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GEOSAFE IN SITU VITRIFICATION SITE DEMONSTRATION

James E. Hansen, Director
Brett E. Campbell, Site Manager
Craig L. Timmerman, Project Manager
Geosafe Corporation
2950 George Washington Way, Richland, WA 99352
(509) 375-0710

INTRODUCTION

This extended abstract presents the results of the EPA SITE Program Demonstration that was conducted on Geosafe Corporation's In Situ Vitrification (ISV) technology at the Parson Chemical/ETM Enterprises Superfund Site in Grand Ledge, Michigan. The significance of the demonstration results are also related to other Geosafe project experience and the current state of the ISV technology.

The ISV technology is a joule-heated electric melting technology that treats contaminated soil and other earthen materials (e.g., sediment, sludge, flyash, mill tailings) for the primary purposes of destroying, removing, or immobilizing hazardous, radioactive, and mixed contaminants. ISV may be applied to materials in their original location within the ground, or to materials placed in a specific location or container, below grade or above grade, for purposes of treatment. A melt is typically initiated at the surface of the material to be treated. Joule heating occurs as electric current flows through the molten material, thus causing the melt to increase in temperature and adjacent material to melt. Typical melt temperatures range from 1,600 to 1,800°C. Single Melts as large as 1,400 tons and exceeding 20-ft in depth have been achieved. Adjacent melts fuse together to form a single contiguous monolith.

Contaminants may be destroyed, immobilized, and/or removed during ISV. The high temperature typically destroys organics by pyrolysis. The predominant disposition of heavy metals is chemical or physical incorporation within the resulting vitreous monolith, which produces a permanent immobilization result. Some vaporizable contaminants may be removed by the process heat without undergoing destruction or immobilization. The specific disposition that may be expected for contaminants at a given site depends on many waste- and site-specific variables. Off-gas treatment is employed to treat and/or remove vaporized contaminants and to ensure gases evolved from the process are safe for release.

The ISV process and equipment system is illustrated in Figure 1. ISV is a truly mobile technology with the majority of process equipment being permanently mounted on trailers.

The Parsons Chemical site was previously owned and operated from 1945 through 1979 by the former Parsons Chemical Works, Inc. which was involved in the mixing, manufacturing, and packaging of agricultural chemicals including pesticides, herbicides, solvents, and mercury-based compounds. These activities resulted in the contamination of soil around the manufacturing facility and in ditch locations of a drainage system that flowed approximately 1/4 mile to a nearby creek. The typical depth of contamination around the site was 5-ft or less. A total of about 3,000 cu-yd of soil was found to be contaminated with a broad range of organics and metals associated with the Parsons Chemical Works' activities at the site. The four contaminants of primary regulatory concern, and their maximum concentrations measured in the site soil, included: chlordane (89,000 ppb), 4,4'-DDT (340,000 ppb), dieldrin (87,000 ppb), and mercury (34,000 ppb). Dioxins were also found on the site at very low levels.

The site soil is a silty clay with some sand present. A sandy layer exists approximately 8 to 10-ft below grade. Water flows through this layer, in a north easterly direction, on a variable basis related to recent rain and snowfall. The site soil is relatively homogeneous with nearly zero rock content. The

