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Project Summary

Evaluation of Soil Washing Technology: Results of Bench-Scale Experiments on Petroleum-Fuels Contaminated Soils

Mary E. Loden

The U.S. Environmental Protection Agency (EPA) through its Risk Reduction Engineering Laboratory's Release Control Branch has undertaken research and development efforts to address the problem of leaking underground storage tanks (USTs). Under this effort, EPA is currently evaluating soil washing technology for cleaning soil contaminated by the release of petroleum products leaking from underground storage tanks.

The soil washing program evaluated the effectiveness of soil washing technology to remove petroleum products (unleaded gasoline, diesel/home heating fuel, and waste crankcase oil) from an EPA-developed synthetic soil matrix (SSM) and from actual site soils. Operating parameters such as contact time, washwater volume, rinsewater volume, washwater temperature, and effectiveness of additives were investigated. Further work was conducted to determine what effect, if any, additives have when added to washwater. The additives investigated were CitriKleen* (a biodegradable degreasing agent) and an organic surfactant. Actual soils from UST sites in Ohio and New Jersey were washed using the optimum parameters derived for the SSM.

The results of the optimization tests using SSM indicated that greater than 90% of petroleum products could be removed from the SSM. In experiments using actual site soils and the same washing conditions, contaminant removal was lower than it was for the SSM experiments. Although the SSM experiments achieved high removals, only 55% of the washed soil mass was recovered and a washwater containing over 20% solids was produced. The washwaters from the actual site soils experiments had less suspended solids, but it also removed fewer contaminants from the SSM.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Based on the Hazardous and Solid Waste Amendments of 1984 and its Land Ban Regulations, the EPA discourages the past practice of excavating contaminated soils from around leaking USTs and disposing of them in landfills. Although EPA has encouraged the use of on-site treatment technologies, problems have plagued the development of on-site technologies to treat petroleum-contaminated soils. Technical support is needed to develop effective long-term corrective actions at leaking UST sites, to design cleanup program guidance, and to help implement state programs.

The remedial options available for the treatment of contaminated soils from UST sites are broadly segregated into two main categories: those removing the contami-

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

nants without excavation (in situ techniques) and those requiring excavation of the soil and subsequent cleaning on site. The first remedial option has not yet demonstrated high efficiency removal of contaminants from the subsurface. These techniques are plagued by the uncertainty of soil contamination levels in the subsurface after treatment. Soil excavation followed by extensive cleaning of the soil will ensure a more complete removal of contaminants than will in situ techniques.

On-site soil washing of excavated soils is a viable alternative to in situ techniques and has been shown to be effective for cleaning hazardous-waste-contaminated soils. The goal of this effort is to determine the feasibility of soil washing for cleaning petroleum-contaminated soils.

Soil washing is a physical process in which excavated soils are contacted with a liquid medium, usually water. The two principle cleaning mechanisms are dissolving the contaminants into the extractive agent and/or dispersing the contaminants into the extraction phase in the form of particles (suspended or colloidal). Separating the highly contaminated fine soil particles (silts, clay, and colloidal) from the bulk of the soil matrix can reduce the volume of the bulk soil. As a result, a significant fraction of the contaminated soil is cleaned and can be put back into the original excavation. Because the contaminants are more concentrated in the fine soil fractions, their removal from the bulk soil increases the overall effectiveness. The spent wash waters and the fine soil fractions need subsequent treatment.

As part of this research program, a synthetic soil matrix (SSM) containing a range of petroleum products at varying concentrations was prepared and subjected to bench-scale performance evaluations of soil washing technology. Operating conditions derived from tests using SSM were used to evaluate soil washing technology on actual samples from leaking UST sites in Ohio and New Jersey.

