INNOVATIVE TECHNOLOGY EVALUATION PROGRAM ,CAMP EDWARDS, MASSACHUSETTS: PART 1 – SOIL TREATABILITY STUDIES

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ABSTRACT

Live fire training activity dating from around 1941 to 1997 resulted in the deposition of spent munitions, propellants, and explosives in impact area soils at the Camp Edwards Training Ranges on the Massachusetts Military Reservation (MMR). Resulting contaminants of concern, including RDX, HMX, TNT, and 2,4-DNT are found in particulate form and are heterogeneously dispersed in the soil. An Innovative Technology Evaluation Program (ITE) was initiated by the Army National Guard in March 2000 to investigate the potential for remediation of these soils.

Remediation technologies chosen for the ITE program to address this problem included: soil washing, low temperature thermal destruction (LTTD), composting, solid phase bioremediation, bioslurry, chemical oxidation, and chemical reduction. The soil washing process was shown in field trials to reduce the volume of soil requiring further treatment by 75%. All technologies were effective on soils that had been treated using soil washing. LTTD, solid phase bioremediation, and bioslurry were effective on untreated soil, while composting was less effective, and chemical reduction and oxidation were not tested on untreated soils.

1. INTRODUCTION

Target practice and other range training operations have historically occurred at Camp Edwards. Such activities were conducted sporadically the 1930s, but increased substantially starting in 1941. In 1997 the US Environmental Protection Agency (USEPA) issued an Administrative Order to cease live fire training based on detections of explosives such as hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) in the drinking water aquifer underlying the base.

The live fire training activity resulted in wide dispersion of low concentrations of spent munitions, propellants, explosives, and heavy metals in particulate form at Camp Edwards. Residual explosives then migrated to the groundwater, approximately 100 feet below ground surface. To support protection of the groundwater, the National Guard Bureau (NGB) instituted the ITE program to study technologies that might meet the requirements for remediating soil and groundwater at the site. Successful innovative soil remediation technologies were defined as those technologies that can meet USEPA requirements to address remediation of the identified areas of concern.

In developing recommendations for ITE studies, the NGB assembled an ITE review team, including NGB, the Army Corps of Engineers (ACE), the Army Environmental Center (AEC), and AMEC Earth and Environmental, Inc. (AMEC) as the supervising contractor. The team assessed remediation technologies for participation in the treatability studies. Soil cleanup goals established for the treatability studies included RDX (120 μg/kg), HMX (250 μg/kg), TNT (250 μg/kg), Lead (300 mg/kg), and Dieldrin (246 μg/kg).

The technologies chosen for the ITE program were: chemical oxidation, chemical reduction, thermal desorption/destruction (LTTD), bioslurry, composting, and solid phase bioremediation.

2. SOIL WASHING PRE-TREATMENT

The team incorporated experience with a soil washing technology already demonstrated on the site as part of a Rapid Response Action. In soil washing, the fraction of the soil containing the contaminants of concern can be isolated and segregated from the remaining clean soil.

This physical process involves the following steps: physical sizing, density separation, classification/attrition, magnetic separation, and water treatment/dewatering. Physical sizing isolates soil fraction containing heavy metals for subsequent density treatment from "clean" soil fractions. Magnetic separation recovers ordnance fragments and other ferrous material. Density separation recovers particulate metal. Classification/attrition partitions the residual organic or sorbed contaminants from the larger soil grains into the organic matter and/or fine soil fraction for subsequent remediation using physical, chemical, or biological processes. Fines and humic material can be removed during the dewatering part of treatment or using a hydrocyclone as a form of density separation.

Because soil washing may be implemented at Camp Edwards, it was determined that washed soil would be used in the ITE studies. Therefore, the studies were performed both on washed soil and on untreated soil collected directly from the site.

3. LABORATORY TREATABILITY STUDIES

In preparing for chemical oxidation and reduction studies, it was determined that these processes would be performed on washed soils only, as part of an overall treatment design to include soil washing as the first treatment step. One chemical reduction study was designed to simulate the reductive treatment of soil as a separate follow-on treatment after the soil washing process. This was done by adding 5% zerovalent iron (ZVI) (mass:mass) in the form of iron filings, acetic acid, and aluminum sulfate solution to washed soils in a mixture of 60% solids and 40% liquid for 5 days. A second study was designed to simulate reductive treatment within the soil washing process, in a slurry of approximately 7% solids. The slurry was agitated for 4 hours, dewatered, and incubated for 5 days.

Chemical oxidation was studied by adding 1% to 4% hydrogen peroxide with ferrous sulfate as a catalyst (Fenton's Reagent) to a 7% solids slurry to simulate oxidization of contaminants during the soil washing process. The slurry was agitated for four hours and then air-dried..

