



SITE Technology Capsule

IITRI Radio Frequency Heating Technology

Abstract

Radio frequency heating (RFH) technologies use electromagnetic energy in the radio frequency (RF) band to heat soil in situ, thereby potentially enhancing the performance of standard soil vapor extraction (SVE) technologies. Contaminants are removed from in situ soils and transferred to collection or treatment facilities.

The Illinois Institute of Technology Research Institute (IITRI) RFH process was evaluated under the U. S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program at a site containing various organic contaminants in a heterogeneous soil matrix. Due to changes in the original design and operational problems experienced during the demonstration, the treatment area was evaluated as two separate zones: the "revised" design treatment zone and the "heated" zone. The revised design treatment zone reflects both changes made to the design of the RFH system and operational problems associated with shallow groundwater at the test site. The heated zone consists of the area that achieved the target temperature of 150°C.

Concentration changes were calculated from paired pre- and post-demonstration soil samples; these concentration changes were evaluated for statistical significance. Conclusions have been drawn based only on data that were statistically significant at greater than or equal to the 90 percent confidence level.

Within the revised design treatment zone the estimated mean concentration decrease for Total Recoverable Petroleum Hydrocarbons (TRPH) was 60 percent. Estimated mean concentration decreases for two semivolatile organic compounds (SVOCs), pyrene and bis(2-ethylhexyl)phthalate were 87 and 48 percent respectively. There were statistically significant increases in the concentrations of four volatile organic compounds (VOCs); the estimated mean concentration increases were 457 percent for 2-hexanone; 263 percent for 4-methyl-2-pentanone; 1,073 percent for acetone; and 683 percent for methyl ethyl ketone.

Outside of the revised design treatment zone, only TRPH showed a statistically significant change with an estimated 88 percent increase in the mean concentration.

Within the heated zone the estimated mean concentration decrease was 95 percent for TRPH.

Outside the heated zone, the estimated mean concentration decrease was 37 percent for bis(2-ethylhexyl)phthalate; estimated mean concentration increases were 423 percent for 2-hexanone; 249 percent for 4-methyl-2-pentanone; 1,347 percent for acetone; and 1,049 percent for methyl ethyl ketone.

Several possible reasons exist for changes in concentration observed. They include inward contaminant migration, low extraction rates, widely varying soil temperatures, low pretreatment contaminant concentrations in the soil, and the potential degradation of TRPH and SVOCs.

The estimated cost to treat 10,152 tons of contaminated soil based on a scaleup of the revised design treatment zone is \$619 per ton; the estimated cost to treat 8,640 tons of contaminated soil based on IITRI's theoretical system design is \$340 per ton.

The IITRI RFH technology was evaluated based on the nine criteria used for decision making in the Superfund feasibility study (FS) process. Results of the evaluation are summarized in Table 1. This evaluation was based on information from the SITE demonstration conducted at Kelly Air Force Base (AFB).

Introduction

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, committed to protecting human health and the environment from uncontrolled hazardous waste sites. CERCLA was amended by the Superfund Amendment and Reauthorization Act (SARA) in 1986.



