APPENDIX A
QUICKLIME SOIL STABILIZATION
February 2, 2007

Mrs. Brandi Little  
Governmental Hazardous Waste Branch Land Division  
Alabama Department of Environmental Management  
P.O. Box 301463  
Montgomery, Alabama 36130-1463

Subject: Quicklime Soil Stabilization at Small Weapons Repair Shop, Parcel 66(7) at McClellan, Anniston, AL

Dear Mrs. Little,

On behalf of the Anniston-Calhoun County Fort McClellan Development Joint Powers Authority (JPA), Matrix Environmental Services, LLC (MES) has prepared this letter as a supplemental response to Alabama Department of Environmental Management’s (ADEM) Review Comments, dated September 1, 2006, on the Draft Corrective Measures Implementation Plan, Small Weapons Repair Shop (CMIP). Comment 1 requested reference material for the selected soil remediation technology of Quicklime Stabilization. The comment also requested information regarding the increase or decrease in the degradation of contamination and how vinyl chloride can be stabilized by adding anhydrous quicklime. The purpose of this memo is to respond to Comment 1 with technical references supporting remediation of volatile organic compounds (VOCs) in soil using quicklime technology. This memo presents a brief background of the Small Weapons Repair Shop site, and then examines two reference projects and one university-level research project where quicklime addition to soil was used to reduce VOC concentrations.

Site Description

The Small Weapons Repair Shop (Parcel 66(7)) consists of 1.15 acres and is located in the central portion of McClellan at the intersection of Waverly Road and Fremont Road. Two buildings (Buildings 335 and 336) are located within the Parcel 66(7) boundary. Building 335 formerly housed the Small Weapons Repair Shop where weapons used for training exercises were stored, disassembled, and cleaned using various solvents.

Nearly all of Parcel 66(7) and the area surrounding the parcel are covered with buildings, asphalt, or concrete pavement; only a narrow strip of ground along the northern and western boundary is covered with vegetation. A 6-foot-high chain-link fence surrounds Parcel 66(7) and the adjacent parking lot. Drainage ditches border the site along Waverly Road to the north and Fremont Road to the west.
**Soil**

The soil at Parcel 66(7) consists of silty clay to clay that ranges from strong brown to yellowish-brown. The runoff and the infiltration of this soil are considered medium. The permeability of this soil is low, and the capacity for available moisture and organic matter content are low.

The geologic data collected during previous environmental investigations show that the upper part of the residuum consists of brown to brownish-gray to yellowish-orange silty-clay and clay, with occasional intervals of highly weathered shale (MES 2006). This sequence extends from the ground surface to approximate depths of 10 to 13 feet below ground surface (bgs). Underlying this interval, and described as the lower portion of the residuum or transition zone, is a variable thickness of highly weathered light gray to black shale that extends to a maximum depth of approximately 30 feet bgs.

Competent bedrock underlying the transition zone consists of moderately hard, slightly weathered, fractured, dark gray to black shale. Some of the fractures in the shale are filled with quartz and/or dolomite.

**Distribution of Contaminants in Soil**

The maximum concentration of contaminants of concern (COCs) in shallow soil is found near the southwest corner of Building 335 (MES 2006). A soil sample from a depth of 0 to 1 feet contained vinyl chloride at a concentration of 2,300 micrograms per kilogram (ug/kg), which exceeds the groundskeeper site specific screening level (SSSL) of (1879 ug/kg). During the RCRA Facility Investigation (RFI), neither subsurface soil samples in this sample location nor adjacent surface or subsurface soil sample locations exceeded construction worker or groundskeeper SSSLs for COCs. This data indicates that the single soil exceedance is localized in the top 0 to 1 feet vertically and 5 feet horizontally (radially) about the soil sample location.

**Quicklime Soil Stabilization Technology**

Anhydrous calcium oxide (CaO), or quicklime, has routinely been used to enhance soil properties in various construction and agricultural applications (Barenberg 1982) and for immobilizing metals in soil (Siergrist 1994). The use of quicklime for the stabilization and treatment of organic contaminants in soil is a technology that is effective due to the reactive nature of quicklime. When water is added to quicklime, a hydration reaction occurs, resulting in the formation of calcium hydroxide (Ca(OH)₂) as shown in the following equation:

\[
CaO + H_2O \rightarrow Ca(OH)_2 + \text{heat}
\]

Hydration is an exothermic chemical reaction which releases energy in the form of heat. Adding quicklime to soil raises the temperature of the soil/quicklime mixture. Chemical constituent concentrations in the soil can be reduced by physical and chemical conditions affected by the hydration reaction. Quicklime has been used to treat soil contaminated with VOCs including chlorinated solvents, short chain carbon molecules, coal tar, petroleum sludge, and explosives (Davis 2007).