Before preparing the quantities of SSM needed for the bench-scale tests, several bench-scale experiments were performed to develop a dose/response relationship between the quantity of petroleum product added to the SSM and the analysis quantification. The petroleum products evaluated during this study included unleaded gasoline, diesel oil, and waste crankcase oil. The SSM was then blended with a specific quantity of petroleum product to obtain a predetermined concentration level. The soils were analyzed for total petroleum hydrocarbons (TPH) to verify the concentration levels for diesel and waste oil, and for benzene, toluene, ethylbenzene, and xylenes (BTEX) to verify the concentration levels for gasoline.

The bench-scale washing experiments were designed to simulate the EPA-developed pilot-scale mobile soils washing system (MSWS). Specifically, the bench-scale experiments were designed to simulate the drum-screen washer that separates the >2-mm soil fraction (coarse material) from the <2-mm soil fraction (fines) by use of a rotary drum screen. A high-pressure water knife operates at the head of the system to break up soil lumps and strip the contaminants off the soil particles.

Synthetic Soil Matrix Characterization

The basic formula for the SSM was determined by others from an extensive review of Superfund sites and a review of the composition of eastern U.S. soils. The SSM was a mixture of clay, silt, sand, top soil, and gravel, prepared by others, in two 15,000-lb batches.

The existing soil characteristics were reviewed, and additional tests further delineated the physical and chemical properties of the SSM. The tests included particle size distribution, moisture retention, Atterberg limits, cation exchange capacity, base saturation, organic matter, chemical constituents, and mineralogy. Quantification and assessment of these specific properties will assist the technical community to understand the differences that may be observed between the performance of soil washing technology on the SSM and on actual UST site soils.

The test results indicated that the SSM is composed of 60% sand, 19% silt, and 21% clay as determined by particle size distribution analysis. This composition of the SSM would be classified (USDA) as a sandy clay loam texture.

The moisture content of the SSM ranged from 33.1% at saturation (0 bar) to 8.7% at the permanent wilting point (15 bars). The moisture content at field capacity (0.1 bar) was 21.0%. The moisture-retention curve developed from the moisture content data was indicative of a finer-textured soil. The moisture content data can be used to evaluate moisture and chemical characteristics of the SSM. For example, the amount of soil water that can be extracted from the SSM under typical environmental conditions (0 to 15 bars) will be 24.4%. The remaining soil water is considered "unavailable" and can only be removed by artificially induced vacuums or pressures.

Bench Scale Soil Washing Tests

The experiments involved washing the SSM spiked with gasoline, diesel fuel, or waste crankcase oil under several operating conditions to evaluate the sensitivity of various parameters affecting soil washing efficiency.

Approximately 1400 g of soil contacted varying amounts of washwater. The contact time was varied as was the rinsewater volume. The soil and washwater were shaken in a 2-gal jar in a shaker table operating with a stroke and frequency of 1.6 in. and 4 Hz, respectively. The soils were rinsed in a Gilson Wet-Vac Model WV-1, which both rinsed the soils and separated the particles into three fractions with the use of No. 10, No. 60, and No. 140 sieve trays. The process of washing and rinsing yielded five distinct fractions: the soils on the three sieve trays, a washwater, and a rinsewater. All fractions were measured for mass (or volume) as well as for contaminant concentration. A measure of total BTEX (benzene, toluene, ethylbenzene, and o-, m-, and p-xylenes) was used on gasoline-spiked soils, and total petroleum hydrocarbons (TPH) was used on diesel-spiked soils.

Preliminary screening tests on soils spiked with diesel and gasoline determined the optimum conditions for contact time, washwater volume, rinsewater volume, and washwater temperature. The full report lists the parameters tested and assesses how the parameter affected removal of TPH or BTEX from the soil and affected particle separation during the washing process. Most parameters had minimal effect on the removals and particle separation for the ranges tested. Increased contact time did somewhat improve the contaminant removal and particle separation. The addition of CitriKleen did not improve contaminant removal, and, in fact, actually decreased the removal. Increased temperature did not improve removals for soils washed with plain water but did improve removals somewhat for washwaters containing CitriKleen or surfactant.

