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SITE Technology Capsule

J.R. Simplot Ex-Situ Bioremediation Technology: Dinoseb

Abstract

The J.R. Simplot Ex-Situ Bioremediation Technology is designed to anaerobically degrade nitroaromatic and energetic compounds in soils and liquids without forming identifiable toxic intermediate compounds produced by other biotreatment methods. This technology was evaluated under the Superfund Innovative Technology Evaluation (SITE) Program on soils contaminated with 2-*sec*-butyl-4,6-dinitrophenol (dinoseb), a RCRA-listed herbicide (P020). The Demonstration was at a county-owned airport in Ellensburg, WA (Bowers Field). A companion SITE Demonstration of this technology was performed on 2,4,6-trinitrotoluene (TNT). Another SITE Technology Capsule will be provided at a later date. The Best Demonstrated Available Technology (BDAT) for dinoseb-contaminated soils is incineration, therefore, any alternative technology that can economically compete with incineration is of interest.

Comparison of the dinoseb levels before and after treatment showed a reduction of greater than 99.8% based on the analytical instrumentation detection limit. The time of treatment for 30 m^3 (39 yd^3) of soil was found to be 23 days, much faster than initially anticipated. This is despite the average temperature within the bioreactor being 18˚C, far below the preferred temperature range of 35 to 37˚C *(1)*. Other compounds, namely nitroaniline; parathion; malathion; and 4,4'-DDT were incidentally and simultaneously reduced from parts-per-million levels in the feed soil to below the analytical detection limit in the treated slurry. No toxic by-products caused by the degradation of dinoseb were found by GC/MS analysis of the post-treatment samples.

Introduction

This Capsule provides information on the J.R. Simplot Ex-Situ Bioremediation Technology, a technology developed to remove nitroaromatic and energetic compounds from soils and liquids. For the purpose of this Capsule, the technology was evaluated on dinoseb-contaminated soil. For more information on the SITE Program please referto the "SITE Program" section of this Capsule. The J.R. Simplot Ex-Situ Bioremediation Technology for the degradation of dinoseb was evaluated under EPA's SITE Program during June and July 1993 at Bowers Field. Soils at Bowers Field were previously contaminated with dinoseb, probably by crop dusting activities. Information in this Capsule emphasizes specific site characteristics and results of the SITE demonstration at Bowers Field. Results obtained independently by the J.R. Simplot Company (Simplot) during treatability studies are summarized in the Technology Status section. This Capsule presents the following information:

- Technology Description
- Technology Applicability
- Technology Limitations
- Process Residuals
- Site Requirements
- Performance Data
- Economic Analysis
- Technology Status
- SITE Program
- Source of Further Information

The J.R. Simplot Ex-Situ Bioremediation Technology was evaluated based on seven criteria used for decision-making in the Superfund Feasibility Study (FS) process. Results of the evaluation are summarized in Table 1.

Technology Description

The J.R. Simplot Company has developed a simple bioenhancement procedure that treats soil contaminated with nitroaromatic compounds by the addition of naturally selected anaerobic soil microorganisms. These microorganisms were originally isolated from this site. The Simplot process is initiated under aerobic conditions, but anaerobic conditions are quickly achieved under designed parameters, thus enabling the microbes to degrade the nitroaromatic contaminants.

At Bowers Field, the contaminated soil was augmented with 0.02 m^3 (a 5-gallon pail) of Bowers Field site soil that was previously remediated by the Simplot process during treatability

Table 1. *Evaluation Criteria for the J.R. Simplot Ex-Situ Bioremediation Technology: Dinoseb*

