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EPA

SITE Technology Capsule

Biogenesis Soil Washing Technology

Introduction

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, committed to protecting human health and the environment from uncontrolled hazardous wastes sites. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) In 1986 — amendments that emphasize the achievement of long-term effectiveness and permanence of remedies at Superfund sites. SARA mandates Implementing permanent solutions and using alternative treatment technologles or resource recovery technologies, to the maximum extent possible, to clean up hazardous waste sites.

State and federal agencies, as well as private parties, are now exploring a growing number of innovative technologies for treating hazardous wastes. The sites on the National Priorities List total over 1200 and comprise a broad spectrum of physical, chemical, and environmental conditions requiring varylng types of remediation. The U.S. Environmental Protection Agency (EPA) has focused on policy, technical, and informational issues related to exploring and applying new remedlatlon technologies applicable to Superfund sites. One such initiative is EPA's Superfund Innovative Technology Evaluation (SITE) program, which was established to accelerate development, demonstration, and use of innovative technologies for site cleanups. EPA SITE Technology Capsules summarize the latest informatlon available on selected innovative treatment and site remedlatlon technologies and related issues. These capsules are designed to help EPA remedial project managers, EPA on-scene coordinators, contractors, and other site cleanup managers understand the types of data and site characteristics needed to effectively evaluate a technology's applicability for cleaning up Superfund sites.

Thls Capsule provldes information on the BioGenesis™ soil washing technology, a technology developed to remove organic compounds from soil. The BioGenesis process was evaluated under EPA's SITE program In November 1992 at a refinery where soils were contaminated with crude oil. Information in this Capsule emphasizes specific site characteristics and results of the SITE field demonstration at the refinery. Results obtained independently by BloGenesls at the refinery and at a wood treating site in Canada were provided by BioGenesis and are summarized in the Technology Status section. This Capsule presents the following information:

- Abstract
- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Source of further information

Abstract

Soil washlng technologies are designed to transfer contaminants from soil to a liquid phase. The BioGenesis™ soil washing technology uses a proprletary surfactant solution to transfer organic contaminants from soil to wastewater. The surfactant used in the soil washing process was selected to enhance biodegradation to further reduce residual contaminant levels. The BioGenesis™ soil

SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

washing process was evaluated under the SITE program at a refinery where soil was contaminated with crude oil. Chemical analyses results show that levels of total recoverable petroleum hydrocarbons (TRPH), an indicator of degraded crude oil, decreased by 65 to 73 percent in washed soils. The TRPHs in residual soils were allowed to blodegrade In a laboratory for an additional 180 days. Results Indicate that soil washlng and blodegradatlon together removed 85 to 88 percent of TRPH In treated soil after 120 days. Further reductions in TRPH levels were not observed after 120 days. BloGenesls expects that TRPH levelsiln treated soil from the site will eventually be reduced to levels that meet regulatory requirements for use as fill material.

TRPH concentrations in wastewater range from 76 to 1,500 milligrams/Liter (mg/L). Large amounts of fine particles were present In the wastewater. Approximately 3,500 gallons (gal) of wastewater were generated during each run because the wastewater was not recycled. Wastewater generated during the SITE demonstration was treated at the reflnery's treatment facility.

The BioGenesis soil washlng 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

Soil washing is conducted with water in a slurry phase and conventlonally relies on mechanical processes to separate particles that contain contaminants. Soil washing can potentially treat a wlde variety of contaminants such as heavy metals, halogenated solvents, aromatics, gasoline, fuel oils, Polychlorlnated biphenyls (PCBs), and chlorinated phenols. The process is based on the fact that contaminants adhere to fine-grained soil (e.g., silt and clay) and organic carbon instead of coarse-grained soil (e.g., sand and gravel).

The BioGenesis soil washlng technology was developed to remove organic compounds from both fine- and coarse-gralned soil. The technology uses a proprietary solution called BioGenesis cleaner to transfer organic compounds from the soil matrix to a liquid phase. The BloGenesls process Involves high-energy mixing of excavated contaminated soils In a mobile washing unit. Because the BioGenesis cleaner, a complex alkaline blend of surfactants, is rapidly degraded by soil microbes, the contaminant-rich wastewater generated during the process can be blodegraded in an aerated reactor. Also, residual BioGenesis solution remaining on soil particles stimulates the blodegradatlon of soil contaminants not removed by the washlng process.