The experiments indicated that the optimal washing conditions for SSM spiked with diesel or gasoline are: 20 to 30 min contact time, 1:1 soil to washwater mass ratio, 3:1 rinsewater to washwater volume ratio, and ambient temperature for the washwater. These conditions resulted in a 90+% removal of TPH and BTEX in the No. 10 and No. 60 sieve fractions. Note that these conditions represent the most cost-effective operating conditions for bench-scale treatment of SSM using soil-washing technology. Operating conditions for each site soil may vary and should be determined on a case-by-case basis.

Experiments were then conducted on site soils from four UST sites in Ohio and New Jersey. The results indicated that the removals in the 10- and 60-sieve fraction were significantly lower than the removals achieved for SSM. The site soils had a significantly different particle size distribution than did the SSM. The bench-scale soil washing apparatus recovered only 55% of the SSM mass after washing, and 45% was washed off into the washwater and rinsewater. Since the site soils contained lower amounts of fines (7% to 43% by weight for the four sites tested), greater amounts of soil were recovered from the washing process, which resulted in lower suspended solids in the washwaters.

Summary and Conclusions

The soil washing experiments involved washing the SSM spiked with gasoline, diesel fuel, or waste crankcase oil under several operating conditions to obtain sensitivity analyses on various parameters affecting soil washing efficiency including: contact time with washwater, washwater volume, washwater temperature, and chemical additives in the washwater such as a surfactant and a degreasing agent (CitriKleen). The SSM experiments yielded highly reproducible results. Since the soils were prepared in the SSM blending facility, the soil characteristics and contaminant content were homogeneous throughout the matrix. Experiments were also conducted using actual site soils, but due to the heterogeneity of these soils, the reproducibility of these experiments was much lower than for the SSM.

The results of the optimization tests using SSM indicated that greater than 90% of petroleum products could be removed from the SSM. As washing conditions were varied, however, no significant change in the removals could be detected for most parameters tested. The contact time in the wash cycle possibly affected the percent removal because of improved mechanical separation of the fines from the larger particles with more shaking time in the wash step. Increased volumes of washwater and rinsewater did not significantly improve contaminant removal. The use of additives such as CitriKleen and surfactant did not improve contaminant removal. Increased amounts of CitriKleen in the washwater decreased contaminant removal; this may be attributed to enhanced adsorption of contaminants to the soil because of the presence of CitriKleen adsorbed onto the matrix. Experiments using surfactant resulted in considerable foaming; this would lead to operational problems in pilot- or full-scale operation.

In experiments using actual site soils and the same washing conditions, contaminant removal was lower than it was for the SSM experiments. The washwaters for the actual site soils also contained much lower suspended solids than did the SSM washwaters. These results indicate that the primary mechanism for contaminant removal for the SSM was particle separation. Since this mechanism alone was able to account for a high percentage of contaminant removal, the experiments showed no significant improvement when conditions were varied. The only parameters that appeared to improve removals were those that would improve the particle separation in the soil matrix.

Although the SSM experiments achieved high removals, only 55% of the washed soil mass was recovered and a washwater containing over 20% solids was produced. The washwaters from the actual site soils experiments had less suspended solids, but it also removed fewer contaminants from the soil matrix. Therefore, to effectively remove contaminants from soils containing a small fraction of fine materials, the solubilization mechanism would need enhancement. The resultant washwaters would also contain lower suspended solids. Future work to evaluate enhancement of the solubilization mechanism in soil washing is recommended.

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Mary E. Loden is with Camp Dresser & McKee Inc., Cambridge, MA 02142.
Chi-Yuan Fan is the EPA Project Officer (see below).
The complete report, entitled "Evaluating of Soil Washing Technology," (Order No. PB91-206 599/AS; Cost: $23.00 subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Edison, NJ 08837

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