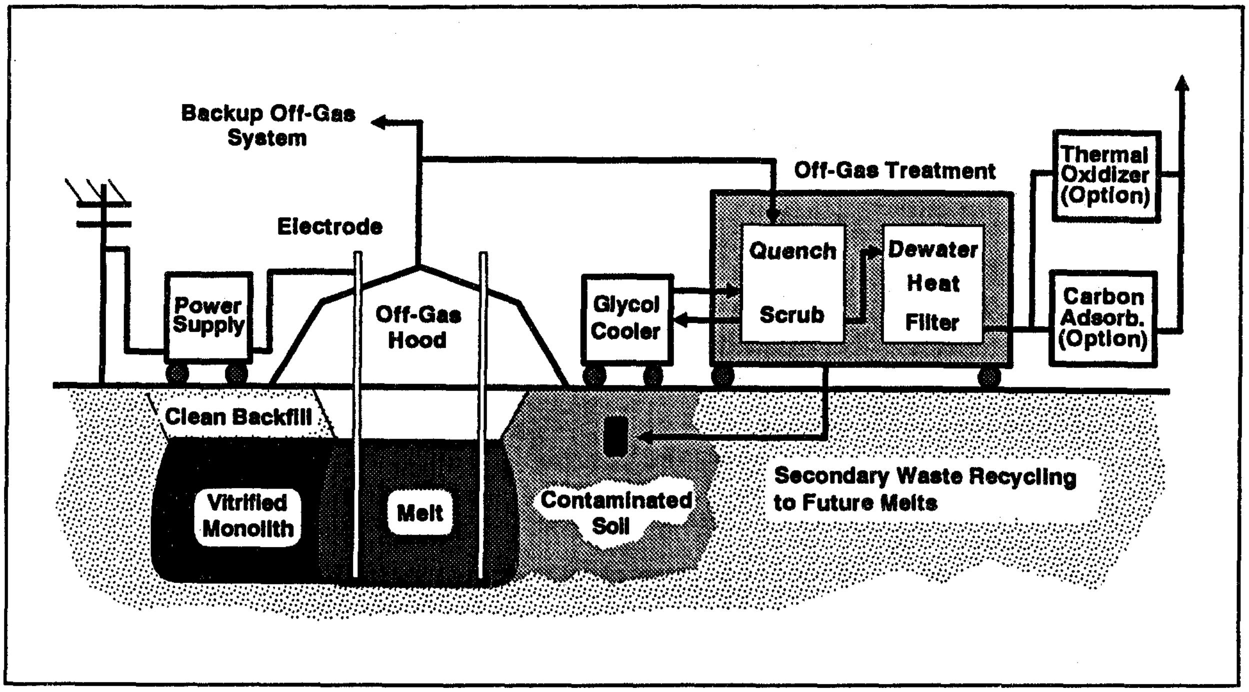

Figure 1. ISV Processing and Equipment Schematic

soil wet density is 1.8 ton/cu-yd; the dry density is 1.5 ton/cu-yd. The soil was found to be very low in load bearing capacity when wet, and very hard and strong when dry. These conditions made it difficult to work with regardless of the season.

METHODOLOGY

EPA and the Michigan State Department of Natural Resources (MDNR) established ARARs for the site including the following cleanup standards for the treated (vitrified) soil: chlordane (1,000 ppb), 4,4'-DDT (4,000 ppb), dieldrin (80 ppb), and mercury (12,000 ppb).

The contaminated soils from around the site were consolidated into a 16-ft deep trench for ISV treatment purposes. The treatment trench was laid out in a manner that would accommodate nine individual melts involving about 400 cu-yd of contaminated soil each. The treatment trench construction included a feature to intercept and divert groundwater that might flow into the site through the sandy layer at the 8 to 10-ft level. This was accomplished by placing a layer of cobble rock under the complete treatment area, deeper cobble-filled trenches along the outside (north-south) edges of the treatment area, and vertical walls of cobble around the complete treatment volume. In addition, two cobble-filled sumps were placed at the northernmost corners of the treatment area to serve as accumulation points for intermittent pumping of intercepted water to a nearby drainage ditch. Figure 2 illustrates the configuration of the treatment trench.

At the time of the project design, it was also believed that the cobble walls would be beneficial to the project as thermal barriers, which would limit melt width and thus minimize the extent of overmelting into clean adjacent soil. In order to construct the cobble walls, concrete walls were placed as vertical forms on the interior of the cobble (side toward the contaminated soil), and pressed wood sheeting was used as forming on the exterior (native soil) side. During the vitrification portion of the project, concern