Figure 1 Is a schematlc dlagram of the BioGenesis soil washlng treatment unit used for the SITE technology demonstration at the refinery. The soil washlng unit was fitted with an oil skimmer, a baffle filter, and an air compressor. Support equipment, such as an American Petroleum Institute (API) oil/water separator, oil coalescer, holding tanks, and bloreactor, were not used during the refinery demonstration. The water used for soil washing *was* supplied by the refinery and was not recycled Steam was used to raise the temperature of the wash water to

Table 1. Criteria Evaluation for the BioGenesis Soil Washlng Technology

	Criteria						
	Overal Protection of Human Health and the Environment	*Compliance with Federal ARARs**	*Long-Term Effectiveness and Performance*	*Reduction of Toxicity, Mobility, or Volume Through Treatment*	*Short-Term Effectiveness*	*Implementability*	***Cost†***
Performance	*Provides **both short-** and long-term protection by eliminating contaminants **in soil.***	***Requires** compliance with RCRA treatment, storage, and land **disposal** regulations. **(of a hazardous waste).***	*Effectivety removes contamlnation source.*	*Significantly reduces toxicity, mobility, and volume of soil contaminants through treatment.*	*Presents potential short-term risks to workers and community from air release during excavation and handling.*	*Involves few administrative **difficulties.***	$106-$444 *per cubic yord*
	***Prevents further** groundwater contamination and off-site migration.*	***Excavation and** construction ond **operation of on-site treatment unit may** requite compliance with location-**specific ARARs.***	*Involves wel-demonstrated technique for removal of contaminants.*			*Used at other sites to address soil contamination.*	
	***Requires** measures **to protect workers and** community during excavation, handling and treatment*	*Emission controls are needed to ensure compliance with oir quotity standards, if volatile compounds **are present.***	*Involves some residuals Treatment (spent carbon, wastewater, sediment) or disposal.*				

Applicable or relevant and **appropriate requirements.*

†*Actual cost of a remediation technology is highly site-specific and dependent on the original target cleanup **level,** contaminant concentrations, soil characteristics, and volume of soil. Cost data presented in this table are for treating 150 to 1,000 cubic yards of soil.*