Table 1. Evaluation Criteria for the IITRI RFH Technology¹

<i>Evaluation Criteria</i>	<i>Performance</i>
<i>Overall Protection of Human Health and the Environment</i>	<ul style="list-style-type: none"> • Site-specific treatability studies will be needed to verify the levels of contaminant removal achievable • Requires measures to protect workers during installation and treatment • Additional contaminants may form at high temperatures if not properly designed or operated
<i>Compliance with Federal ARARs²</i>	<ul style="list-style-type: none"> • Vapor collection and treatment are needed to ensure compliance with air quality standards • Construction and operation of an onsite vapor treatment unit may require compliance with location-specific ARARs • RF generator must be operated in accordance with National Institute of Occupational Safety and Health (NIOSH) and Federal Communication Commission (FCC) requirements
<i>Long-term Effectiveness and Performance</i>	<ul style="list-style-type: none"> • As with all SVE-based systems, the contamination source may not be adequately removed • Involves some residuals treatment (vapor stream)
<i>Reduction of Toxicity, Mobility, or Volume through Treatment</i>	<ul style="list-style-type: none"> • Potentially concentrates contaminants, reducing waste volume • Potentially reduces contaminant mobility, although downward mobility of contaminants during treatment has not been quantified • May form new contaminants, thereby potentially reducing or increasing toxicity, if not properly designed or operated
<i>Short-term Effectiveness</i>	<ul style="list-style-type: none"> • Presents minimal short-term risks to workers and community from air release during treatment • No excavation is required, although drilling will disturb the soil to some extent
<i>Implementability</i>	<ul style="list-style-type: none"> • RF generator must be operated in accordance with NIOSH and FCC requirements • Pilot-scale tests have been completed at two other sites to evaluate the technology; no full-scale applications to date • Because of operational problems experienced during the SITE demonstration, consistent soil heating was not observed
<i>Cost³</i>	<ul style="list-style-type: none"> • Cost evaluation based on revised design treatment zone is \$619 per ton; cost evaluation based on IITRI's theoretical system design is \$340 per ton
<i>State Acceptance</i>	<ul style="list-style-type: none"> • No excavation is required, which should improve state acceptance
<i>Community acceptance</i>	<ul style="list-style-type: none"> • No excavation is required, which should improve community acceptance • Potential health effects of RF fields may be an issue

¹ Based on the results of the SITE demonstration at Kelly AFB

² ARARs = Applicable or Relevant and Appropriate Requirements

³ Actual cost of a remediation technology is site-specific and dependent on the target cleanup level, contaminant concentrations, soil characteristics, and volume of soil. Cost data presented in this table are based on the treatment of 10,152 tons of soil (scale-up based on the revised design treatment zone) and 8,640 tons of soil (based on IITRI's theoretical system design).

These amendments emphasize the achievement of long-term effectiveness and permanence of remedies at Superfund sites. SARA mandates implementing permanent solutions and using alternative treatment technologies or resource recovery technologies, to the maximum extent possible, to clean up hazardous waste sites.

State and federal agencies, as well as private parties, are now exploring a growing number of innovative technologies for treating hazardous wastes. The sites on the National Priorities List total more than 1,200 and comprise a broad spectrum of physical, chemical, and environmental conditions requiring varying types of remediation. The EPA has focused on policy, technical, and informational issues related to exploring and

applying new remediation technology applicable to Superfund sites. One such initiative is EPA's SITE Program, which was established to accelerate development, demonstration, and use of innovative technologies for site cleanups. EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment and site remediation technologies and related issues. These capsules are designed to help EPA remedial project managers, EPA on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to effectively evaluate a technology's applicability for cleaning up Superfund sites. Additional details regarding technology demonstrations are presented in the Innovative Technology Evaluation Reports.

This capsule provides information on the IITRI in situ RFH technology. This technology was developed to improve the removal of VOCs and SVOCs from the soil using standard SVE technologies. The IITRI RFH process was evaluated under the SITE Program from January through August 1993 at Kelly AFB in San Antonio, Texas. This demonstration was performed in conjunction with a technology evaluation performed by the U.S. Air Force (USAF). Information in this capsule emphasizes specific site characteristics and results of the SITE field demonstration at Kelly AFB. The capsule presents the following information:

- Technology Description
- Technology Applicability
- Technology Limitations
- Process Residuals
- Site Requirements
- Performance Data
- Technology Status
- Sources of Further Information
- References

Technology Description

RFH technologies use RF energy to heat soil in situ, thereby potentially enhancing the performance of standard SVE technologies. The RF energy causes dielectric heating of the soil, which is a faster and more efficient mechanism for heating solids than is convective heating. Some conductive heating also occurs in the soil.

In IITRI's proprietary system, an RF generator supplies energy to exciter electrodes, which are copper pipes installed in vertical boreholes. Copper balls welded onto the ends of the exciter pipes help distribute the energy, which tends to concentrate at these points. As the soil is heated due to the dissipation of the RF energy, contaminants and moisture in the soil are vaporized and pulled toward ground electrodes, which also serve as vapor extraction wells. The vaporized water may act as a steam sweep to further enhance the removal of organic contaminants. A standard SVE system provides a vacuum to the ground electrodes and transfers the vapors to collection or treatment facilities. Contaminants are treated using standard vapor treatment techniques. After soil treatment is complete, the soil is allowed to cool. The SVE system may be operated during part or all of this cooling period. The exact numbers of exciter and ground electrodes, electrode configurations, vapor collection or treatment techniques, and other design details are site-specific.