Criteria						
Overall Protection of Human Health & the Environment	*Compliance with Federal ARARs*	*Long-Term Effectiveness*	*Short-Term Effectivenes*	*Reduction of Toxicity, Mobility, or Volume through Treatment*	*Implementability*	*Cost*
Provides both short- and long-term protection by eliminating exposure and permanently destroying contaminants in soil. *Prevents groundwater contamination and off-site migration.* *Require measures to protect workers and community during excavation, handling, and treatment.*	*Requires compliance with RCRA treatment, storage, and land disposal regulations (for hazardous waste).* *Excavation, construction, and operation of onsite treatment unit may require compliance with location-specific ARARs.* *Emission controls are needed to ensure compliance with air quality standards if volatile compounds are present.*	*Permanently destroys contamination and intermediates.* *Provides reduction in contamination levels; duration of treatment determines final contaminant levels.*	*Presents potential short-term risks to workers and nearby community, including exposure to noise and contaminants released into the air during excavation and handling. These can be minimized with correct handling procedures and borders.*	*Reduces toxicity and mobility of soil contaminants.* *Does not leave known toxic intermediate compounds as a result of biodegradation when operated properly. Could leave intermediates if terminated prematurely.* *If not fully dried, increases volume of treatment material by addition of water to create slurry.*	*Major equipment is limited to bioreactor and agitation/suspension devices.* *Support equipment includes earthmoving equipment (for excavation, screening, and loading of bioreactor) and monitoring equipment (for recording pH, redox potential, and temperature).* *Once onsite, the small portable bioreactor can be assembled and ready to load within two days. The time to excavate pits for use as bioreactors is determined by the volume of contaminated soil. The larger modular bioreactor requires approximately four days for erection. After excavation, bioreactor loading activities (soil and water) are a function of the treatment volume.* *After treatment is complete, the small bioreactor can be emptied and demobilized in three days. Treated soil can be placed in the excavated area and used as fill material. For lined pits and erected bioreactors, the integrity of the liner can be intentionally breached when treatment is complete, and the liner abandoned in place.*	*$127/m^3 ($97/yd^3) for treatment in four lined pits utilized as bioreactors and a total treatment volume of 3,824 m^3 (5,000yd^3) of soil. This estimated cost is based on a 30-day batch treatment time. For longer treatment times, the treatment costs will increase.* *Actual cost of a remediation technology is highly specific and dependent upon the volume of soil, soil characteristics, contaminants present, and the original and target cleanup levels.* *Depending on site characteristics, an additional cost of up to $131/m^3 (100/yd^3) may be assessed to the client by the developer.*

studies. This previously treated soil contained the necessary microorganisms to biologically degrade dinoseb. Previous laboratory results have indicated that this augmentation may enhance the degradation rates. In cases where the microorganisms are not present in the contaminated soil, the volume of inoculation can be increased. To date, the minimum number of required microorganisms to initiate the process has not been determined.

The Simplot technology utilized a portable tank as the bioreactor during the Demonstration Test because of the small volume of test soil. In applications where larger volumes of soil are treated, in-ground lined pits, or erected lined tanks each capable of remediating 956 m^3 (1,250 yd^3) of soil may be used. The bioreactor used for these tests was a steel tank mounted on wheels. It was 12.2 m long, 2.4 m wide, and 2.6 m tall (40 ft x 8 ft x 8.5 ft) which approximates to 75,700 L (20,000 gal). Water was first placed in the bioreactor and then soil was added in a ratio of approximately 1 L of water to 1 kg of soil. Nutrients (a J.R. Simplot Company potato-processing starch by-product) and pH-regulating agents (buffers) were added to induce the aerobic microorganisms to consume oxygen from the soil. The characteristics of the potato-processing starch byproduct include the following: 42% solids; 215 mg of available starch per gram; 6.7 mg of total nitrogen per gram; 2.6 x 10^4 culturable heterotrophic bacteria per gram; and 8 x 10^3 culturable amylolytic bacteria per gram. The addition of the nutrients and pH-regulating agents lowered the redox potential (E_h) and created anaerobic conditions. Anaerobic conditions with E_h less than -200 mV promote the establishment of anaerobic microorganisms capable of degrading dinoseb and other nitroaromatic compounds.

Figure 1 shows the Simplot process flow diagram. Initially, the excavated test soil was sent through a vibrating screen to remove large rocks and other debris >12.7 mm (1/2") diameter. Since dinoseb is water-soluble, the rocks and debris larger than 12.7 mm diameter at the Bowers Field site were rinsed with water to remove dinoseb contamination from the surface. The rinse water was combined with make-up water and placed in the bioreactor. Enough make-up water was added until the bioreactor contained an amount of water sufficient to provide the 1-L to 1-kg ratio required to form a suitable treatment slurry. A phosphate buffer was added to the system to control the pH to 7 to 7.5. Batches of soil and the J.R. Simplot potato-processing starch by-product were mixed together in a pug mill (homogenization unit) and added to the bioreactor until all of the treatment soil was in the bioreactor. The bioreactor was sized so that it was approximately 75% full when loaded.