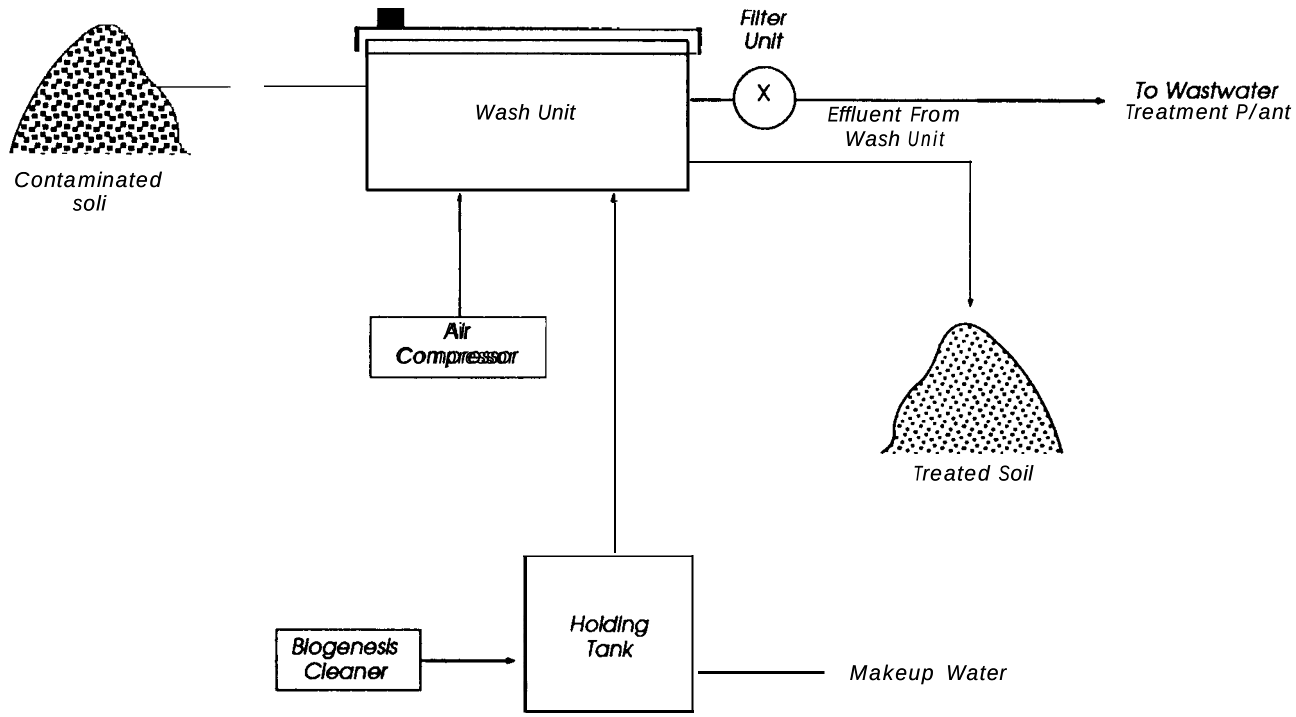

Figure 1. **Biogenesis** soil *washlng process.*

60°C before its introduction into the wash unit. Wastewater from the soil wash unit was pumped to the refinery's wastewater treatment system, which Is equipped with oil/ water separators.

During the treatment process at the refinery, the BioGenesis system pumped approximately 1,000 gal of water into the wash unit and loaded it with as much as 20 cubic yards (cu yd) of soil. After the wash unit was loaded, three mechanical shakers on each side of the wash unit agitated the soil and water mixture. Next, about 1,500 gal of additional water and approximately 8 gal of BioGenesis cleaner were pumped into the wash unit. The resulting slurry was agitated by the shakers and a series of aerators at the bottom of the wash unit. After the slurry was sufflciently mixed, approximately 1 ,000 gal of addltional water was added to ralse the fluid level, allowing floating oil product to flow out of screened ports on the sides of the wash unit. Once the floating oil product was removed, the soil was agltated agaln.

When agitation was complete, the fluld level was raised, and floating oil product was again removed from the system. Valves at the bottom of the wash unit were then opened, and contaminated wastewater was drained from the wash unit. The process of adding water and BioGenesis cleaner and agitating the soil was repeated. Treated soil was then dralned of wastewater, removed from the wash unit and placed in a holdlng area for sampling and for biodegradatlon. Because no bloreactor was used durlng the demonstration at the refinery, the contaminated wastewater was pumped to the refinery's wastewater treatment system. Refinery personnel were responsible for the disposal or recycling of treated waters.

Technology Applicability

The BioGenes soil washing technology can be used as a stand-alone technology because it Includes biodegradation to reduce residual contaminant levels and toxiclty of washed soils. In general, soils containing sand and other coarse materials are the most Ideal for treatment by soil washing. Soil containing large amounts of silt, clay, and humlc substances, and soils wlth high total organic carbon (TOC) content are not treated as effectively by most soil washlng technologies. BloGenesls claims that its technology may be effective for soils containing high percentages of silt and clay. The BioGenesis technology also does not require the screening out of particles larger than 4 to 6 inches In diameter. However, to ensure representative sampling for monitoring purposes, it is preferable to screen out large particles because contaminants associated with large particles are usually mlnlmal.

BioGenesis claims that the process Is capable of extracting volatile and nonvolatile hydrocarbons, including petroleum hydrocarbons, chlorinated hydrocarbons, pesticides, PCBs, and polycyclic aromatic hydrocarbons (PAH) from most solls. Includlng clays. Under the SITE program, in addition to the refinery site, the BloGenesls technology has been tested at one other site. A treatabllity study was conducted in Santa Maria, CA where soils were contaminated with heavy bottom residues of the petroleum distillation process. The results from the treatability study indicate that for soils contaminated with heavy petroleum hydrocarbons, more than one washing cycle Is needed to reduce contaminant levels In treated solls.