A proprietary LTTD process was tested on both washed and unwashed soil. LTTD involves slowly heating soil to between 200° and 300°C, and holding for a minimum of 24 hours at the elevated temperature. These temperatures were chosen to bracket the temperatures at thermal processes would degrade or vaporize explosives compounds, for example HMX melts at 285ºC and TNT boils at 240ºC.

The bioslurry process was tested on washed and unwashed soils. Molasses was added at a ratio of 0.3% (mass:mass) to a slurry of 30% soil and 70% water. Two studies were performed during the study period of 35 days, one where slurry was constantly stirred at a low speed, and one where the slurry was intermittently stirred. Intermittent stirring may facilitate anaerobic conditions, which are preferred for RDX and HMX degradation.

Composting was also tested on both the washed and unwashed soils. Each of 12 reactors contained approximately 30% soil and 70% organic matter, including various forms of locally available manure, cranberry mash, and wood chips, and were maintained at treatment temperatures for 12 to 45 days.

Solid phase bioremediation studies were performed on both washed and unwashed soil. Two separate forms of the proprietary DARAMEND® treatment were tested. In addition, powdered iron was added to the soil to control the redox potential. An initial 2% application of DARAMEND® was added to the soil, as well as 0.2% powdered iron. Weekly amendments of 0.5% DARAMEND® and 0.2% powdered iron were then added to the soil during the 50-day test period.

4. RESULTS AND CONCLUSIONS OF LABORATORY SCALE STUDIES

Several findings were observed during the course of the studies. First, the heterogeneous distribution of the explosives residues of RDX and HMX at this site resulted in soil concentrations ranging up to five orders of magnitude difference within duplicate samples. This heterogeneous distribution affected conclusions drawn after review of the analytical results.

Second, the explosive contaminants RDX and HMX do not adsorb onto the sandy soil grains at Camp Edwards. After soil washing, a significant proportion of explosive contaminants was co-located with the process water and organic matter. Therefore the initial soils available for the study contained lower concentrations of explosives than expected. However, this finding may further support the use of soil washing as a treatment process in that the vast majority of the explosive contaminants may be removed from the mineral soil particles and isolated into the organic matter and process water.

Third, in previous studies, 95 – 99% of fresh RDX has been shown to be extracted using 18-hour sonication in acetonitrile, but only 85 – 90% of weathered RDX was extracted using the same technique. This may have implications for the time required for dissolution of weathered RDX into water, which affect analytical results. However, it has even broader impact on the design of soil sampling procedures for sites containing weathered explosives, and on remediation processes that will be effective on these soils, as will become apparent in the results of these studies.

Washed soils. In general, all studies on washed soils showed reductions of RDX and HMX, there being no detectable or low concentrations in the initial samples. Figures 1 and 2 show results for the chemical oxidation and reduction studies, both of which were performed using the washed soil. Chemical oxidation did not reduce explosives concentrations below soil cleanup goals. Therefore no further study of this process was made. Chemical reduction was shown to be effective in reducing the RDX concentrations to below soil cleanup goals. Results suggest that the iron plus aluminum sulfate treatment in a post-soil washing treatment regime was the most effective and yielded results below soil cleanup goals for explosive compounds.

Untreated soils. The studies on unwashed soils showed varying success in reducing RDX concentrations. Figures 3, 4, 5, and 6 display results for LTTD, bioslurry, solid phase bioremediation, and composting. The following summarizes the results.

- LTTD was effective in degrading explosive compounds in soil below soil cleanup goals when temperatures of 250°C or more were applied, as expected. The lower temperature of 200°C was ineffective in destroying HMX.
- Bioslurry was effective in degrading explosive compounds to concentrations below the soil cleanup in the intermittently stirred reactors, but not in the constantly stirred reactors.
- Composting was effective in achieving soil cleanup goals for HMX but not RDX.
- Solid phase bioremediation was effective in degrading explosive compounds below soil cleanup goals in one of two similar unwashed soil tests.

As noted previously, the heterogeneous and particulate nature of explosives in soils had implications on data evaluation and comparison of laboratory studies. The average concentration can be greatly influenced by the existence of particulates, especially in smaller data sets, and is not necessarily representative of overall contamination of the soil. For example, if the average concentration alone is used as a measure of success, composting and solid phase bioremediation do not successfully degrade RDX. Therefore, the median concentration is also provided in the figures to give a balanced view of the effectiveness of the technology in treating explosives-contaminated soil. The median concentration is an indicator 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 shown.