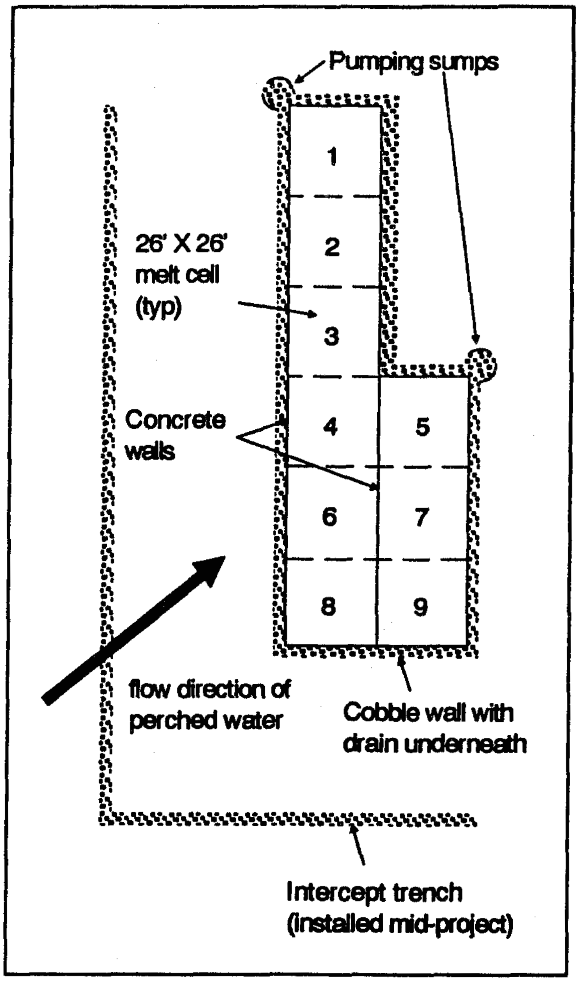

Figure 2. Treatment Trench Configuration

developed over having the intercept water and cobble materials located immediately adjacent and beneath the contaminated soil. Therefore, about midway through the project, another intercept trench was constructed away from the treatment trench for purposes of intercepting the groundwater before it could reach the vicinity of the treatment trench. This new intercept trench was successful in minimizing the amount of water reaching the original intercept and diversion system.

The SITE Demonstration Program identified one critical objective and seven secondary objectives for their evaluation of the demonstration. They determined that the demonstration would be performed on the sixth melt performed at the site. Their objectives were:

- To determine if the final soil cleanup levels were achieved (critical objective)
- To evaluate the leachability characteristics of the vitrified product using the TCLP
- To determine the approximate levels of residual contaminants in the vitrified soil
- To characterize the pesticide and mercury content of the off-gas scrubber water
- To evaluate emissions from the process
- To identify operational parameters of the technology
- To develop operating cost estimates and projections, and to assess equipment reliability
- To examine potential technical, institutional, operational, and safety impediments related to the use of the ISV technology.

Extensive sampling and analysis of the demonstration soil volume was performed to establish a pre-vitrification contamination level. Composite sample results for the contaminants of concern were: chlordane (2,000 ppb), 4,4'-DDT (72,000 ppb), dieldrin (12,000 ppb), and mercury (12,000 ppb). These values were reported as estimates since they were less than the reporting detection limit for the methods used, but greater than the method detection limits.

Geosafe utilized conventional ISV processing methods for performance of the individual melts. The "feeding electrode" concept was employed, wherein the depth of the electrodes were controlled by feeders. The depth of the melt could be determined at each electrode by lowering the electrodes to the bottom of the melt. Two notable changes from the initial operating mode were made midway through the project. First, because of the tendency for the soil conditions at the site to produce wider than usual melts, and because of the limited performance of the cobble walls to limit melt width, it was determined to employ refractory concrete barrier panels in place of the cobble rock for the last five of the melts. Second, due to the presence of a nonhazardous but sometimes offensive odor present within the off-gas emissions, a thermal oxidizer was added as an off-gas polishing step midway through the project to eliminate the odor.