Technology Limitations

In general, soil washlng technologies only reduce contaminant volume. Because the BioGenesis process uses both soil washlng and biodegradation, however, reduction in contaminant mass, toxicity. and volume reduction are expected.

Contamlnants in silty or clayey solls are usually strongly sorbed and difficult to remove, and soil washing technologies are generally ineffective. BioGenesis claims that its process is effective in soils with high clay concentrations. Soils treated at the refinery were sandy In nature with 5% silt and 6% clay content.

According to BioGenesis, Its technology is capable of treating soil contaminated with both organic compounds and metals. However, this SITE demonstration was designed to evaluate organics removal only. It should be noted that high concentrations of metals may be toxic to microorganisms involved In blodegradation of organics. Cold climates may also adversely affect the rate of blodegradation.

Process Residuals

The BloGenesls process generates three waste streams: treated soilds, wastewater, and sediments in wastewater. A fourth waste stream, air emissions, potentially can be generated If solls contain volatile compounds.

After washing and biodegradation, treated solids may require disposal at permitted facilities. Because contaminated soil at the refinery was not hazardous as defined by RCRA, it was being stored In a large pile at the refinery. TRPHs in the treated soil from the refinery will be allowed to biodegrade for the amount of time that BioGenesis expects will be needed for TRPHs to decrease to levels that will meet local regulatory requirements for the reuse of the soil as fill material.

Wastewater will usually require further treatment. For most sites, BioGenesis proposes to recycle wastewater and treat It with its oil/water separators and the bioreactor. Such equipment was not used at the refinery, however, sediments In the wastewater, if present at appreciable amounts, require further treatment. Although the BioGenesls wash unit is equipped with carbon filters to treat volatile emissions, they were not used at the refinery because volatile compounds were not present in the refinery soil.

Site Requirements

The BioGenesis soil washing system consists of several major components: the wash unit, the volatile organic compounds (VOC) emissions hood, holding tanks, oil skimmers, strainers, transfer pumps, the API separator, the oil coalescer, a bloreactor, and a flat-bed trailer for ancillary equipment. Once onsite. the treatment system can be operational within 1 day If all necessary facilities, equipment, utilities, and supplies are avalible. Onsite assembly and maintenance requirements are expected to be mlnlmal. After the treatment is completed, the treatment system can be demobilized and moved offsite within 1 day. Access roads are needed for equipment transport. Approximately 30,000 sq ft are needed to accommodate the BioGenesls unit, support equipment and facilities, treated and untreated soil and water, and office trailer. A paved area Is needed to accommodate the wash unit. Berms are needed to control soil and water runoff. A storage area Is needed to allow solls to biodegrade over time.

If contaminated soil requires excavation before soil washing. the soils should be wetted to minimize particulate emissions. If volatile compounds are present in soils, the wash unlt should be covered, and volatile emissions should be collected and treated with the carbon filter system.

Utility requirements for the BioGenesis system are water, electricity, compressed alr, and, at some sites, steam. Approximately 3,500 gal of water are needed to treat 18 cu yd of soil. If wastewater recycling is possible. the total volume of water needed to treat large volumes of soils could be less than 5,000 gal. The BloGenesls system requires one 200-ampere. 480-volt, trlple-phase electrical clrcult. BioGenesis equipment includes a 48-ft-long flat-bed trailer that houses a generator to supply the required electricity. The flat-bed trailer also houses three 25-hp. air-cooled air compressors. If residential neighborhoods are near the treatment site, an alternative source of electricity Is needed because the generator may violate noise requirements.

Performance Data

Because the BioGenesis technology was developed to treat soils contaminated with organic compounds and because the principal contaminants In soil from the refinery are degraded petroleum hydrocarbons, TRPHs were considered the critical parameter. Approximately 2,000 cu yd of solls at the refinery were contaminated with crude oil, as indicated by hlgh concentrations of TRPHs. Results of soil analyses indicate that all other chemicals, including VOCs. were either not detected or were present at low levels In untreated soils.