Figure 1 is a schematic diagram of the IITRI RFH system used for the SITE technology demonstration at Kelly AFB; Figure 2 is a cross-section of IITRI's RFH system. A 40-kW RF generator served as the energy source for the system. Energy was supplied to the exciter electrodes for approximately 9 weeks via coaxial cables. Reflected energy was measured, and the electrical characteristics of the transmitted RF energy were adjusted as necessary. Exciter electrodes were constructed of 2.5 and 4-inch (nominal diameter) copper pipe and were installed in 10-inch boreholes to a depth of 19.5 feet below the surface. The boreholes were backfilled around the electrodes using a material similar to the surrounding soil. Four exciter electrodes spaced 2.5 feet apart were installed in a row.

Two rows of eight ground electrodes each were installed parallel to and on either side of the exciter electrode row. The ground electrodes were fabricated from 2-inch-diameter aluminum pipes. The electrode configuration was designed to direct the flow of RF energy through the soil and contain the energy within the treatment zone. With the exception of the four corner electrodes that were not perforated, the ground electrodes were perforated on the side facing the treatment zone to permit the collection of vapors from the soil. They were perforated in 8 uniform pattern over the full length of the electrodes. Each perforated ground electrode was connected to a manifold, which led to the vapor treatment system. Two additional perforated vapor extraction pipes were installed parallel to the ground surface to prevent buildup of vapors below the vapor barrier.

As shown in Figure 1, the insulated vapor barrier extended several feet over the surface of the ground end exciter electrodes to prevent heat loss, contaminant emission, and air infiltration. A sheet of expanded aluminum covered the same area as the vapor barrier and was designed to contain RF energy. An arched aluminum shield that covered only the electrodes in the treatment zone was also designed to contain RF energy. To complete the RF containment system, the arched RF shield was electrically connected to the ground electrodes by aluminum wire mesh.

The system was designed to heat the soil evenly to a temperature of approximately 150°C. The soil heating began at the top of the treatment zone near the exciter electrodes, and the heated zone expanded outward and downward over time. The original area to be treated measured 10 feet wide by 17.5 feet long by 29 feet deep. Due to shallow groundwater and operational problems encountered during the demonstration, the treatment zone was revised to 10 feet wide by 14.1 feet long by 23.3 feet deep. The RFH system was evaluated using this "revised" design treatment zone. The RFH system was also evaluated using the "heated" zone, which is the area that achieved the target temperature of 150°C. This zone measures 5.7 feet wide by 10.3 feet long by 20.0 feet deep. Temperatures within and outside both treatment zones were monitored at various depths throughout treatment. Contaminant removals inside and outside each of these zones were evaluated separately; results of these evaluations are presented in the Performance Data Section.

The vapor extraction system was operated throughout the 9-week heating period and for approximately 2 months during the cooldown period. The vapor extraction system was operated at a suction pressure of at least 7 inches of water column while heat was being applied to the soil. Vapors were extracted from the soil at a rate of approximately 120 standard cubic feet per minute (scfm). Condensate that formed in the system was collected; uncondensed vapors were burned in a propane flare.

Technology Applicability

The heat provided by the RFH process increases the vapor pressure of contaminants in the soil, thereby potentially improving the effectiveness of SVE. RFH may make it possible to remove SVOCs that would not normally be removed by standard SVE technologies. RFH may also speed the removal of VOCs, which can be removed by standard SVE technologies. Contaminants that can potentially be removed using RFH include a wide variety of organics such as halogenated and