The bioreactor was loosely covered and equipped with two mixers with 1.1 m (44") diameter blades rotating at 37 rpm for agitation at each end of the bioreactor. A high speed mixer with 0.36 m (14") diameter blades rotating at 450 rpm was placed in the center of the bioreactor and used only during loading of the soil into the bioreactor. “Dead spots” occurred in the bioreactor due to insufficient mixing of the slurry by the agitators. Therefore, lancing of the bioreactor was performed. This was accomplished by placing the suction end of a diaphragm pump into the settled sediment and pumping it into a well-mixed region of the bioreactor. The bioreactor was equipped with instrumentation to monitor pH, temperature, and redox potential. Optimum operating conditions are 35 to 37˚C, pH below 8 (ideally between 7 and 7.5 for dinoseb degradation), and redox potential <-200 mV *(1)*.

Technology Applicability

The technology is a stand-alone technology that can be used to destroy nitroaromatic compounds without the presence of identifiable toxic intermediate compounds in contaminated soils at the completion of treatment. If the soils contain rocks or debris greater than approximately 38 mm (1.5") in diameter, the technology may be used with a rock/soil washing system. In some cases the rocks can be crushed to the required diameter and added to the bioreactor for remediation. Results from the Demonstration Test showed that in addition to reducing the levels of dinoseb to below the analytical detection limit, similar effects were found on a variety of pesticides, namely 4,4'-DDT; malathion; parathion; and nitroaniline. However, these results are based on less rigorous data. There appeared to be no degradation of atrazine, chlordane, or endosulfan in these 23 days at thest conditions. During treatability studies, dinoseb levels of 800 mg/kg were successfully reduced to below the analytical detection limit.

Simplot claims that any soil type can be treated, providing the soil is thoroughly mixed with the carbon source (potato byproduct). The soil type used during the Demonstration Test was a clayey sand with gravel. The soil itself need not contain the microorganisms required to degrade the dinoseb, since the bioreactor can be inoculated with the appropriate microorganisms. These microorganisms can be obtained from previous site remediations or treatability studies.

Technology Limitations

This technology is claimed to be suitable for a variety of soil types that are contaminated with nitroaromatic compounds. However, if the soil contains rocks or debris greater than 38.1 mm (1.5") diameter, the contaminants need to be removed from these large particles by a separate technology or can be crushed to the required diameter and remediated in the bioreactor.

The presence of heavy metals in the feed soil does not adversely affect the process. As this technology is a sulfate reducing process, toxic metals in the feed soil such as cadmium, lead, etc. are converted to their sulfide forms, making them in nocuous. Simplot claims that this technology is less susceptible to the effects of the toxic metals than most bioremediation systems. If total hydrocarbons are found in the soil at concentrations greater than 1,000 mg/kg Total Recoverable Petroleum Hydrocarbons (TRPH), this may be toxic to the particular microorganisms degrading dinoseb. However, the hydrocarbons can be removed from the soil using the cloud-point separation technique prior to bioremediation. This technique incorporates the addition of a surfactant/water solution to the waste. Heat aids the separation of the organic phase from the aqueous phase, and gravity aids the separation of the solid phase. After separation from the soil the hydrocarbons will contain a portion of the dinoseb and must be sent to a RCRA-permitted facility for disposal. Although previous laboratory results indicate that optimum degradation occurs at higher temperatures *(1)*, this demonstration showed that the operating temperature could be lowered and degradation could still be performed. However, degradation rates can be restricted if freezing conditions exist. This problem can be