The BioGenesis technology was evaluated to determlne its ability to extract TRPHs from soil. The objectives for the project were to:

- determine removal efficiencies for TRPHs In the treatment system,
- evaluate whether the treatment system's performance Is reproducible at constant operating conditions,
- gather information necessary to estimate treatment costs, including process chemical dosages and utility requirements, and
- obtain Information on biodegradation of residual TRPHs In washed soil by monitoring TRPH concentrations in the treated soil over a period of time.

Three runs were conducted on three different batches of 18 cu yd of soil at the refinery over 2 days. Each batch of soil was washed twice wlth water containing the BioGenesis solution at a temperature of 60 _C. Mixing time, solution concentration, and mixing intensity were kept at constant operating condltlons. TRPH concentrations In treated and contaminated soils, water, and wastewater were monitored. Other parameters monitored included percent moisture in soils, metals concentration, pH, particle size dlstributlon, and TOC of selected soil samples: volume and density of untreated soils; and total suspended soilds (TSS) of wastewater samples. Metals concentrations were monltored to determine toxicity potential to microorganisms. Percent moisture, TOC, particle size distribution, and pH were monltored to determine the physical and chenical characteristics of the soil that may affect treatment. Volume and density were monitored to determine the quantity of soil treated. The amount of soilds transferred to the liquid phase was determined by monitoring TSS in wastewater.

Analytical results for untreated and washed soils from Runs 1, 2, and 3 are presented In Tables 2, 3, and 4, respectivety. The metals concentration data show that metals were present at levels generally found in natural soils and were not expected to be toxic to microorganisms. Metals concentrations In the treated and untreated soils did not, and were not expected to, reflect any discernable effect of the soil washing because metals were not targeted with a metal washing surfactant blend. TOC and pH, which were analyzed for untreated soil only, showed comparable values between runs. TOC values, which ranged from 1.6% to 1.8%, indicated that petroleum hydrocarbons would strongly sorb onto the soil. These TOC values, however, are comparable to values generally found in surface soils. The pH In untreated soils was near neutral levels and was not expected to affect the treatment process. Soils at the reflnery had average particle size distribution of 13% gravel, 76% sand, 6% silt, and 5% clay.

Average TRPH concentrations in treated and untreated soils are summarized In Table 5 below. The volume of soils treated durtng each run was 18 cu yd. The masses of soils treated during each run were the same for all runs because only an average soil density value was determined for all untreated soil TRPH removal during Runs 1, 2, and 3 were 65%. 73%. and 72%. respectively. These data show that the treatment system's performance Is reproducible at constant operating conditions.

Although wastewater samples were collected during the demonstration, some of the wastewater was discharged directly Into the drains leading to the refinery's wastewater treatment system. During each wash, wastewater samples were collected twice: once from wastewater skims containing mostly olly materials and again from wastewater drained at the end of the wash. In the wastewater skims for all runs, TRPH values ranged from 76 to 1,500 mg/L, and TSS values ranged from 12,000 to 83,000 mg/L. At the end of the wash, TRPH values In wastewater ranged from 95 to 700 mg/L, and TSS values ranged from 4,000 to 7,000 mg/L. The TSS data indicate that large amounts of flnes were present In the wastewater. A mass balancing of TRPHs in the system was not possible because the volume of wastewater was not available. TRPH concentrations in water from the storage tank and in BioGenesis cleaner were either at low levels or below detection limits and were not expected to affect TRPH levels in soils.

Treated soils from Runs 2 and 3 were collected In 5-gal buckets and stored at 20 °C In a laboratory for monitorlng over a period of time. Samples were collected from the buckets on Day 14, Day 40. Day 60. Day 90. Day 120, and Day 180 after soil washing to determine the extent of biodegradation in treated soil. Results of TRPH analyses are presented In Table 6. Average TRPH concentrations in these samples are plotted in Figure 2. Table 6 and Figure 2 indicate that TRPH concentrations continued to decrease at the end of 120 days. However, TRPH levels were higher in samples collected on Day 180 than levels In samples collected on Day 120, Indicating cessation of blodegradation between 120 and 180 days. It should be noted that at the beginning of the treatability study, addltional nutrients were added to the laboratory samples. It is probable that blodegradatlon ceased due to nutrient Ilmltatlons. BloGenesls applied supplemental nutrients to on-site treated soils between 120 and 150 days, and expects that treated soils at this site will continue to blodegrade. The mlcroorganlsms apparently requlred an acclimatization perlod of about 40 days.