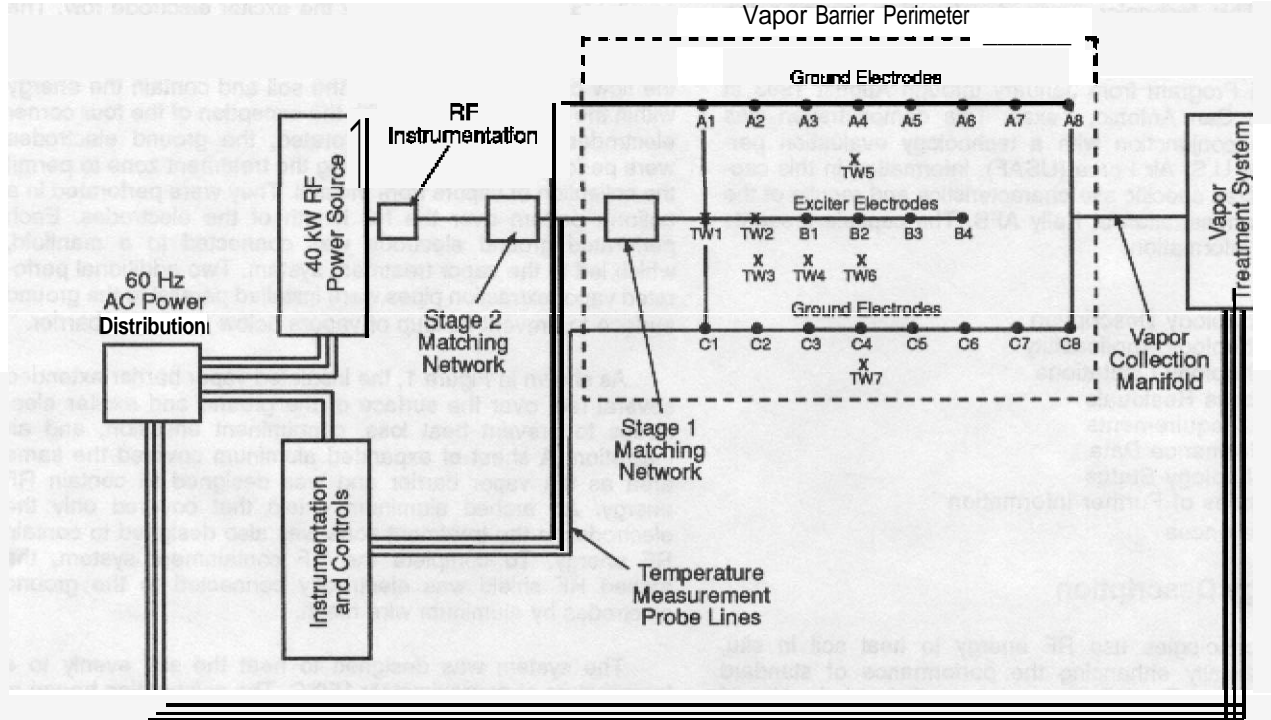


Figure 1. Schematic diagram of IITRI's RFH system.

nonhalogenated solvents and straight-chain and polycyclic aromatic hydrocarbons found in gasoline, jet fuel, and diesel fuel. Inorganics, metals, and other nonvolatile contaminants will not normally be treated by SVE or RFH technologies.

A previous study (not sponsored by the SITE program) conducted at Volk AFB indicated that IITRI's RFH system effectively removed VOCs and SVOCs from a small treatment zone containing homogenous, sandy soils. The soil in the Kelly AFB treatment zone was a heterogeneous mixture of sand, clay, and gravel. Due to the operational problems encountered during the Kelly AFB study, it cannot be determined how the heterogeneous soil matrix affected RFH system effectiveness. However, soils containing large amounts of silt, clay, and humic substances tend to adsorb organic contaminants more tightly. Soils containing a large fraction of clay may also have insufficient air permeability for adequate contaminant removal by SVE or RFH technologies. Site-specific, in situ treatability studies will need to be conducted to confirm the applicability of this technology.

Technology Limitations

IITRI claims its technology is not ready for commercialization. Considerable development and optimization of the process would be required before a full-scale system would be ready for field use. For example, IITRI must demonstrate the system's ability to treat an entire site and to use an RF generator that can supply more than 40 kW of RF energy. The IITRI RFH technology cannot be used as a stand-alone technology. Vaporized contaminants and steam must be collected

for reuse or treatment. In some cases, residual contaminants may remain in the soil after treatment

This technology currently appears to be limited to unsaturated soils, although groundwater pumping may be used to lower the water table and extend the treatment zones. RFH is further limited to soils contaminated with VOCs and SVOCs. Nonvolatile organics, metals, and inorganics will not normally be removed by RFH or SVE technologies.