The following paragraphs briefly describe three investigations where quicklime was used to reduce chlorinated solvent concentrations in soil under conditions similar to those encountered at the Small Weapons Repair Shop site. The investigations include two
chlorinated solvent contaminated sites remediated using quicklime soil treatment to achieve cleanup goals and a university-level research project that investigated the chemical reaction resulting in chlorinated solvent contaminant reduction.

**Florida Department of Transportation (FDOT) Site, Fairbanks, Florida**

The Florida Department of Environmental Protection found that the addition of quicklime to contaminated soil greatly reduced organic contaminant concentrations.

![FDOT Bureau of Materials Research remediation site in Fairbanks, FL (Dean 2005).](image)

Figure 1 – FDOT Bureau of Materials Research remediation site in Fairbanks, FL (Dean 2005).
Fairbanks, Florida was the location of the FDOT Bureau of Materials Research field laboratory where tests were conducted to determine specification compliance of asphalt paving materials. During asphalt testing, solvents, including trichloroethylene (TCE) and 1,1,1-trichloroethane (TCA), were used to dissolve the asphalt. Wastes and residues from these tests were disposed onsite resulting in soil and groundwater contamination. Remediation of the known areas of contamination began in the mid-1990s; however, an additional source area was discovered in 1998. Dense Non-Aqueous Phase Liquid (DNAPL) was found approximately 35 feet below ground surface (bgs). Soil was excavated, processed, and stored in a lined pond for vacuum extraction. As soil became more clayey at 32 feet bgs, the trommel (cylindrical piece of construction equipment used to sort material by size) could not be used to screen the soil, and quicklime was added at a five percent quicklime to soil ratio to improve the soil handling properties. After adding quicklime, heat was generated from the exothermic hydration reaction. Following the chemical reaction, samples were collected and after analysis demonstrated COCs to be less than remediation target concentrations (Dean 2005). Quicklime stabilization was then used, instead of vacuum extraction, as a more economical remediation technology for the remainder of the contaminated soils. Confirmation soil samples verified the treatment goals had been achieved, and the treated soil was returned to the excavation to stabilize the slopes. Approximately 10,000 cubic yards (cy) of soil were treated with quicklime.

**University of Florida Bench-scale Study**

The success in the remediation of chlorinated solvent-contaminated soil at the FDOT Fairbanks project led the University of Florida to begin laboratory tests to determine the dominant mechanism of contaminant reduction during quicklime stabilization, evaluate the conditions and parameters that impact the treatment process, and assess the feasibility
of quicklime addition as a cost-effective, efficient and regulatory-permissible treatment technology.

The laboratory bench-scale research included two types of tests: batch tests and real-time tests. Batch tests considered the reaction of quicklime and VOCs in a closed system and provided a convenient method of comparing concentrations before and after the reaction. Real-time tests allowed a controlled air stream to flow through the system. These real-time experiments permitted the researchers to monitor the system to measure when the thermal treatment occurs.

Batch test experiments were conducted in special closed-system 100 milliliter (mL) vials, shown below. Vials contained 20 grams (g) sand, 1g-2g of water, and cis-dichloroethylene (cis-DCE) or TCE. Quicklime was then added and the reaction allowed to proceed.

Figure 3 – Diagram of 100mL vial used in bench scale tests (Townsend 2005).
Real-time experiments were conducted in 100mL vials similar to those used in the Batch experiments.

In the real-time tests, air was pumped through the vessels throughout the reaction to simulate an open system. Temperatures were also monitored throughout the experiments to measure the maximum temperature reached during the reaction. As can be seen in the University’s graphs below, the temperatures during the reaction varied with moisture content and the amount of quicklime added. The temperature peaked quickly, minutes after treatment. The maximum temperatures ranged from 50°C to 184°C in the selected mole ratios of quicklime to water.
Following the reactions, the chloride concentration in the water was measured and found to have increased in the larger ratios of quicklime-to-water in the samples collected from the 5% moisture content (MC) soil, and to have increased dramatically with the 10% MC soil, as shown in the University’s figures below.