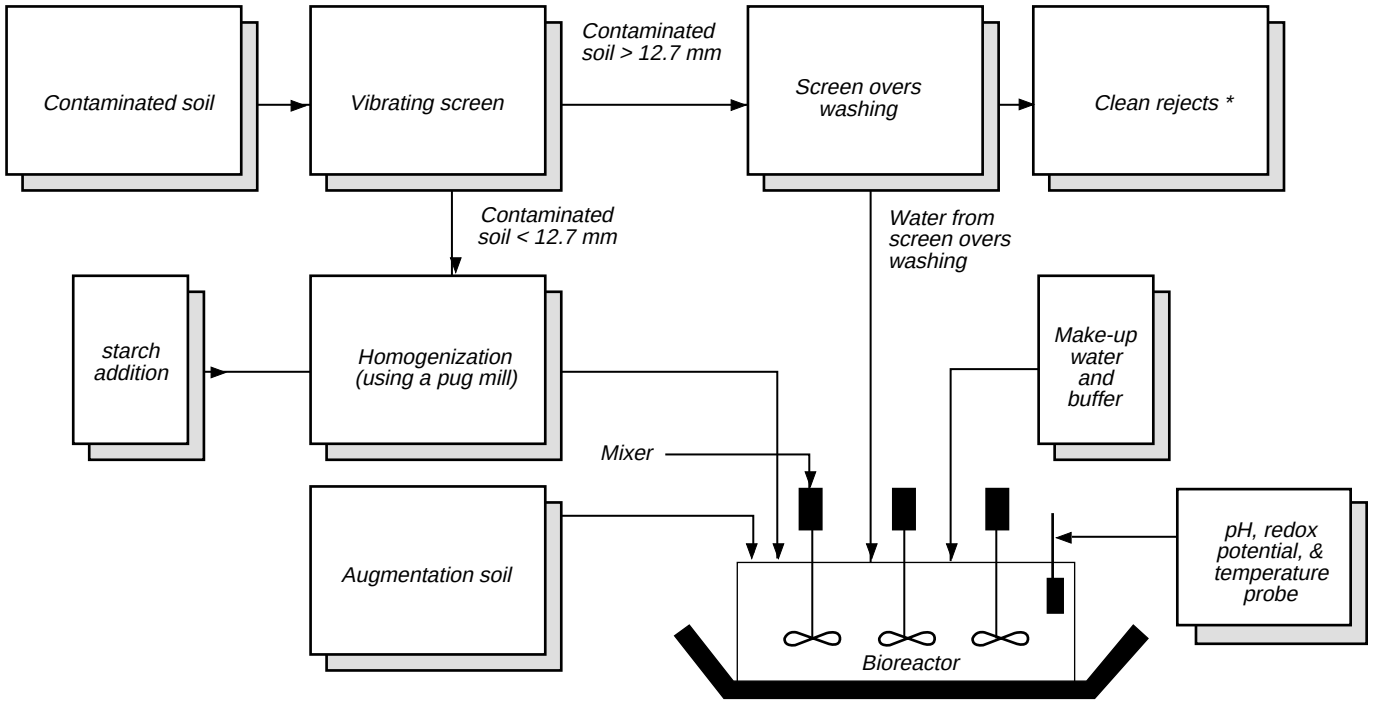

Figure 1. *J.R. Simplot process flow diagram for the bioremediation of Dinoseb-contaminated soil during the demonstration test.*

overcome by adding heaters to the system, but at an additional cost to the remediation.

Process Residuals

Three process residuals are generated by the Simplot ex-situ bioremediation process. These are the treated soil, wastewater, and the washed rocks and debris with diameters greater than 12.7 mm (1/2"). Prior to the Demonstration Test at Bowers Field, the Washington Department of Ecology (WADOE) established a clean-up level at which the soil no longer presented a hazard to human health, and therefore, would no longer be considered hazardous. After treatment in the bioreactor at Bowers Field, the dinoseb concentrations in the treated soil and liquid were below the analytical detection limits. The treated soil could then be replaced within the excavated area and used as fill material. In states where clean-up levels have not been established or when the clean-up levels are not met, then disposal of the soil at a RCRA-permitted facility may be necessary. If nitroaromatic compounds other than dinoseb are remediated disposal of the soil at a RCRA-permitted facility is required only if the compound is a listed waste or has hazardous waste characteristics.