RESULTS

SITE Demonstration Program data indicated that cleanup objectives for the site were achieved. Table 1 presents pre-test, post-test, and regulatory limit values for the contaminants of concern. It should be noted that the pre-test value for chlordane was found to be below regulatory limits, although prior samples from the site were well above limits. The fact that the materials were excavated and staged for treatment could be expected to provide a mixing of soils and an "averaging down" of contamination levels. It should also be noted that the ISV process is a destruction and removal process for organics, and is primarily a removal process for mercury. Mercury is notable compared to other heavy metals in that its low solubility in silicate melts, and its high vapor pressure at ISV melt temperatures, result in nearly total removal by vaporization to the off-gases. This behavior is in contrast to other heavy metals of environmental concern, which predominantly are retained in and immobilized by the vitrified product.

Vitrified product TCLP data was obtained for the target contaminants as well as other priority pollutant metals (see Table 2). It should be noted that the indication of organics being present at below the detection limit for the analytical method used is an improbable result due to the fact that organics cannot exist at the temperatures experienced in the ISV melt. The TCLP results were all very good, and were in agreement with many prior tests of ISV vitrified product that show the benefit of vitrification for immobilization of heavy metals and destruction of organics.

Results of stack gas emissions analyses are presented in Table 3. The less than values for the target pesticides are based on detection limit values for the analytical methods used. No pesticides were detected in the off-gas. Because of the presence of other metals within the soil in addition to the target metal contaminant (mercury), the metals arsenic, chromium and lead were designated as critical analytes of the off-gas emissions. As indicated in Table 3, all metals emissions results were in compliance with established regulatory guidelines. Arsenic was below reporting detection limits in all samples.

The purpose of the wet scrubber in the off-gas treatment system is to remove particulate and condensible vapors that may escape the treatment zone and enter the off-gases. The concentration of such materials in the scrub solution increases over time. SITE Demonstration Program analyses of the scrubber water confirmed that it contained volatile organics, partially oxidized semivolatile organics, mercury, and other metals. Geosafe sent the scrubber solution offsite for treatment and disposal at the

TABLE 1. COMPARISON OF PRE-TEST AND POST-TEST SOIL CONTAMINANT CONCENTRATIONS WITH CLEANUP CRITERIA*

Contaminant	Pre-Test	Post-Test	Regulatory Limit
Chlordane	<80**	<80	1,000
4,4'-DDT	13,000	<16	4,000
Dieldrin	4,600	<16	80
Mercury	3,800	33	12,000

* All results by SITE Demonstration Program; all units are μg/kg

** < values indicate not detected at or above presented value (detection limit)

TABLE 2. VITRIFIED PRODUCT TCLP DATA FOR CONTAMINANTS OF INTEREST*

Contaminant	Post-Test Concentration (µg/kg)	TCLP Result (µg/L)	Regulatory Limit (µg/L)
Chlordane	<80**	<0.50	30
4,4'-DDT	<16	NA	NA
Dieldrin	<16	NA	NA
Arsenic	3,100	13	5,000
Barium	3,600	440	100,000
Cadmium	NA	<5.0	1,000
Chromium	13,000	<10	5,000
Lead	8,600	1,100	5,000
Mercury	33	0.18	200
Selenium	NA	<300	1,000
Silver	NA	<10	5,000

* All results by SITE Demonstration Program
** < values indicate not detected at or above presented value (detection limit)

TABLE 3. STACK EMISSIONS PERFORMANCE DATA COMPARED TO REGULATORY GUIDELINES*

Contaminant	Emissions Value (lb/hr)	Regulatory Limit (lb/hr)
Chlordane	$<1.0 \times 10^{-5}$**	2.5×10^{1}
4,4'-DDT	$<2.0 \times 10^{-6}$	1.0×10^{-2}
Dieldrin	$<2.0 \times 10^{-6}$	2.8×10^{-4}
Arsenic	$<1.9 \times 10^{-6}$	***
Chromium	2.1×10^{-5}	***
Lead	2.8×10^{-5}	***
Mercury	1.1×10^{-4}	5.9×10^{-4}

* All results by SITE Demonstration Program
** < values indicate not detected at or above presented value (detection limit)
*** Emissions levels were deemed acceptable by MDNR

end of the project. Alternatively, it is believed that several means may be employed to remove the contaminants from the water, such that the contaminants could be replaced in the soil for additional destruction/immobilization treatment by a subsequent ISV melt. Such alternatives were not attempted during the demonstration.

