Neozymes® - **NONTOX™.**

SOIL REMEDIATION CASE STUDY

Petroleum Contaminated Soils Management

INTRODUCTION

Information in this report was adapted from a report originally prepared by Metcalf & Eddy (M&E). It summarises the recent work performed by M&E at Beale air force Base (Beale AAFB). Beale AFB is located ten miles east of Marysville, California. It was first used as a U.S. Army Base (Camp Beale) and then a U.S. Air Force Base. During its fifty years of operation, approximately 1,000 underground storage tanks (USTs) were installed for residential, office and industrial fuel storage as well as aircraft fuel storage. As part of the Air Force's installation restoration program, Beale has initiated a UST site closure program to cleanup and achieve closure of the 1,100 UST sites.

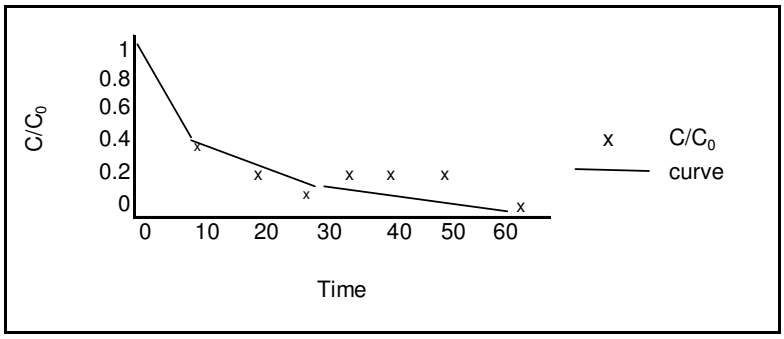
Under contract with the Air force Centre for Environmental excellence (AFCEE), M&E was tasked with the underground storage tank (UST) removal and remediation of soil at Beale AFB. Since the program's inception in 1993, the Beale UST Closure Program has steadily grown to include nearly all of the 1,100 UST sites, with an estimated 50,000 cubic yards of petroleum hydrocarbon (TPH) contaminated soil.

EVALUATION OF SOIL AMENDMENTS TO OPTIMISE CELL OPERATION

To determine the most rapid and effective means for treating the TPH impacted soil, an optimisation study was performed from June 13, 1995 to August 10, 1995. The purpose of the study was to determine the relative effects that different soil amendments have on the ex-situ degradation rate of TPH. The study consisted of seven test cells, each with 2 cubic yards of TPH impacted soil. Six of the test cells were enhanced with soil amendments 1) fertiliser (15-15-15 (N:P:K)); 2) compost; 3) Neozyme's NONTOX bio-organic catalyst; 4) an enzyme solution; and 5 & 6) two microbial inoculants. No amendments were mixed with the seventh test cell, which served as a control.

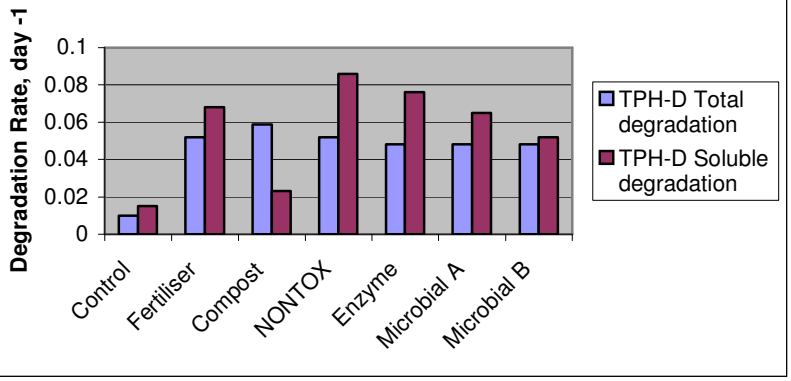
The treatability study was designed to determine differences between the ex-situ biodegradation of water soluble (mobile) diesel range petroleum hydrocarbon contamination (TPH – D) and total TPH-D soil contamination. Soluble TPH-D was determined by performing the State of California Waste Extraction Test (Cal-WET) using a deionised water extract, with no filtering. Total TPH-D concentrations were determined using EPA methods 8015/8020 for soil. Figure 1 shows an example decay curve for the fertiliser amendment test cell. Note that the curve follows first order decay kinetics of the form: $C/C_0 = e^{-kt}$ where, C = concentration at time; C_0 = initial concentration; k = degradation rate; and t = time. First order decay kinetics were also observed for the other test plots, with the exception of the control cell.

FIGURE 1: EXAMPLE DECAY CURVE FOR THE FERTILISER ADDITIVE TEST PLOT, BEALE AFB



A summary of first order degradation rates, with 95% confidence intervals, is shown in Figure 2 for each of the test cells. Degradation rates shown in Figure 2 may be converted to half lives using the following equation: Half Life = -0.693/(degradation rate) (2).