Subcontractors were requested to focus on reduction and/or destruction of explosive contaminants. Other contaminants were described but not emphasized, including metals and pesticides. Chemical reduction and LTTD were found to be reasonably likely to achieve the RRA soil cleanup goals for dieldrin. LTTD was also found to achieve these goals for the remaining organic COCs. Metals were not treated by any technology tested.

5. RECOMMENDATIONS FOR FIELD DEMONSTRATIONS

Evaluation of the laboratory treatability studies for soil remediation was completed in October, 2001. Recommendations for field-scale demonstrations were made for chemical reduction as secondary treatment after soil washing, biodegradation using either bioslurry or solid phase bioremediation as a secondary treatment after soil washing, and LTTD as either a stand-alone process or secondary after soil washing. Implementation of LTTD will also require review by the Department of Defense's Explosives Safety Board.

a) NGB is currently in the process of developing designs and cost estimates for field demonstrations of these technologies, as well as evaluating the work required to support the field demonstration.

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FIGURES

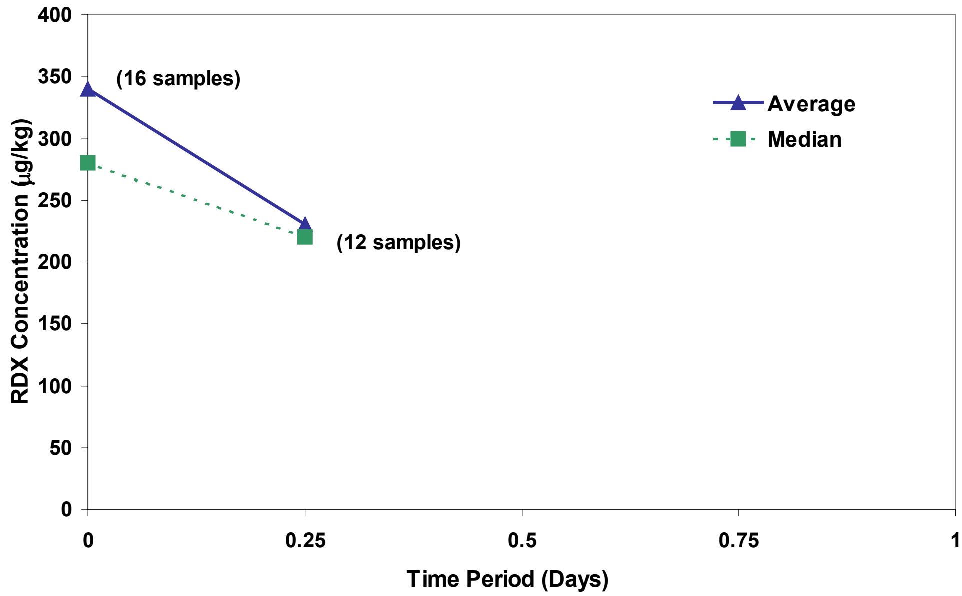

Figure 1. Chemical oxidation results, washed soils - Brice/UNL

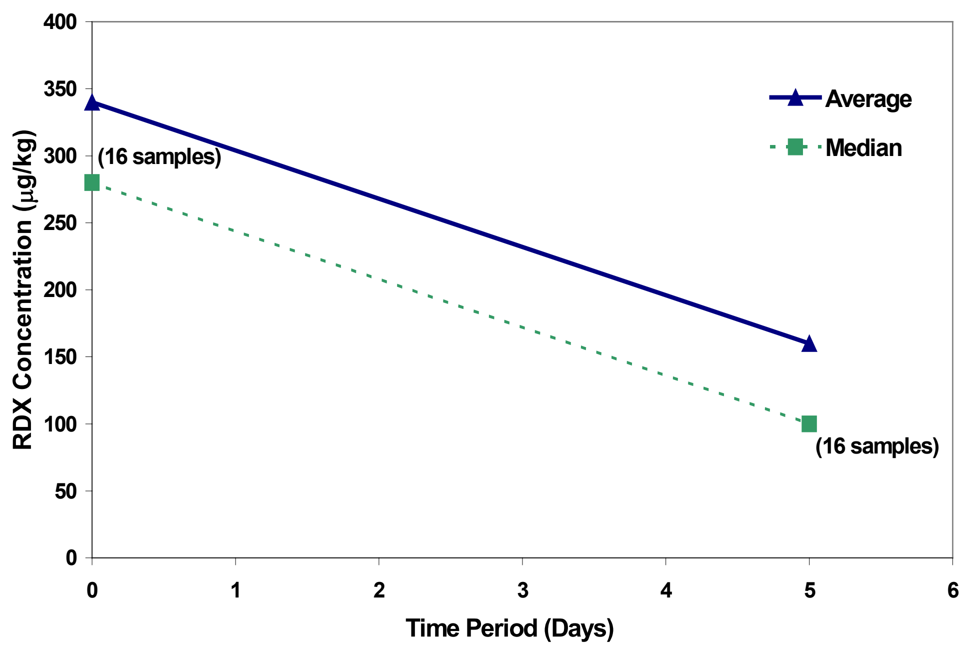

Figure 2. Chemical reduction results washed soils - Brice/UNL

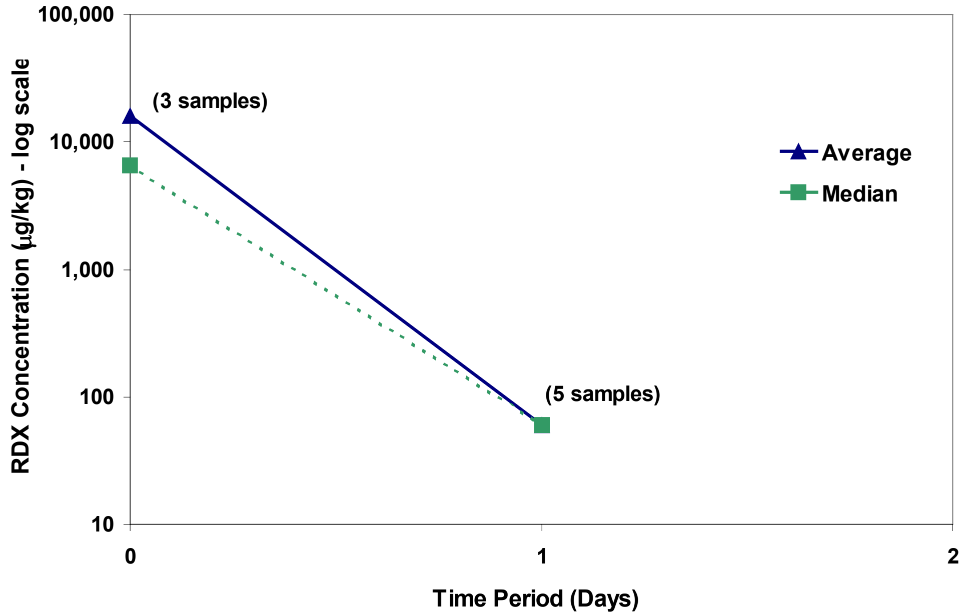

Figure 3. Low temperature thermal destruction, untreated (unwashed) soils - TerraTherm

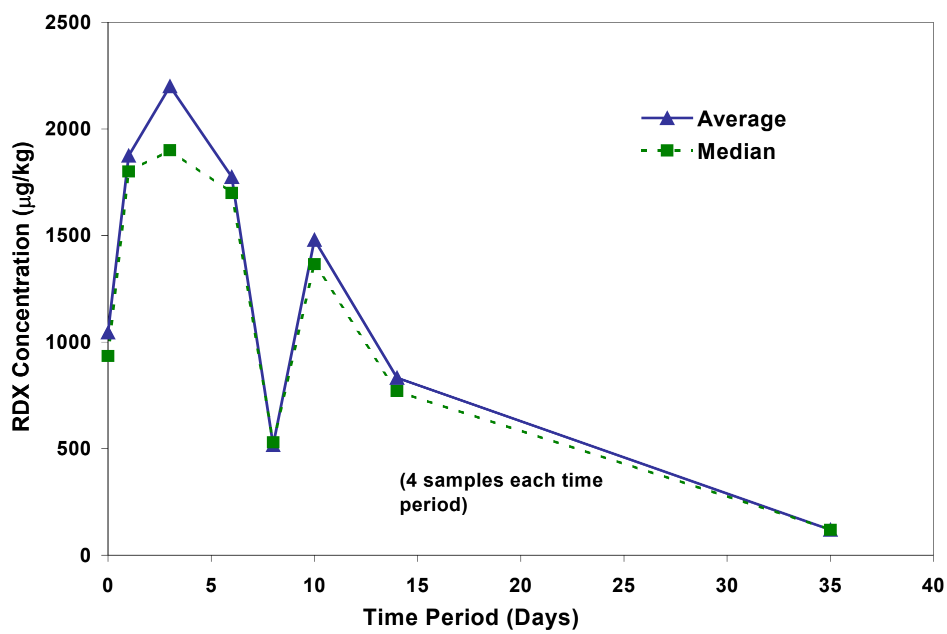

Figure 4. Bioslurry results, intermittent stirring, unwashed (untreated) soils - Envirogen