Water is used to wash the dinoseb from the separated rocks and debris. This rinse water is then added to the bioreactor with the make-up water to be remediated by the process. After treatment in the bioreactor at Bowers Field, the dinoseb concentrations in the water were below the analytical detection limit. Thus, the wastewater could be disposed through the local sewer system.

The third waste stream, the untreated but washed rocks and debris, may present a disposal problem. However, since dinoseb is highly water soluble, it was assumed that the washing process transferred the dinoseb from the rocks to the rinse water. The decontaminated rocks and debris could then be replaced into the excavated area as fill material. In the case where the nitroaromatic compound is not water soluble, the contamination needs to be transferred from the oversized fraction to the smaller grain sizes or the oversize rocks and debris may require disposal at a RCRA-permitted facility.

Site Requirements

The site requirements for the Simplot technology are a function of the quantity of soil to be treated. If 30 m^3 (39 yd^3) or less of soil is to be remediated, a small 75,700-L (20,000-gal) portable bioreactor can be used. If the site contains greater than 30 m^3 of contaminated soil, one or more excavated lined pits, or one or more erected lined bioreactors can be used. Equipment requirements are limited to front-end loaders, backhoes, and dump-trucks for excavation of lined pits, a vibrating screen (or other size-separating device), conveyors, and, if needed, a rock or soil washing system. The bioreactor requires a form of slight agitation to occasionally “turn over” the soil in the slurry. Equipment to measure the pH, temperature, and redox potential is also necessary to monitor the treatment process.

The time required to excavate, screen, and homogenize the soil with the potato starch prior to forming the slurry in the bioreactor is a function of the soil type, moisture content, and soil volume. In the future, Simplot anticipates homogenizing the potato starch with the water in the bioreactor prior to soil addition. Once the bioreactor has been filled and the monitoring equipment is in place, maintenance requirements are minimal. Access roads are needed for equipment and office trailer transportation. After the treatment is completed, the small, portable bioreactor can be emptied, agitation equipment removed, and all equipment shipped offsite within three days. For the case of the lined pits and large modular bioreactors, upon the completion of treatment, the integrity of the liner base

can be breached and the liner abandoned in place. The walls of the erected tank can be removed and shipped to the next remediation project.

If the contaminated soil contains volatile organic compounds (VOCs), then some form of cover equipped with a VOC collection device (carbon adsorber or biofilter) is required during the excavation phase of treatment. The soil stockpiled after excavation should be wetted and covered with plastic to minimize airborne emissions.

Utility requirements for this technology include water and electricity. Approximately 29,000 L (7,650 gal) of water was needed to treat 30 m^3 (39 yd^3) of soil. An electrical circuit is required to power the agitators, screening, and homogenization equipment. The current required is a function of the size of the equipment, which in turn depends on the size of the site.

Performance Data

The Simplot technology was evaluated to determine its effectiveness in degrading dinoseb in soil without forming any toxic intermediate compounds known from other bioremediation processes. The critical objective for this project was to determine the percent reduction of dinoseb based on the concentration of the pre-treatment slurry on a dry basis and the post-treatment slurry on a dry basis. Other noncritical objectives for this evaluation were:

- to determine if the reduction of dinoseb was a result of the bioremediation process;
- to determine the presence of any known intermediate compounds in the soil before and after treatment;
- to obtain information on other pesticides and herbicides in the soil before and after treatment; and
- to develop operating costs.

Sufficient material was excavated and screened to provide 30 m^3 (39 yd^3) of contaminated soil to feed into the bioreactor. Prior to homogenizing the feed soil with the potato starch, 61 primary samples were taken of the feed to determine the average dinoseb concentration. Each of these primary samples was a composite of 4 grab samples taken while the soil was being fed to the homogenization unit. In the same manner, except that composites were made up of 12 grab samples, aliquots were taken for the analysis of metals, pesticides, and chlorinated herbicides. Three grain size distribution and Atterberg limits samples were taken directly from the stockpiled feed soil. These samples were taken to identify the soil type being remediated. A total of 29,000 L (7,650 gal) of potable water was added to the bioreactor before introducing the soil. This water was sampled and analyzed for the chemical parameters specified above. Approximately 570 L (150 gal) of water from the rock- and debris-washing process was sampled and added to the bioreactor.