Process Residuals

The IITRI RFH process generates one process waste stream that contains vaporized contaminants and steam diluted in extraction air. This waste stream can be treated by any of a number of standard vapor treatment technologies including vapor-phase carbon, condensation, or incineration. During the SITE demonstration at Kelly AFB, a propane flare was used to treat uncondensed contaminants in the vapor waste stream.

Steam and contaminants in the vapor stream that condensed in the vapor collection system were collected prior to the flare. These condensed residuals were handled along with other site wastes at Kelly AFB. When groundwater is pumped to lower the water table, the groundwater must also be handled as a liquid residual.

Some soil contaminants may remain after treatment. Significant quantities of several organics remained in the soil after treatment was completed at Kelly AFB, although remediation of

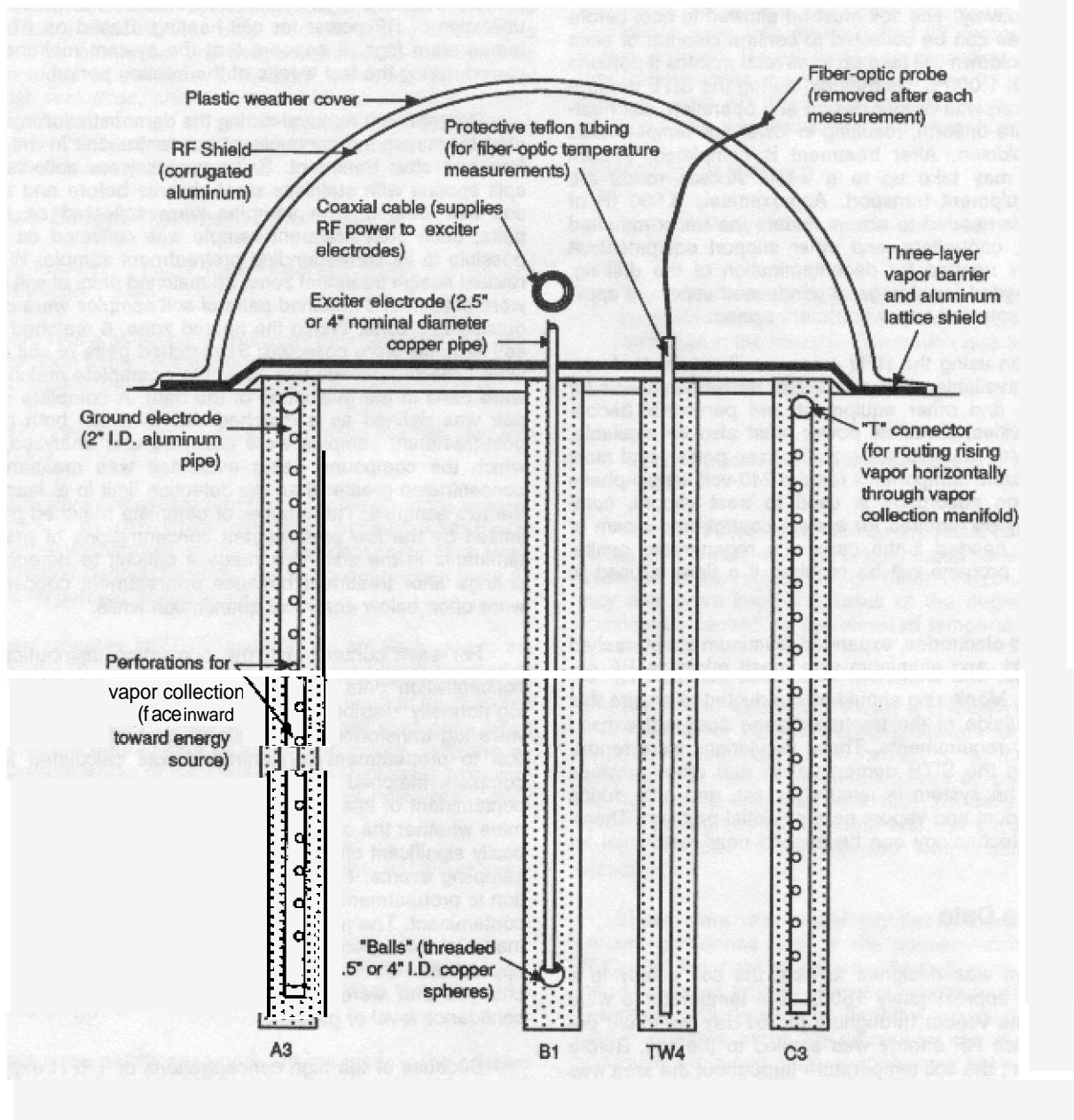


Figure 2. Cross-section of IITRI's RFH system.

the site was not an objective of the demonstration. Further treatment will be required to fully remediate these soils.

