APPENDIX C
TECHNOLOGY EVALUATION MEMORANDUM, VEG/OIL BARK MULCH ENHANCEMENT (ORIGINALLY PRESENTED DURING THE SWMU B-3 REMOVAL ACTION, REGULATORY COMMUNICATION MEETING, JULY 22, 2002, CSSA, BOERNE TEXAS)

CSSA is considering a three-pronged approach to control and reduce contaminant migration into the underlying groundwater aquifer and toward possible receptors. As a initial step, buried debris and contaminated material present in the SWMU B-3 trench is scheduled for excavation and off-post disposal in August 2002, which should eliminate the largest continuous contaminant source from contributing further to the degradation of groundwater quality in the aquifer. The second step is intended to remove the bulk of the chlorinated solvent residuals remaining in the fractured media through soil vapor extraction (SVE). The third and final approach is designed to use an innovative, low cost, approach to produce or sustain a stable or decreasing contaminant plume in the associated groundwater by enhancing the biological attenuation characteristics within the plume. This enhancement will be attempted through a combination of fast acting and slow release carbon sources which will add the necessary substrate to enhance the natural biological degradation that is already occurring in the fractured bedrock and groundwater system. Natural rain recharge would provide the delivery mechanism to the fractures where the contamination has likely migrated.

Site Background

SWMU B-3 is a landfill area that is thought to have been primarily used for garbage disposal and burning trash. The trench areas were reportedly filled in 1990-1991. SWMU B-3 is located in the inner cantonment area northeast of the main compound, and southeast of Well 16. Several investigations have been performed to identify the extent of the trenches and to characterize the waste that is present.

Two large anomalous areas were identified by geophysical test methods in 1995. It was concluded that SWMU B-3 consists of two trench areas of unknown depths, and VOC contamination was present at the site. The trenches have been designated as the east and west (main) trenches. The trenches were reportedly created by taking advantage of the natural slope to the west and cutting into the weathered limestone to provide greater disposal volume. The main trench appears to be the deeper trench based on the grade of the surface limestone, extending to depths up to 18 feet below grade. The main trench was also the area identified by the soil gas survey to contain the highest potential levels of VOC contamination.

Proposed Actions

Excavation and off-post disposal has been selected as the remedial option to remove the bulk of the contaminant mass from the site by removing all buried material from SWMU B-3. This work is scheduled for August 2002.

SVE is proposed as the technology to remove the chlorinated solvent residuals from the unsaturated fractured media underlying the site. Treatability studies conducted in 1996 through 1997 and additional data collected in 2000 demonstrated that SVE could be operated effectively at the site. These studies also demonstrated unique capabilities of the SVE system to establish a large radius of influence through the highly fractured bedrock material, and capable of removing more than 2,000 pounds of VOCs per year.

Reductive dechlorination is the dominant biological mechanism for the degradation of TCE and PCE in groundwater. Common breakdown products from this reaction (cis-1,2-DCE) are encountered at high levels in soil gas collected from the SWMU B-3 SVE system and from groundwater samples collected from CSSA wells CS-Well D and CS-Well 16, providing a strong line of evidence that this reaction is occurring at least in the vadose zone near the buried materials. Availability of electron donor concentrations can limit the rate and extent of this dechlorination reaction. CSSA is planning to gather additional information from groundwater sampled at Well 16 and Well D to evaluate the amount of biological activity that may be present within the groundwater contaminant plume, and to assess whether there is sufficient assimilative capacity to effectively contain the contaminant levels encountered. CSSA is considering installing a system in the SWMU B-3 trench after excavation that would supply a continuing source of organic carbon into the groundwater recharge fractures and ultimately into the groundwater to further augment the biological attenuation processes that may already be occurring, rather than backfill the excavated trenches with soil and limiting infiltration.

The first step in enhancing the natural attenuation is to flush the system with lactate. Lactate has been shown in several studies to augment natural degradation. The open trench will be flooded with large amounts of lactate, allowing it to infiltrate rapidly through the substrata into the groundwater. This rapid infiltration will energize the system, providing a carbon source for aerobic bacteria, depressing the dissolved oxygen (D.O.) concentration and creating anaerobic conditions. Lactate was chosen for the initial flush because it is more mobile and bio-available than hydrophobic vegetable oil.

The second step is to backfill the trenches with organic mulch. Natural organic bio-walls have been used to treat groundwater contaminated with chlorinated solvents. The organic matter in mulch is slowly leached into the groundwater. Aerobic and denitrifying bacteria consume the organic matter, thereby further depressing the D.O. and oxygen-reduction potential. Once anaerobic conditions are created, the organic mulch ferments, releasing hydrogen. The hydrogen is then used to promote biological reductive dechlorination. Observations and measurements of water levels within the SWMU B-3 main trench indicate that water accumulates in the trench immediately following a rainfall event and continues to rise event after the rainfall event ceases. It appears that water continues to enter the trench through interflow through the shallow fractures from upslope drainage. This accumulation of precipitation should facilitate ideal circumstances for delivering low oxygen water with some dissolved carbon into the underlying fractures and ultimately into the aquifer.