Results of TRPH concentrations In untreated and washed soils from Run 1 and TRPH concentrations after following washing and biodegradation from Runs 2 and 3 are plotted In Figure 3. Washed and blodegraded soil from Run 2 showed a removal efficiency of 83% and from Run 3.88%.

Information available on capital and utility costs are preliminary In nature. Based on available information, the treatment cost for 1,000 cu yd of soil Is $106/cu yd. This cost can be expected to vary dependlng on contamination type, level, and volume of soil treated.

Technology Status

BloGenesls completed washing 2,000 cu yd of crude oll-contaminated soil at the refinery. In addition to samples collected during the SITE demonstration, three untreated soil samples were collected by BloGenesls h April, July, and October 1992. Results of TRPH analyses, conducted by an independent laboratory show TRPH levels ranging from 16,500 to 40,148 mg/Kg. Results of untreated soil samples and results of treated samples collected during SITE demonstration, show TRPH removal efficiencies ranging from 85 to 94% from washing alone, and 85 to 97% from washing and biodegradation together when the soil is allowed to biodegrade for up to 120 days. Treated soil at the refinery is currently stored onsite to allow further reduction In contaminant levels through biodegradation.

The BioGenesis technology's silt and clay cleaning capability is being tested In Environment Canada's Contaminated Sediment Treatment Technology Program. The BioGenesis technology was used in June 1993 to treat sediments contaminated by wood treating activities at Thunder Bay Harbour, Ontario, Canada. Primary contaminants on site included PAHs containing two to five aromatic rings. Particle size distribution analysis showed that 80% of the sediment consisted of silt and clay sized partlcles. BioGenesis used a fleld prototype wash unit capable of treating two cu yd of sediment per hour. Results of PAH analyses showed that removal efficiencies from washing alone ranged from 83.3 to 94.8% for the indivldual PAHs. Average PAH removal from soil washing was reported at 89.5%.

BioGenesis is currently modifying Its wash unit and is manufacturing a unit capable of treating up to 40 cu yd of soil per batch.

Table 2. Analytical Results from Run 1 of the BioGenesis Site Demonstration, mg/kg solids, dry weight

	Untreated Soil				Treated Soil			
Parameter	Aliquot 1	Field Duplicate 1	Aliquot 2	Aiiquot 3	Aiiquot 1	Field Duplicate 1	Aiiquot 2	Aliquot 3
TRPH	8,300	7,500	7,600	7,500	2,900	3,000	2,400	2,600
Percent Moisture	8.6	7.5	8.6	7.6	6.1	4.8	7.1	7.1
Arsenic	2.8	2.2	NA*	NA	1.8	2	2.5	NA
Barium	36	19	NA	NA	19	16	36.3	NA
Cadmium	0.39+	<.37	NA	NA	<0.36	<0.37	<0.37	NA
Chromium	13	7.7	NA	NA	9.4	10.3	15	NA
Copper	8.7	5.8t	NA	NA	9.1	7.7	9.5	NA
Lead	10	4.5	NA	NA	5.6	3.8	9.4	NA
Mercury	0.05t	0.05t	NA	NA	0.06t	0.04+	0.05+	NA
Nickel	12	7.9	NA	NA	9.1	7a	13	NA
Selenium	0.48	<.38	NA	NA	<0.36	<0.37	<0.36	NA
Silver	<0.75	<0.75	NA	NA	<.72	<0.74	<0.75	NA
Sodium	160	130t	NA	NA	120+	98t	150+	NA
Zinc	26	13	NA	NA	35	18	26	NA
pH (pH units)	8.1	8.2	NA	NA	NA	NA	NA	NA
TOC	16,000‡	16,000‡	NA	NA	NA	NA	NA	NA

* Not analyzed.
† Less thon five times detection limit.
‡ Average of TOC and TOC analytical values.