Site Requirements

Onsite assembly of the full-scale system will take several weeks, including drilling time. It is expected that medium to large sites will be divided into several sections that will be treated consecutively. The soil must be allowed to cool before final soil samples can be collected to confirm cleanup of each section. Soil cooldown will take up to several months if portions of the soil reach 1,000°C, as they did during the SITE demonstration. However, with proper design and operation, soil heating may be more uniform, resulting in lower soil temperatures and faster cooldown. After treatment is completed, system demobilization may take up to a week. Access roads are needed for equipment transport. Approximately 4,600 ft² of level ground are needed to accommodate the trailer-mounted RF generators, controllers, and other support equipment. A bermed area is needed for decontamination of the drill rig. Area is also needed for storage of condensed vapors, if applicable, and the selected vapor treatment system.

Remediation using the RFH process will require that certain utilities be available at the site. Water must be available for steam-cleaning and other equipment and personnel decontamination activities. Electrical power must also be available. The RF generator requires 480-volt, 3-phase power, and most of the minor system components require 240-volt, single-phase power. If carbon adsorption is used to treat vapors, compressed air may be required for system control, and steam or hot air will be needed if the carbon is regenerated onsite. Natural gas or propane will be required if a flare is used to control vapors.

The ground electrodes, expanded aluminum sheet, arched aluminum shield, and aluminum wire mesh minimize RF energy emissions. Monitoring should be conducted to ensure that the RF field outside of the treatment zone does not exceed NIOSH or FCC requirements. These regulations were reportedly met during the SITE demonstration and other previous field studies. The system is relatively quiet, and only during installation will dust and vapors be a potential problem. Therefore, the RFH technology can be applied near residential areas.

Performance Data

The system was designed to heat the soil evenly to a temperature of approximately 150°C. Soil temperatures were monitored by the vendor throughout the 61-day treatment period during which RF energy was applied to the soil. Before treatment began, the soil temperature throughout the area was approximately 20°C. During the SITE demonstration, the RF energy applied to the exciter electrodes progressed gradually from the surface to the deepest point of each exciter electrode. The soil temperature near the ground electrodes increased gradually as RF energy flowed from the exciter electrodes to the ground electrodes. Near the end of the demonstration all exciter electrode temperatures varied widely; maximum temperatures near the exciter electrodes exceeded 1,300°C. Temperatures near the ground electrodes did not exceed 112°C near the surface, and did not exceed 52°C below 24 feet. Based on temperature measurements, it appears that a system malfunction could have resulted in incomplete heating of the revised design treatment zone. ITRI believes this malfunction was a result of electrical problems due to shallow groundwater.

Groundwater levels may have been higher than originally expected by the vendor. Due to the presence of shallow groundwater, ITRI shortened the exciter electrodes to avoid potential system operational problems. Groundwater levels were monitored infrequently, so insufficient data are available to determine exact water levels during the demonstration. However, exciter electrodes removed after the demonstration had melted. Since copper melts at approximately 1,100°C, these electrodes provide evidence of a system malfunction that prevented full utilization of RF power for soil heating. Based on ITRI's soil temperature logs, it appears that the system malfunction occurred during the last weeks of the heating period.

Contaminant removal during the demonstration was evaluated by measuring contaminant concentrations in the soil before and after treatment. Soil samples were collected using split spoons with stainless steel sleeves before and after the soil was treated. The samples were collected as matched pairs; each post-treatment sample was collected as near as possible to its corresponding pretreatment sample. Within the revised design treatment zone, 26 matched pairs of soil samples were collected; 9 matched pairs of soil samples were collected outside this zone. Within the heated zone, 6 matched pairs of soil samples were collected; 31 matched pairs of soil samples were collected outside this zone. Only complete matched pairs were used in the evaluation of the data. A complete matched pair was defined as a matched pair in which both pre- and post-treatment samples were collected and analyzed, and in which the compound being evaluated was measured at a concentration greater than the detection limit in at least one of the two samples. The number of complete matched pairs was limited by the low pretreatment concentrations of many contaminants in the soil. This made it difficult to determine any change after treatment because pretreatment concentrations were often below analytical quantitation limits.

