Innovative Application of Environmental Technologies Simplifies Soil Remediation at Training Ranges

David Hill, National Guard Bureau; Katherine Weeks, Mike Warminsky, Mark Applebee, AMEC Earth and Environmental, Inc.

Introduction

In March 2000, the Army National Guard Bureau (NGB) initiated an Innovative Technology Evaluation Program (ITE) to identify and evaluate promising technologies to remediate explosives-contaminated soil at the Camp Edwards Impact Area and Training Ranges on the Massachusetts Military Reservation (MMR). The NGB expects that lessons learned from this program will have applicability to similar armed services training installations, where artillery target practice and other live fire range operations have been conducted.

Historic live fire training at Camp Edwards resulted in the deposition of spent munitions, explosive, and propellant compounds in soils at several locations. Resulting contaminants of concern, including hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), and 2,4,6-trinitrotoluene (TNT), are typically present in particulate form and are widely dispersed in low concentrations in the soil.

In developing recommendations for the first phase of the ITE program, the NGB assembled a review team, including the Army Corps of Engineers (ACE), the Army Environmental Center (AEC), and AMEC Earth and Environmental, Inc. (AMEC). The team developed selection criteria by which to assess potential remediation technologies and provided recommendations of technologies to participate in the treatability studies. The major criteria included: experience with treatment in soils, experience with treatment of explosives compounds, level of clean-up achieved, and time frame to complete remediation. Soil cleanup goals for the ITE studies were conservatively established at 120 μg/kg for RDX, 250 μg/kg for HMX, and 250 μg/kg for TNT. The technologies selected to perform laboratory studies in this first phase were:

- Soil Washing – Brice Environmental Services Corporation (Brice),
- Low Temperature Thermal Desorption/Destruction (LTTD) - TerraTherm Inc.,
- Composting - BSI Environmental, Inc. (BSI),
- Bioslurry – Envirogen, Inc.,
- Solid Phase Bioremediation - Grace Canada, Inc. (Grace),
- Chemical Reduction - Brice, working with University of Nebraska-Lincoln (UNL), and
- Chemical Oxidation - Brice / UNL.

Soil Washing as a First Step

The studies incorporated experience with a soil washing technology already demonstrated at Camp Edwards by Brice as part of other remedial activities. In soil washing, the fraction of the soil containing the contaminants of concern is isolated and segregated from the remaining clean soil, reducing the volume of soil requiring remediation. Because innovative technologies may be implemented as a secondary treatment after soil washing, studies were performed for all technologies using washed soil. Composting, bioslurry, solid phase bioremediation, and LTTD studies were also performed on untreated soils.

After the soil washing process, explosives contamination was particularly hard to find in the washed soils. This difficulty may point to an unexpected benefit - that soil washing as a stand-alone process may be sufficient for remediating explosives-contaminated soils. During soil washing lab and field studies, a significant proportion of explosive contaminants was contained in the process water and organic matter. This finding led the ITE Team to two hypotheses. First, due to attrition of soil materials during the wet sieving subprocesses, the weathered explosives particulates may break into smaller pieces, and dissolve more quickly due to the freshly created surfaces. Second, the explosives could be adsorbed to the organic matter during soil washing. Optimization of the soil process could result in a volume reduction of 95% to 98%. (Is this a range or a 3% reduction?)

This reduction may be possible by increasing the residence time of fine soils in the slurry phase and then treating all process water through a sand/carbon filter system before recycling the water into the plant operations. The addition of a hydrocyclone, a form of separator taking advantage of different densities of material, may be more effective in separating COCs from soil grains than the current system components of clarifiers and sieve separators.

<u>Overview of the Treatability Studies</u>

A major difficulty in the ITE studies was finding consistently contaminated soil to study. Using uniformly contaminated soil was critical to obtain consistent results from each process testing the unwashed soils. As a result of military training, explosives are heterogeneously dispersed in low concentrations? Areas with contaminated soil were initially identified by sampling, however, once the soil was collected, subsequent sampling yielded varying concentrations. Five separate soil sampling operations occurred before appropriately contaminated soil was found. The samples were then provided to each vendor and tested under observation by the ITE Team members.

TerraTherm tested a proprietary LTTD process on both washed and unwashed soil by slowly heating soil to between 200° and 300°C for a minimum of 24 hours.

BSI tested composting technology on both the washed and unwashed soils by adding 70% organic matter, including various forms of manure, cranberry mash, and wood chips to 30% soil and analyzing RDX and HMX degradation over a period of 45 days.

Envirogen tested a bioslurry process on unwashed soil by adding 0.3% molasses to a slurry of 30% soil and 70% water in a study that lasted 35 days. Molasses provides a substrate for naturally occurring microorganisms to grow and consume contaminants of interest.

Grace performed treatability studies on both washed and unwashed soil by adding a 2% application of DARAMEND®, along with as 0.2% powdered iron, and then adding more of each once per week, over a study period of 50 days. The proprietary DARAMEND® amendment, derived from plant material, works to provide a substrate for naturally occurring microorganisms to grow and consume contaminants of interest.

Brice/UNL tested chemical reduction on washed soils only, by adding 5% zerovalent iron (ZVI) in the form of iron filings, acetic acid, and aluminum sulfate solution to washed soils in a mixture maintained at 60% solids and 40% water in a study period lasting 5 days. They also tested chemical oxidation by adding Fenton's Reagent (hydrogen peroxide and ferrous sulfate) in concentrations of between 1% and 4% hydrogen peroxide to a 7% soil slurry to oxidize contaminants, taking less than 1 day for each test.

Results and Conclusions

Results of the studies indicated that all technologies are likely to be effective on washed soils except chemical oxidation. LTTD and bioslurry also showed promise on untreated soil. Composting and solid phase bioremediation experienced difficulties in degrading RDX and HMX in the untreated soils, likely due to the presence of weathered particulate explosives. The presence of weathered particulate explosives appears to be a critical factor in the remediation of ranges.

Technology	Effective on Washed Soil	Effective on Unwashed Soil
Soil Washing	NA	Yes
LTTD	Yes	Yes
Composting	Yes	No
Bioslurry	Yes	Yes
Solid Phase Bioremediation	Yes	No
Chemical Reduction	Yes	Unknown
Chemical Oxidation	No	Unknown

The presence of weathered particulates had a significant effect on the results of several studies, as can be seen in the graph of composting results. This figure shows the average and median concentrations of RDX over time, using the composting study results as an example of the phenomenon. Significant differences in RDX concentrations at a given time can be seen when looking at the average concentrations. Conversely, the median concentration, which shows the concentration for the sample that lies in the middle of the range of samples, usually shows a smoother trend. The use of the median concentration provides one measure of the overall success of the technology. However, the technology must be able to treat explosives in all forms, including the particulate form, and therefore it is important to see the impact of the particulates on the outcomes of the studies. For this reason, both average and median degradation curves are presented.

In conclusion, the heterogeneous, weathered, and particulate nature of explosives in soils made it a challenge to find contaminated soil, evaluate results, and then fairly compare the effectiveness of the different technologies. Bioslurry and LTTD appear to be able to remediate untreated soils containing explosives compounds. However, one of the clear winners is the soil washing process, which reduces soil volumes requiring further remediation by 75 to 95%. Once the soils are processed, all technologies except chemical oxidation were then able to degrade or destroy the explosives contaminants in the soil. The ITE Team is continuing to evaluate these technologies and extrapolate the lessons into remediation successes.