Figure 2. Degradation Rate Summary

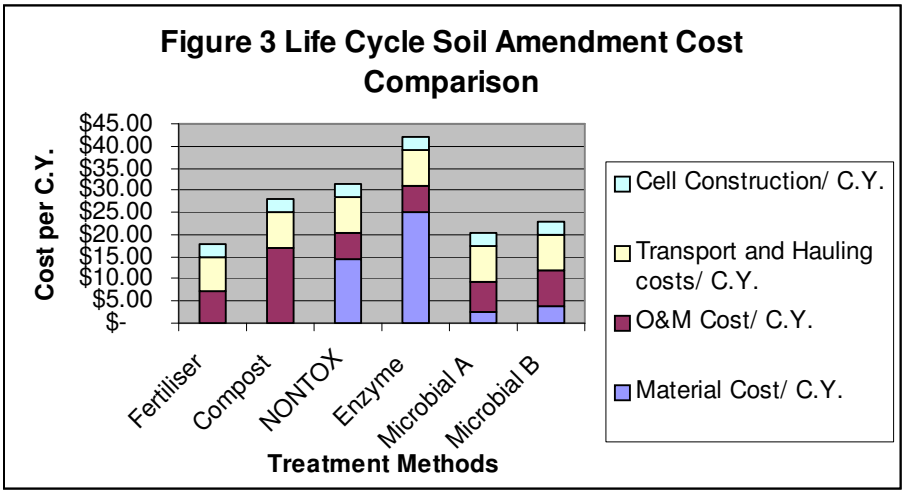


The following major conclusions can be drawn from Figure 2:

- Degradation rates for total TPH-D were statistically indistinguishable for all non-control test cells, ranging from 0.04/day to 0.06/day (12 to 17 day half lives). The control cell revealed a negligible degradation rate.
- Degradation rates for soluble TPH-D ranged from 0.03/day to 0.09/day for the non-control test cells (8 to 23 half lives). Soil treated with NONTOX had the highest degradation rate. NONTOX and the enzyme additive appeared to preferentially degrade soluble TPH-D over total TPH-D. Decay constants ranged from 0.08/day to 0.09/day for soluble TPH-D (8 to 9 day half life). In comparison, total TPH-D degradation rates were observed at 0.05/day (14 day half live). Statistical analysis verified with 95 % certainty that the NONTOX enzyme treatment degraded the soluble fraction of TPH-D more rapidly than the total TPH-D. The role of volatilisation of TPH-D was not evaluated in this study.

- The compost additive test cell revealed low degradation of the soluble TPH-D (0.03/day), yet showed more aggressive degradation of the total TPH-D (k = 0.06/day). Using the degradation rates shown on Figure 2, along with regulatory agency imposed cleanup levels of TPH-D (total) ≤ 500mg/kg and TPH-D (DI-WET) ≤ 5 mg/l, the following treatment times were estimated for the Beale AFB full scale 3,100 mg/kg, and unfiltered DI-WET concentration of 72 mg/l.
    - Fertiliser 40 days per batch
    - Compost 102 days per batch
    - NONTOX 31 days per batch
    - Enzyme 35 days per batch
    - Microbe A 40 days per batch
    - Microbe B 57 days per batch

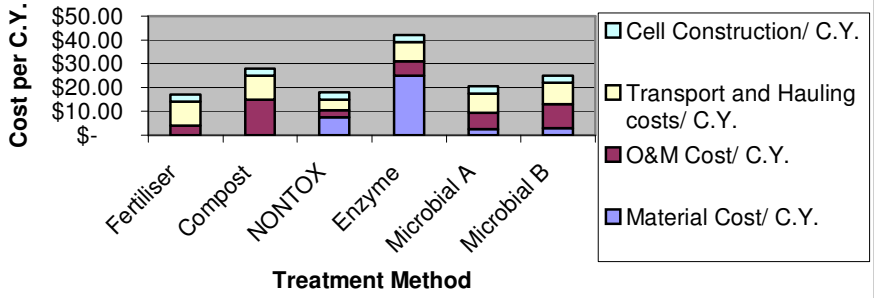
Thus, the NONTOX treatment option would appear to be the most effective additive for the full-scale treatment cell operation on the basis of the most rapid treatment time. However, the cost of the NONTOX treatment option was greater than the cost of fertiliser per cubic yard of soil. Figure 3 is a presentation of Metcalf & Eddy's original cost analysis for each of the treatments evaluated. The estimated cost for remediating soil to regulatory agency guidelines (500ppm TPH) was about $18.00 per cubic yard for fertiliser as compared to $32.00 per cubic yard for NONTOX.



A review of cost calculations revealed that the actual cost of remediation with NONTOX would be significantly lower than originally determined. First, the price of NONTOX used in Materials Cost calculations was 25% higher than current retail price. Second, due to new regulatory guidelines based on risk assessment, removal of soluble TPH instead of total TPH levels will be used to determine regulatory thresholds for site remediation. By re-evaluating costs based on the time to remediate the soluble fraction, the NONTOX Operation and Maintenance (O&M) costs are significantly reduced. Revaluated costs are presented in Figure 4. The cost to remediate the soluble fraction using NONTOX treatment was reduced to $18.00 per cubic yard. A

subsequent study has confirmed the cost of NONTOX treatment can be reduced to no greater than the fertiliser treatment option.

Figure 4 Revised Cost Comparison Based on Soluble Fraction



SUMMARY AND RECOMMENDATIONS

NONTOX preferentially degraded the soluble fractions of petroleum hydrocarbon contamination over non-soluble fractions. This result was verified with 95% confidence. Considering that the soluble fraction is the more mobile fraction and should be of highest concern to the regulatory community, the potential for using NONTOX in the future is high, if the material cost of NONTOX can be economical when compared to fertiliser amendments. Subsequent tests summarised in Section VI confirm that NONTOX treatment can be reduced to a cost comparable to fertiliser.