For each contaminant, the population distribution of the concentration data was evaluated. Most contaminants were log-normally distributed, and as a result, concentration data were log transformed. The ratio of post-treatment concentration to pretreatment concentration was calculated for each complete matched pair. The resulting set of ratios for each contaminant of interest was evaluated using a t-test to determine whether the contaminant concentration exhibited a statistically significant change between the pre- and post-treatment sampling events. The mean ratio of post-treatment concentration to pretreatment concentration was also calculated for each contaminant. The mean ratio was then converted to either the mean percent decrease or the mean percent increase, as appropriate. Conclusions have been drawn based only on changes that were statistically significant at the 90 percent confidence level or greater.

Because of the high concentrations of TRPH expected at the site, TRPH was designated as an indicator (i.e., critical) contaminant. Method 418.1 [1] was used to determine TRPH concentrations in the soil samples following extraction with Freon according to Method 9071 [2].

Soil samples were extracted by Method 3540 [2] and analyzed for SVOCs using Method 8270 [2]. Five SVOCs were designated as indicator (i.e., critical) compounds because their concentrations were expected to be significant. These included 2-methylnaphthalene; naphthalene; 1,2-dichlorobenzene; 1,3-dichlorobenzene; and 1,4-dichlorobenzene. Because a preliminary statistical evaluation did not indicate any significant changes in the concentrations of these compounds, none of them were included in the final statistical evaluation and no conclusions

can be drawn. Two other (i.e., non-critical) SVOCs were statistically evaluated because they exhibited concentration decreases.

Method 8240 [2] was used to determine VOC concentrations in the soil samples. Benzene, toluene, ethylbenzene, total xylene, and chlorobenzene were designated critical VOCs because of their expected high concentrations. A preliminary statistical evaluation conducted for these five compounds indicated that only chlorobenzene exhibited a change in concentration, and was, therefore, the only indicator VOC included in the final evaluation. However in the final statistical evaluation, chlorobenzene did not exhibit a statistically significant change at the 90 percent confidence level. Four other VOCs were statistically evaluated because they exhibited concentration increases.

Revised Design Treatment Zone Results

The following results were observed within the revised design treatment zone:

- There was a statistically significant decrease in TRPH concentration at the 95 percent confidence level: the estimated decrease in the mean concentration was 60 percent.
- No conclusions can be drawn regarding the five indicator SVOCs.
- There were statistically significant decreases in the concentrations of two other SVOCs, pyrene and bis(2-ethylhexyl)phthalate, at the 97.5 percent confidence level; estimated decreases in the mean concentrations were 87 and 48 percent, respectively.

The decreases in TRPH and SVOCs are likely due to the performance of the RFH system, which may have resulted in the volatilization of contaminants, allowing them to be collected by the SVE system. These decreases may also have been caused by the degradation of these compounds from the elevated temperatures of the RFH system. Decreases from outward migration are unlikely, since the configuration of the SVE system would limit this type of migration.

For the VOCs within the revised design treatment zone, the following results were observed:

- * There was no statistically significant change in the concentration of chlorobenzene at the 90 percent confidence level. No conclusions can be drawn regarding the other four indicator VOCs.
- There were statistically significant increases in the concentrations of four other VOCs (all ketones) at the 99 percent confidence level; estimated increases in the mean concentrations were 457 percent for 2-hexanone, 263 percent for methyl-2-pentanone, 1,073 percent for acetone, and 683 percent for methyl ethyl ketone.