The SITE Demonstration Program also evaluated the reliability and operating efficiency of the ISV process and equipment. The demonstration melt was found to take 10 days to complete, melting approximately 600 tons of soil at an average specific power consumption of 0.72 MWh/ton. The ISV process equipment operated very well during the demonstration with only minimal downtime for addition of electrode segments and minor adjustments.

Lastly, the SITE Demonstration Program performed order of magnitude (+50%, -30%) estimates of cost for ISV processing based on the costs incurred during the demonstration melt. They estimated the cost for three cases involving different quantities of material treated and depth of treatment, as follows: Case 1: 1,700 tons at 5-ft depth - $740/ton; Case 2: 5,700 tons at 15-ft depth - $430/ton; and Case 3: 7,900 tons at 20-ft depth - $370/ton. It is noted that ISV costs should be computed on a per ton basis since the throughput capability is related to melting mass as opposed to volume. Processing rates vary directly with soil wet density. It is appropriate to use wet density in such determinations since the process consumes time and energy for removal of water as well as for melting soil.

CONCLUSIONS

The SITE Demonstration Program reported that the ISV technology performed well relative to all the critical demonstration objectives, and that the ISV technology should be applicable to other sites with similar contaminants and soil conditions.

The demonstration reporting noted that the contamination conditions at the Parsons Chemical site were not severe enough to enable measurements and calculation of destruction and removal efficiencies (DREs) for the pesticides treated at the site. This is a typical problem where contamination levels are too low relative to the capabilities of analytical methods to detect contaminants at low enough levels to determine DREs in the range of 4-9s (99.99%) or greater. Relative to this limitation of the demonstration, Geosafe notes that a large number of ISV tests have been performed that have demonstrated repeatedly the capabilities of the process to attain DRE's in the range of 99.99% to >99.9999% for volatile, semivolatile, and nonvolatile organics. One such demonstration was performed at large-scale immediately after the Parson Chemical Project. This demonstration was Geosafe's National TSCA Demonstration Project which was performed at a private site in Region 10. The site contained PCBs to a maximum level of 17,000 ppm. The project was performed under the auspices of EPA's TSCA organization, as a demonstration in support of Geosafe's application for a National TSCA Operating Permit for PCB treatment. The project clearly demonstrated the capability of the process to exceed 99.9999% DRE for PCBs.

Geosafe concurs with the SITE Demonstration Program's order of magnitude cost estimates for ISV based on the conditions experienced at the Parsons Chemical site. However, there are several factors that should be noted relative to considering the cost of ISV at other sites. It should first be recognized that specific conditions at the Parsons Chemical site made it a more costly endeavor than may be typical for other sites. The primary determinants of cost are four: 1) the price of electricity at the site, 2) the depth of processing, 3) the amount of water to be removed by the process, and 4) the amount of clean soil that is melted to ensure that the full target volume has been treated. The Parsons Chemical project was at the higher end of all these variables except processing depth.

Because of the large amount of electricity purchased, it is typically possible to obtain a negotiated project rate of approximately 1/2 the local residential rate. The price of electricity for ISV within the