University of Florida researchers concluded from their experiments that quicklime treatment decreases the concentration of chlorinated solvents in the soil and increases dissolved chloride concentration in the water within the system. They recommended further research to isolate specific reaction mechanisms and variables affecting degradation efficiency.

**Electrical Power Generating Station, Confidential Client, Indiana**

In 2003, quicklime was used to treat chlorinated solvent-contaminated soil at a previous project on the property of an Electrical Power Generating Station in Indiana. The Hazardous Materials Storage Building on the facility was used to store hazardous waste (chlorinated and non-chlorinated solvents), bulk virgin oils, and non-hazardous waste oils. The building’s defective sump allowed the solvents and oil to leach into the soil immediately beneath the building and the groundwater adjacent to the building. Because the footprint of the building was relatively small (24-feet by 35-feet) and the concentrations of chlorinated solvents (and degradation daughter products) were...
relatively low, quicklime stabilization was chosen as a more rapid and cost-effective alternative to a soil vapor extraction system.

A total of approximately 90 cy of contaminated soil was stabilized in place using hydraulic excavation equipment to blend quicklime at a ten percent quicklime to soil ratio. Treated material was analyzed for COCs and resulted in concentrations less than the method detection limit for each COC, as shown in the table below.

Table 1 – COCs in soil treated with quicklime (Earth Tech 2004).

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Sample Location</th>
<th>Date</th>
<th>1,1-Dichloroethane</th>
<th>1,1-Dichloroethene</th>
<th>Methylene chloride</th>
<th>Tetrachloroethene</th>
<th>1,1,1-Trichloroethane</th>
<th>1,1,2-Trichloroethane</th>
<th>Vinyl chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential RISC Standard</td>
<td>NA</td>
<td>NA</td>
<td>5600</td>
<td>58</td>
<td>23</td>
<td>58</td>
<td>1900</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>SW3-3 (Before Treatment)</td>
<td>Building Floor</td>
<td>4/03</td>
<td>25000</td>
<td>25000</td>
<td>125</td>
<td>600</td>
<td>2200000</td>
<td>120</td>
<td>7000</td>
</tr>
<tr>
<td>TREAT1  Treated Material</td>
<td>12/03</td>
<td>5.80 U</td>
<td>4.5 U</td>
<td>5.60 U</td>
<td>7.50 U</td>
<td>19.8 B</td>
<td>10.2 U</td>
<td>3.2 U</td>
<td></td>
</tr>
<tr>
<td>TREAT2  Treated Material</td>
<td>12/03</td>
<td>5.80 U</td>
<td>4.5 U</td>
<td>5.60 U</td>
<td>7.50 U</td>
<td>10.2 U</td>
<td>10.2 U</td>
<td>3.2 U</td>
<td></td>
</tr>
</tbody>
</table>

Table Notes:
- All values given in ug/kg
- NA - Not Applicable
- U - Compound not detected at given Method Detection Limit (MDL)
- B - Compound detected between the MDL and the Reporting Limit (RL)

As shown on Figure 9, the logarithmic degradation curve for COCs, all COCs decreased in concentration during the quicklime treatment process to concentrations less than their respective remediation target levels.
Figure 9 – Degradation curves for chlorinated solvents in soil at Indiana project (Earth Tech 2004).

Conclusion

Treatment of organic contaminants in soil using quicklime is an effective technology, and an increasing number of full-scale remediation projects and university-level research projects are leading to wider implementation and regulatory approval of this economic technology. In response to ADEM’s comments dated September 1, 2006, MES prepared this letter to demonstrate that quicklime has successfully been used to remediate chlorinated solvents in soil. If you have any further questions regarding this technology, please give either of the undersigned a call at 303.572.0200 at your convenience.

Sincerely,

MATRIX ENVIRONMENTAL SERVICES, LLC.

Julie A. Carver, PE   Wesley M. Dickinson, PE
Senior Project Manager   Project Engineer
Cc: Mrs. Tracy Strickland, ADEM
    Ms. Miki Schneider, JPA
    Ms. Lisa Holstein, U.S. Army
    Ms. Michelle Klomp
    Anniston Project File
    Denver Project File
References