The third step is the addition, or blending, of vegetable oil to the organic mulch. Vegetable oil has been used both as a primary and secondary treatment option for source zone removal of chlorinated solvents. The oil will be added to the mulch rather than directly to the fractured formation to avoid the possibility of blocking some of the smaller fractures. A secondary consideration for not delivering the vegetable oil emulsion to the fractured media is that it would possibly partition a large portion of the PCE and TCE that it comes in contact with in the fractures, thus making the PCE and TCE unavailable for removal by the SVE system. Blending the oil with the bark much creates a more appropriate delivery system for the vegetable oil because it has low solubility in water and therefore would be slowly released into the groundwater. Following addition of the vegetable oil, the site will be covered with a layer course gravel to protect the mulch, plus enable future additions of lactate, vegetable oil, or other amendments, as appropriate.

The initial addition of lactate as a quick acting carbon source flooding the site will add a quick pulse of energy into the system to provide the necessary activation energy for the degradation conditions to be achieved. The slower acting mulch and vegetable oil rely on rainwater infiltration to transport the carbon to the groundwater providing long term cost effective plume stabilization. CSSA does not anticipate that the addition of the carbon sources will be sufficient to treat much of the contamination throughout the fractured rock zone, particularly considering that operation of the SVE system will serve to pull atmospheric air back into the fractures after the water drains. Instead, this approach is intended to create an environment within the plume that will promote plume stabilization and reduce or stop the spread of the contamination through the groundwater.

To monitor the effectiveness of the treatment, historical contaminant trend data from Well 16 and Well D will be compared with data collected from the wells after the treatment is in place. The ratio of degradation products (cis-1,2-DCE, trans-1,2-DCE) and other indicator parameters before and after the treatment will be measured for all degradation products with historical data for comparison. In addition, any groundwater that accumulates in extraction wells could be tested qualitatively for PCE, TCE, breakdown products or any other evidence that the system is working as intended.

Summary

Although the specific combination of treatment technologies proposed here for the groundwater treatment has not been applied at other sites, each individual treatment technology has been shown to be effective. The specific combination of treatments proposed for SWMU B-3 was chosen to maximize potential effectiveness at CSSA, and to take advantage of the unique situation where it may be possible to actually deliver the amendments into the same groundwater recharge fractures that transported the bulk of the contaminants. The generally low contaminant levels (less than 1.0 ppm) within the plume and the location SWMU B-3 relative to the post boundary and off-post receptors provide time to enable this passive approach to be attempted. The following table provides a brief summary of sites where the individual remediation treatments have been applied.

Technology	Contaminant	Location	Synopsis	Results	Reference
Wood Mulch	Nitrate	Canada	Wood mulch, saw dust, and leaf compost has been used in subsurface reactive barriers to denitrify groundwater	60 to 90 percent reduction in nitrates	*Permeable Reactive Barriers: Case Study Review.* November 2001 Groundwater Remediation Technologies Analysis Center. www.gwrtac.org
Wood Mulch	PCE, TCE	Offutt AFB Nebraska	A mixture of wood mulch and sand was used as a permeable reactive biowall and additional organic matter was applied to the surface above the plume. Rainwater was the delivery mechanism to transport dissolved organic matter to the plume. In both the wall and the surface application, the organic matter ferments, producing hydrogen to stimulate reductive dechlorination.	Mean of 73 percent TCE removal over the 19-month test period. Vinyl chloride did not accumulate.	Mulch Biowall and Surface Amendment Pilot Test; Site Building 301, Offutt AFB Nebraska. Air Force Center for Environmental Excellence Technology Transfer Division, Brooks AFB
Vegetable Oil	TCE	Laboratory Bench scale	Soil and groundwater obtained from a TCE contaminated site in Florida were treated with vegetable oil. Transport, solubility and distribution were evaluated.	Studies showed oil effective slow release after the bulk of TCE removed by another method.	Sequestration and Degradation of TCE Following DNAPL Source Remediation. Battelle 2001
Vegetable oil	PCE, TCE	Cape Canaveral AFS Florida.	In a two phase study approximately 1,910 gallons of soybean oil was injected into the contaminated aquifer.	TCE showed a thirty-fold decrease in concentrations. DCE has similar results. An increase in vinyl chloride was seen.	In-Situ Bioremediation of Chlorinated solvents via vegetable oil injection at the hanger K site Cape Canaveral AFS Florida. Air Force Center for Environmental Excellence, Brooks AFB
Lactate	PCE, TCE	Watertown, Massachusetts	Groundwater recirculating cell with 3 each injection and extraction wells. Lactic acid used in anaerobic conditions as the carbon source	80 percent reduction of TCE in anaerobic phase. Site switched to aerobic phase and DEC and vinyl chloride decreased.	In Situ Bioremediation (Anaerobic/Aerobic) at Watertown, Massachusetts www.frtr.gov
Lactate	PCE, TCE, DCE	Dover AFB	Groundwater recirculating cell with 3 each injection and extraction wells. Lactic acid used in anaerobic conditions as the carbon source	75 percent TCE and 80 percent DCE removal	InSitu Bioremediation using Bioaugmentation at Area 6 of the Dover AFB. www.frtr.gov