U.S. typically falls in the range of $0.02/kwh (for large government applications) to $0.06/kwh. The price of power at the demonstration site totalled about $0.07/kwh. The 15-ft processing depth at the site is considered to be a good economical depth for ISV. Deeper processing depths are more economic than shallow depths because overall equipment utilization efficiency (time spent melting versus time spent moving equipment between melts) is greater for deeper depths. The amount of water that had to be removed at the demonstration site was considered to be extreme compared to typical sites. Whereas the process will operate on fully saturated soils, the energy and time-related costs associated with removal of water from the soil favors drier soil conditions. At the Parsons Chemical site, the saturated soil conditions, the ability of the high clay content soil to absorb water, and the probability that additional water entered the treatment zone from the sandy layer during the project, resulted in unusually high water removal requirements at this site. The soil moisture content and other properties also had the effect of producing melts with a higher width:depth ratio than was expected. This resulted in the necessity to overmelt, widthwise, into clean soil in order to allow additional time to reach the desired melt depth. Such overmelting has a significant cost impact. Geosafe believes that these factors contributed to the cost of this project being 10 to 20% higher than might be expected at more favorable sites. It should be noted that the Parsons Chemical site was Geosafe's first large-scale remediation project. A large number of improvements to the equipment and operating methods were made during and since the project with the effect of improving overall operating efficiencies. Geosafe's current cost estimate for ISV treatment of typical nonradioactive sites within the U.S. is in the range of $350-450/ton.

Lastly, Geosafe notes that the ISV technology has significant adaptability to varying site conditions. For example, modifications can be made to the off-gas treatment system to accommodate unusual contaminant conditions or specific State emissions standards as required. In addition, there is a broad range of application configurations that may be employed to most economically treat contaminated materials. The ISV technology may be a preferred technology for challenging sites due to its unique capabilities, including: 1) the ability to simultaneously treat mixtures of contaminant types, 2) high treatment efficiencies (contaminant destruction, removal, immobilization), 3) high volume reduction (25-50% for soils), and 4) onsite and in situ safety benefits.

REFERENCES

The reader is referred to the full suite of SITE Demonstration Program documents and the video for details regarding this demonstration. The reader is referred to Geosafe Corporation literature for details regarding other test, demonstration, and remediation projects that have been performed using the ISV technology.

FOR MORE INFORMATION:

Ms. Teri Richardson, Technical Project Manager
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7949

UNTERDRUCK-VERDAMPFER-BRUNNEN (UVB):
AN IN SITU SYSTEM FOR REMEDIATION OF CONTAMINATED AQUIFERS

Michelle A. Simon
US EPA
Risk Reduction Engineering Laboratory
Cincinnati, OH 45268
(513) 569-7469 (phone) (513) 569-7676 (fax)

Roger R. Argus and Benjamin L. Hough
PRC Environmental Management, Inc.
4065 Hancock Street, Suite 200
San Diego, CA 92110
(619) 225-1883 (phone) (619) 225-9985 (fax)

INTRODUCTION

Traditionally, contaminated groundwater is pumped to a surface facility for treatment, often by air stripping. An innovative technology, the Unterdruck-Verdampfer-Brunnen (UVB), German for Vacuum Vaporizing Well, is an in situ groundwater remediation technology that combines air-lift pumping and air stripping to clean aquifers contaminated with volatile compounds. Additionally, the developer claims that in some cases the technology is capable of simultaneous recovery of soil gas from the vadose zone. An evaluation of this process is discussed in this abstract.

A UVB system consists of a single well with two hydraulically separated screened intervals installed within a single permeable zone. The air-lift pumping occurs in response to reduced pressure introduced at the wellhead by a blower. This blower creates a vacuum that draws water into the well through the lower screen and the water rises toward the top of the well. A submersible pump ensures a flow rate of approximately 20 gallons per minute (1.26×10^{-3} meter^3 per second). Air stripping occurs as ambient air, also flowing in response to the vacuum, is introduced through a sieve plate located within the upper screened section of the well.

Air bubbles form in the water column causing volatile compounds to transfer from the aqueous to the gas phase. The rising air transports volatile compounds to the top of the well casing, where they are removed by the vacuum blower. The blower effluent is passed through granular activated carbon before being released to the atmosphere.

The transfer of volatile compounds is further enhanced by a stripping reactor located immediately above the sieve plate. The stripping reactor consists of a fluted and channelized column that facilitates the transfer of volatile compounds to the gas phase by increasing the contact time between the two phases and by minimizing the coalescence of air bubbles.

Once the upward stream of water leaves the stripping reactor, the water falls back through the well casing and returns to the aquifer through the