Samples were also taken of the feed soil to undergo toxicity testing (earthworm reproduction, early seedling growth, and root elongation). It was anticipated that the toxicity tests could be performed on the pre- and post-treatment soils to determine if the formation of intermediate compounds had caused the relative toxicity of the soil to increase because of the degradation of dinoseb. However, it was found that the presence of pesticides and herbicides other than dinoseb already in the soil would negate the relevance of these analyses. To determine if the relative toxicity increases because of this process, toxicity testing was performed during the TNT SITE demonstration. Its decrease in toxicity is reported in the associated Capsule.

Monitored parameters during remediation were pH, temperature, and redox potential. Measurements of these parameters were taken every 15 sec and recorded by a data logger.

During the course of remediation, anaerobic conditions (E_h <-200 mV) were achieved in three days and the pH stabilized at 7.1, as shown on Figure 2. However due to the unusually cool summer experienced in the Pacific Northwest during 1993, the average temperature in the bioreactor was less than 18°C. This was lower than the preferred bioreactor temperature range of 35 to 37°C *(1)*. It was anticipated, based on treatability studies, that treatment time would be on the order of six weeks. Therefore, after 23 days (an anticipated mid-point) samples were obtained to determine the progress of the remediation. Analysis of these mid-point samples indicated that the dinoseb had been completely degraded. Full post-treatment sampling of the bioreactor was then initiated.

A total of 39 primary post-treatment slurry samples were collected throughout the bioreactor. These samples were analyzed for dinoseb. Six primary samples were taken for pesticides and chlorinated herbicide analysis.

The average concentration of dinoseb in the feed soil, on a dry basis, was 27.3 mg/kg with a range of 14.0 to 34.2 mg/kg. The 95% confidence interval for this average was 26.4 to 28.3 mg/kg. No dinoseb was found in the post-treatment slurry samples. Upon arrival in the laboratory, the slurry samples were phase separated and the solid and liquid phases analyzed separately. The analytical method used for the analysis of dinoseb was a high performance liquid chromatography (HPLC) method developed specifically for this demonstration *(2)*. This method gave analytical detection limits of 0.015 mg/L for the liquid samples and 0.03 mg/kg for the solid samples. An extraction study was performed for this compound on soil from Bowers Field and showed excellent recoveries. This extraction study is detailed in the companion Technology Evaluation Report (TER). Based on the average pre-treatment soil concentration and the analytical detection limit for the post-treatment samples, the percent reduction of dinoseb in the bioreactor was >99.8%, on a dry basis.

Another outcome of the HPLC analysis for the pre-treatment soil and post-treatment slurry was that no known intermediate compounds from the degradation of dinoseb were found. To investigate this further, gas chromatography/mass spectrometry (GC/MS) scans were run on selected pre- and post-treatment samples. These analyses confirmed that no compounds had been formed during remediation as identified by these analytical methods.

Nitroaniline was found in the feed soil at an average concentration of 13.3 mg/kg. This compound was also degraded to below its analytical detection limit in the post-treatment slurry samples (0.75 mg/kg and 0.75 mg/L), thus, leading to a reduction of >88.6%. Other pesticides such as 4,4'-DDT; malathion; and parathion were reduced from parts-per-million levels to below their analytical detection limits (0.75 mg/kg and 0.75 mg/L). The process had no effect on atrazine, chlordane (alpha, gamma, and technical), and endosulfan (I and II).

Metals concentrations in the pre-treatment soils were at levels generally found in natural soils and were not thought to be toxic to the microorganisms. The metals concentrations were not expected to change due to remediation and therefore post-treatment samples were not analyzed.