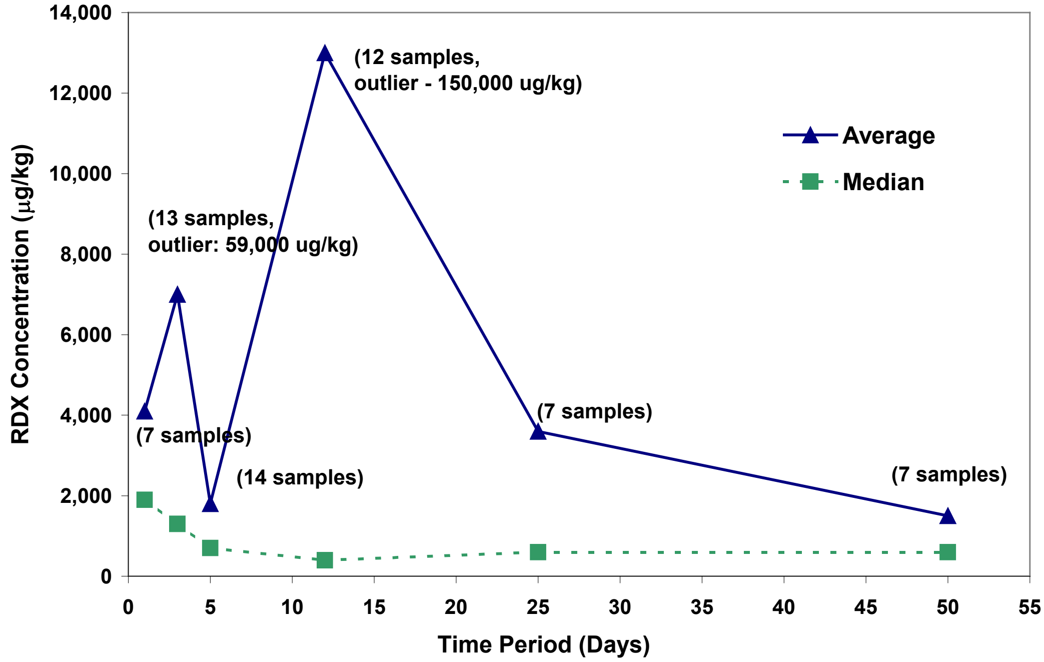

Figure 5. Composting results, untreated (unwashed) soils- BSI

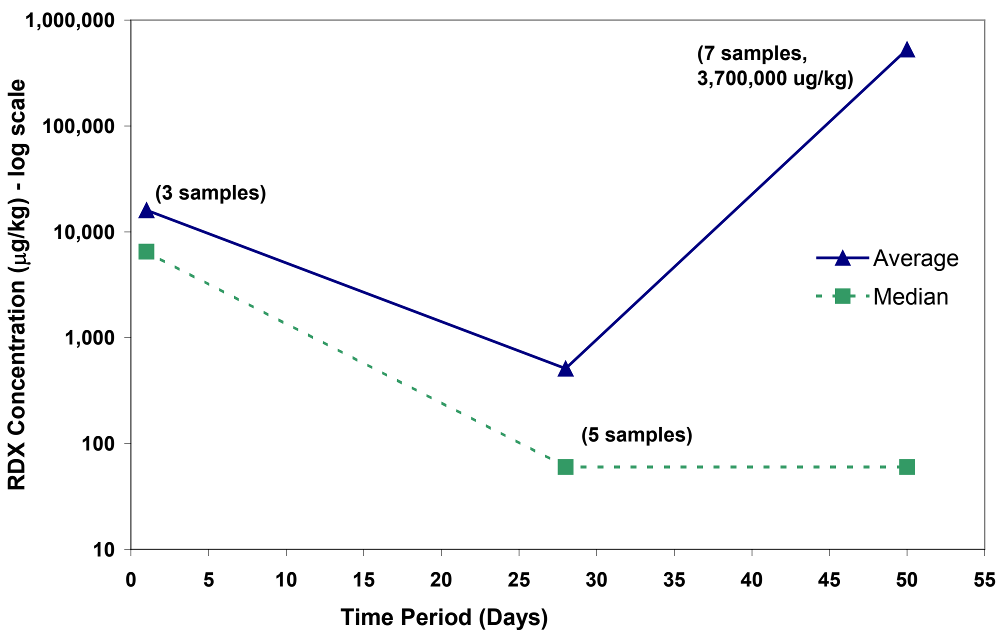

Figure 6. Solid phase bioremediation results, untreated (unwashed) soils - Grace Canada