The ketones may have been formed by the degradation of TRPH and SVOCs near the exciter electrodes, where soil temperatures were highest. A possible degradation pathway may be the pyrolytic conversion of TRPH to unsaturated hydrocarbons. In the presence of sufficient oxygen and a catalyst (e.g., silica in the soil), the RF energy may convert these hydrocarbons into ketones. The increase in ketones may also have been caused by inward migration. Possible sources of

ketones are the groundwater, which was not sampled, and the soil beyond the sampled area, although these sources cannot be verified. However, there are insufficient data to confirm or disprove either of these hypotheses. Statistically significant changes in TRPH, SVOC, and VOC concentrations in the revised design treatment zone are listed in Table 2.

Outside of the revised design treatment zone, only TRPH showed a statistically significant change at the 95 percent confidence level, with an estimated 88 percent mean concentration increase. Based on the configuration of the SVE system, this increase may have been due to inward migration; however, it is not likely this increase was due to outward migration from the revised design treatment zone.

Heated Zone Results

The following results were observed within the heated zone:

- There was a statistically significant decrease in TRPH concentration at the 97.5 percent confidence level: the estimated decrease in the mean concentration was 95 percent.
- No conclusions can be drawn regarding the five indicator SVOCs.
- No conclusions can be drawn regarding the five indicator VOCs.

The TRPH decrease may be the result of the SVE system pulling the contaminants out of the heated zone into the vacuum wells. As in the revised design treatment zone, this decrease may also have been the result of the degradation of these compounds caused by the elevated temperatures of the RFH system.

There was also a statistically significant decrease in the concentration of bis(2-ethylhexyl)phthalate at the 90 percent confidence level outside the heated zone; the estimated decrease in the mean concentration was 37 percent. As inside the two zones, this decrease may be caused by the SVE system pulling the contaminant into the vacuum wells or by degradation due to the elevated temperatures of the RFH system.

There were statistically significant increases at the 99 percent confidence level in the concentrations of four other VOCs (all ketones) outside the heated zone. The estimated mean increases for these four ketones were 423 percent for 2-hexanone, 249 percent for 4-methyl-2-pentanone, 1,347 percent for acetone, and 1,049 percent for methyl ethyl ketone. As previously explained, these ketones may have been formed by the degradation of TRPH and SVOCs or inward migration.

Several possible reasons exist for changes in concentration observed. They include inward contaminant migration, low extraction rates, low soil temperatures achieved in some areas, and low pretreatment contaminant concentrations in the soil.

Two-dimensional modeling of gas flow rates was used to qualitatively evaluate inward migration and treatment zone extraction rates. The results of this modeling indicate inward gas flows. Due to inefficiencies in the design of the SVE system, gas flows between the outer edge of the impermeable cap and the extraction wells are five times greater than those between the two rows of extraction wells. As a result, contaminant

migration into the treatment zone is possible, especially near the outer edges, and contaminant removal from the treatment zone may have been relatively slow as compared to inward contaminant migration.

Concentrations of TRPH and specific VOCs and SVOCs in the gas stream were monitored by a USAF subcontractor and were not part of the SITE demonstration. However, the appropriateness of the methods used and the quality of the data are unknown. The results appear to qualitatively indicate removals of TRPH and certain VOCs and SVOCs. Because of limitations of the sampling and analytical methods, the quantity of contaminants removed cannot be estimated.

Technology Status

Information is currently available from IITRI on two field studies (not sponsored by the SITE program) conducted at Volk AFB and Rocky Mountain Arsenal [3][4]. IITRI is performing a larger test at Sandia National Laboratory. Results of the Kelly AFB demonstration are documented in this capsule.

IITRI claims its technology is not ready for commercialization. Considerable development and optimization of the pro-

cess would be required before a full-scale system would be ready for field use.

A 300-kW full-scale system has been proposed. The cost of a full-scale treatment system, based on the results obtained from the revised design treatment zone, is estimated to be \$619 per ton for a site containing 10,192 tons of contaminated soil. The cost of a full-scale system treatment system, based on IITRI's theoretical system design, is \$340 per ton for a site containing 9,640 tons of contaminated soil. Costs associated with analyses, site preparation, permitting, effluent treatment and disposal, and residuals and waste shipping are considered site-specific costs that will be assumed by the site owner or responsible party. As a result, these costs are not included in the per ton cost estimates.

Disclaimer

Although the technology conclusions presented in this report may not change, the data have not been reviewed by EPA Risk Reduction Engineering Laboratory Quality Assurance personnel at this time.

Sources of Further Information

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