soil in the treatment zone to the output of the power transmitter. This hardware minimizes energy reflected from the soil and maximizes the energy absorbed by the soil. Making these adjustments allows soil heating to continue up to 250°C or greater.

A field demonstration has evaluated the application of resistive heating and dielectric heating on an old disposal pit containing a complex mixture of organic chemicals, oils and containerized wastes. Process monitoring systems included automated vapor sampling and analysis of the extracted contaminants and subsurface pressures to monitor vapor capture in the treatment zone.

*Demonstration Results:* The power line frequency heating occurred for 30 days and increased the average soil temperature to 83°C over the entire treatment volume. Total contaminant concentrations increased by 400% over the baseline ambient temperature vacuum extraction. After letting the soil return to near ambient temperatures, radiofrequency heating began and lasted for 30 days raising the average soil temperature to 112°C. Heating during this period caused contaminant extraction concentrations to increase 500-1000% over baseline.

## Costs

Costs are being evaluated for commercial applications. Currently, cost estimates are approximately $\$130/yd^3$.

## Point of Contact

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