Table 3. Analytical *Results from Run 2 of the BioGenesis Site Demonstration, mg/kg Solids. dry weight*

	Untreated Soil			Treated Soil		
Parameter	Aliquot	Aliquot 2	Aliquot 3	Aliquot 1	Aliquot 2	Aliquot 3
TRPH	7,700	7,900	7,100	2,100	2,000	2,000
Percent Moisture	10	10	11	6.3	8.4	7.9
Arsenic	2.9	NA*	NA	2.8	NA	NA
Barium	33	NA	NA	14	NA	NA
Cadmium	0.39	NA	NA	<0.38	NA	NA
Chromium	13	NA	NA	14	NA	NA
Copper	9.8	NA	NA	6.3†	NA	NA
Lead	9.7	NA	NA	4.5	NA	NA
Mercury	<0.048	NA	NA	<0.042	NA	NA
Nickel	13	NA	NA	12	NA	NA
Selenium	0.38	NA	NA	<0.38	NA	NA
Silver	<0.78	NA	NA	<.77	NA	NA
Sodium	230†	NA	NA	130†	NA	NA
Zinc	26	NA	NA	16	NA	NA
pH (pH units)	7.8	NA	NA	NA	NA	NA
TOC	16,600‡	NA	NA	NA	NA	NA

* Not analyzed.
† Less than five times defection limit.
‡ Average of TOC and TOC analytical duplicate values.

Table 4. Analytical Results *from Run* **3 of** *the BioGenesis site Demonstratlon, mg/kg solids. dry weight*

	Untreated Soil			Treated Soil		
Parameter	Aliquot 1	Aliquot 2	Aliquot 3	Aliquot 1	Aliquot2	Aliquot 3
TRPH	8,800	10,000	11,000	2,700	2,900	2,900
Percent Moisture	9.8	8.0	8.5	7.1	6.9	8.7
Arsenic	3.6	NA*	NA	NA	NA	NA
Barium	30	NA	NA	NA	NA	NA
Cadmium	<0.37	NA	NA	NA	NA	NA
Chromium	13	NA	NA	NA	NA	NA
Copper	11	NA	NA	NA	NA	NA
Lead	11	NA	NA	NA	NA	NA
Mercury	<0.047	NA	NA	NA	NA	NA
Nickel	11	NA	NA	NA	NA	NA
Selenium	0.66†	NA	NA	NA	NA	NA
Silver	<0.75	NA	NA	NA	NA	NA
Sodium	110†	NA	NA	NA	NA	NA
Zinc	26	NA	NA	NA	NA	NA
pH (PH units)	7.8	NA	NA	NA	NA	NA
TOC	18,000‡	NA	NA	NA	NA	NA

* Not analyzed.
† less than five times defection limit.
‡ Average of TOC and TOC analytical duplicate values.

Table 5. Average TRPH Concentrations in Untreated and Washed Soils, mg/kg

Run Number	Untreated Soil	Treated Soil
1	7,666	2,650
2	7,567	2,033
3	9,933	2,833

Table 6. TRPH *Concentrations In* **Treated Soil, mg/kg**

Run/Day	Aliquot 1	Aliquot 2	Aliquot 3
Run 2:			
Day 0	2,100	2,000	2,000
Day 14	2,200	2,100	2,600
Day 40	2,000	2,000	2,000
Day 60	1,600	NA*	NA
Day 90	1,100	970	1,000
Day 120	980	920	970
Day 180	1,060	1,100	1,000
Run 3:			
Day 0	2,700	2,900	2,900
Day 14	3,100	3,200	2,900
Day 40	2,600	3,300	2,700
Day 60	2,100	NA	NA
Day 90	1,500	1,400	2,300
Day 120	1,200	1,100	1,000
Day 180	1,380	1,590	1,390

* Not available.