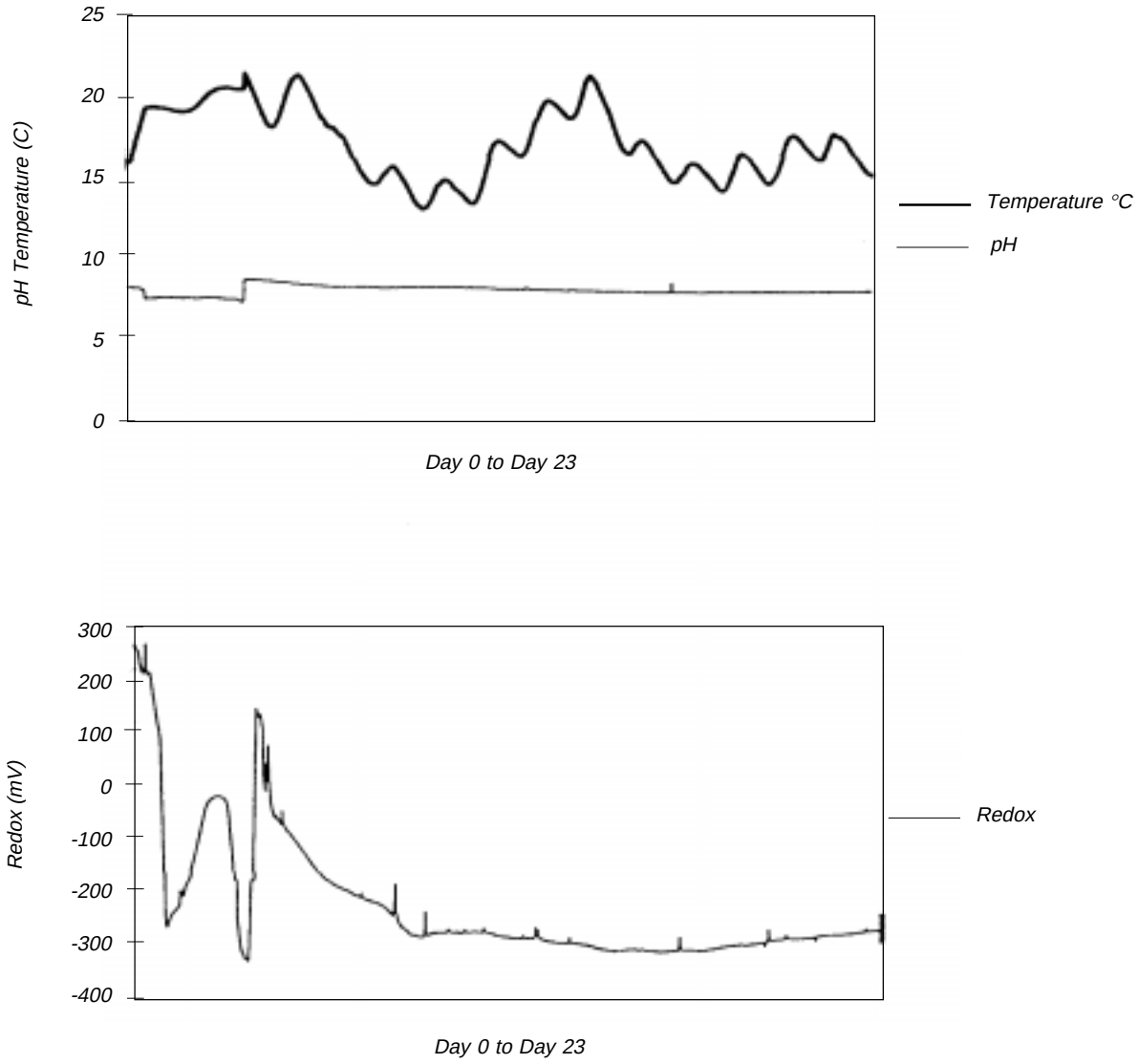

Figure 2. *Monitored parameters during demonstration test.*

A negative control that consisted of a 0.02 m^3 (5-gal) High Density Polyethylene (HDPE) pail 75% full of pre-treatment soil was set-up. This pail was left in the vicinity of the bioreactor throughout the course of the test. Samples were taken from the pail at the beginning and completion of the test to determine if the dinoseb and nitroaniline had degraded without the assistance of the process. The results from this control indicated that the dinoseb and nitroaniline in the soil naturally degraded during the treatment period. However, dinoseb and nitroaniline levels in the negative process control were only reduced by 26.8% (from 28.0 mg/kg to 20.5 mg/kg, on a dry basis) and 51% (from 10.2 mg/kg to 5.0 mg/kg, on a dry basis), respectively. This is lower than the reduction levels of these compounds achieved in the bioreactor: >99.8% and >87.3%.