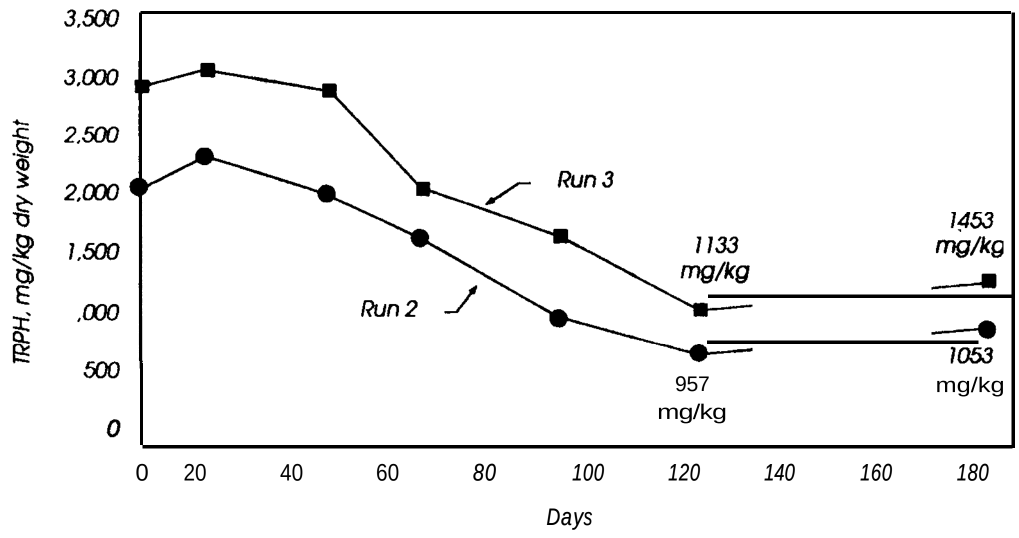

Figure 2. Biodegradation results: TRPH concentrations from treated soils over time.

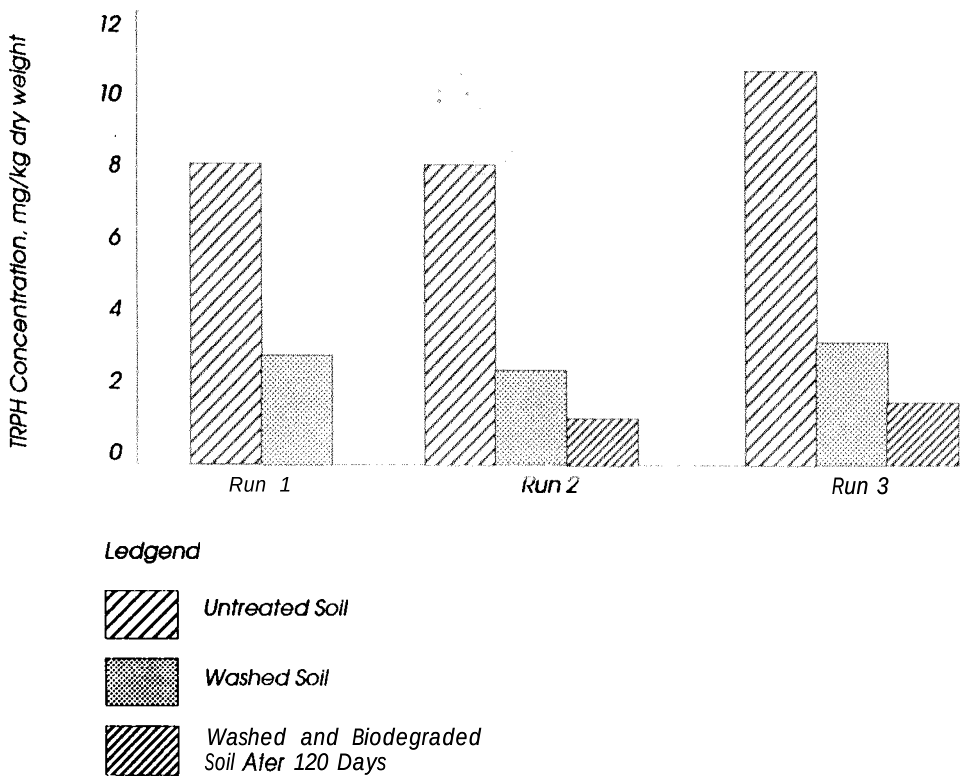

Figure 3. Average TRPH concentrations in treated and untreated soils. Biodegradation study only conducted during runs 2 and 3

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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