A sterile control was also attempted on the slurry after the mixing of the soil, water, and potato starch. However, after the sterile control had received 1.56 Mrads of gamma radiation, biological plate counts showed that dinoseb degraders were still present. However, treatability studies have shown that the degradation of dinoseb is a result of the biological process *(3)*.

Economic Analysis

Estimates on capital and operating costs have been determined for a treatment volume of 3,824 m^3 (5,000 yd^3) of dinoseb-contaminated soil. This cost is estimated to be $127/$m^3$ ($97/$yd^3$). This estimate is based on information gathered during the Demonstration at Bowers Field and information provide by Simplot. Excavation of the dinoseb-contaminated soil is not included in this cost estimate. The estimated costs presented can be expected to vary depending on contamination level, soil type, site facilities, and site location. The cost for

treating approximately 3,824 m^3 of dinoseb-contaminated soil are based on:

- construction of four lined pits, each 50 ft wide, 340 ft long, and 4 ft deep with a 1-ft berm;
- treatment of dinoseb-contaminated soils with levels and soil characteristics similar to the Demonstration Test soil;
- a direct scale-up of chemical usage from the SITE demonstration; and
- a batch treatment time of 30 days.

If Simplot scales up its process differently than stated (i.e., using modular bioreactors rather than lined pits), the cost of remediation per cubic meter of contaminated soil will change. These cost estimates are representative of charges typically assessed to the client by the vendor and do not include profit. These costs do not include an additional cost that may be charged by the J.R. Simplot Company. Depending on site characteristics, an additional cost of up to \$131/m^3 (\$100/yd^3) may be assessed to the client for supplemental technical assistance, soil nutrients, a carbon source, and other process enhancements. A detailed explanation of these costs can be found in the Innovative Technology Evaluation Report (ITER).

Technology Status

The J.R. Simplot Company is presently going forward with remediation of the entire Bowers Field site. This remediation is anticipated to be performed in a lined pit because of the volume of soil. The J.R. Simplot Company is remediating another dinoseb-contaminated site (30 m^3) in Post Falls, ID. This site contains high levels of hydrocarbons (approximately 4,000 ppm TRPH). In this case, the soil will have to go through the cloud-point separation technique before bioremediation can be initiated.

As mentioned previously, this technology is also being evaluated under the SITE Demonstration Program on the nitroaromatic, TNT. This was performed on 23 m^3 (30 yd^3) of soil contaminated with approximately 1,510 mg/kg of TNT on a dry basis. This Demonstration took place at a Department of Defense facility in Weldon Spring, MO. In this instance a Removal Efficiency of 99.4% to an average of 8.7 mg/kg (dry weight) was achieved in approximately 9 months over the cold winter of 1993, when freezing conditions dominated.

All of the equipment used by this remediation technology is rented. Therefore, there is no time delay while waiting for a previous site to be remediated. All equipment can be on-site in a short period of time.

SITE Program

In 1980 the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. The SITE Program is a formal program established in response to SARA. The primary purpose of the SITE Program is to maximize the use of alternative technologies in cleaning up hazardous waste sites by encouraging the development and demonstration of new, innovative treatment and monitoring technologies. It consists of four major elements: the Demonstration Program, the Emerging Technology Program, the Monitoring and Measurement Technologies Program, and the Technology Transfer Program. The J.R. Simplot Ex-Situ Bioremediation Technology was originally researched through the Emerging Technology Program and then evaluated under the Demonstration Program. This Capsule was published as part of the Technology Transfer Program. Other documentation resulting from this SITE Demonstration include an Innovative Technology Evaluation Report (ITER) that expands on the results and conclusions presented in this capsule and a Technical Evaluation Report (TER) that details the SITE Demonstration Test. A video is also produced that documents the SITE Demonstration activities and results.

Disclaimer

While the technology conclusions presented in this report may not change, the data has not been reviewed by the Quality Assurance/Quality Control office.

Source of Further Information

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