United States
Environmental Protection
Agency

EPA/540/SR-93/517
September 1993

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

Technology Demonstration Summary

Toronto Harbour Commissioners (THC) Soil Recycle Treatment Train

A demonstration of the Toronto Harbour Commissioners' (THC) Soil Recycle Treatment Train was performed under the Superfund Innovative Technology Evaluation (SITE) Program at a pilot plant facility in Toronto, Ontario, Canada. The Soil Recycle Treatment Train, which consists of soil washing, biological treatment, and metals chelation, is designed to treat inorganic and organic contaminants in soil.

During the demonstration test, soil from a site that had been used for metals finishing and refinery and petroleum storage was processed in the pilot plant. The demonstration test results were mixed. The primary developer's claim to produce gravel and sand that met the THC target criteria for medium to fine soil suitable for industrial/commercial sites was achieved for the sand and gravel products. The fine soil from the biological treatment process exhibited anomalous oil and grease behavior and, although exhibiting a significant reduction in polynuclear aromatic hydrocarbon (PAH) compounds, did not meet the target level of 2.4 ppm for benzo(a)pyrene.

This Technology Demonstration Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the SITE Program demonstration that is fully documented in two separate reports (see ordering information at back).

Introduction

In response to the Superfund Amendments and Reauthorization Act (SARA) of 1986, the U.S. Environmental Protection Agency (EPA) established a formal program called the Superfund Innovative Technology Evaluation (SITE) Program. The SITE Program was established to accelerate the development, demonstration, and implementation of innovative technologies at hazardous waste sites across the country. The program is a joint effort between EPA's Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER). The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to implement new cleanup standards that require greater reliance on permanent remedies. This is done through technology

Printed on Recycled Paper

demonstrations designed to provide engineering and cost data on selected technologies.

The Toronto Harbour Commissioners conducted an extensive evaluation of this treatment train at a 55 tons/day pilot plant located on the Toronto Harbour Front, Toronto, Ontario, Canada. An EPA SITE demonstration was conducted in April 1992. The SITE project examined, in detail, the processing of soil from one of the sites being evaluated as part of the overall project. The treatment train consists of three processes shown conceptually in Figure 1. The first process uses an attrition soil wash process to separate relatively uncontaminated soil from a more heavily contaminated fine slurry. The contaminated fine slurry is then further processed in a metals removal process or a bioslurry reactor process or both to remove organic and heavy metal contamination. THC has estimated that as much as 2.2 million tons of soil from locations within the Toronto Port Industrial District (PID) may require some form of treatment because of heavy metal, organic contamination, or both.

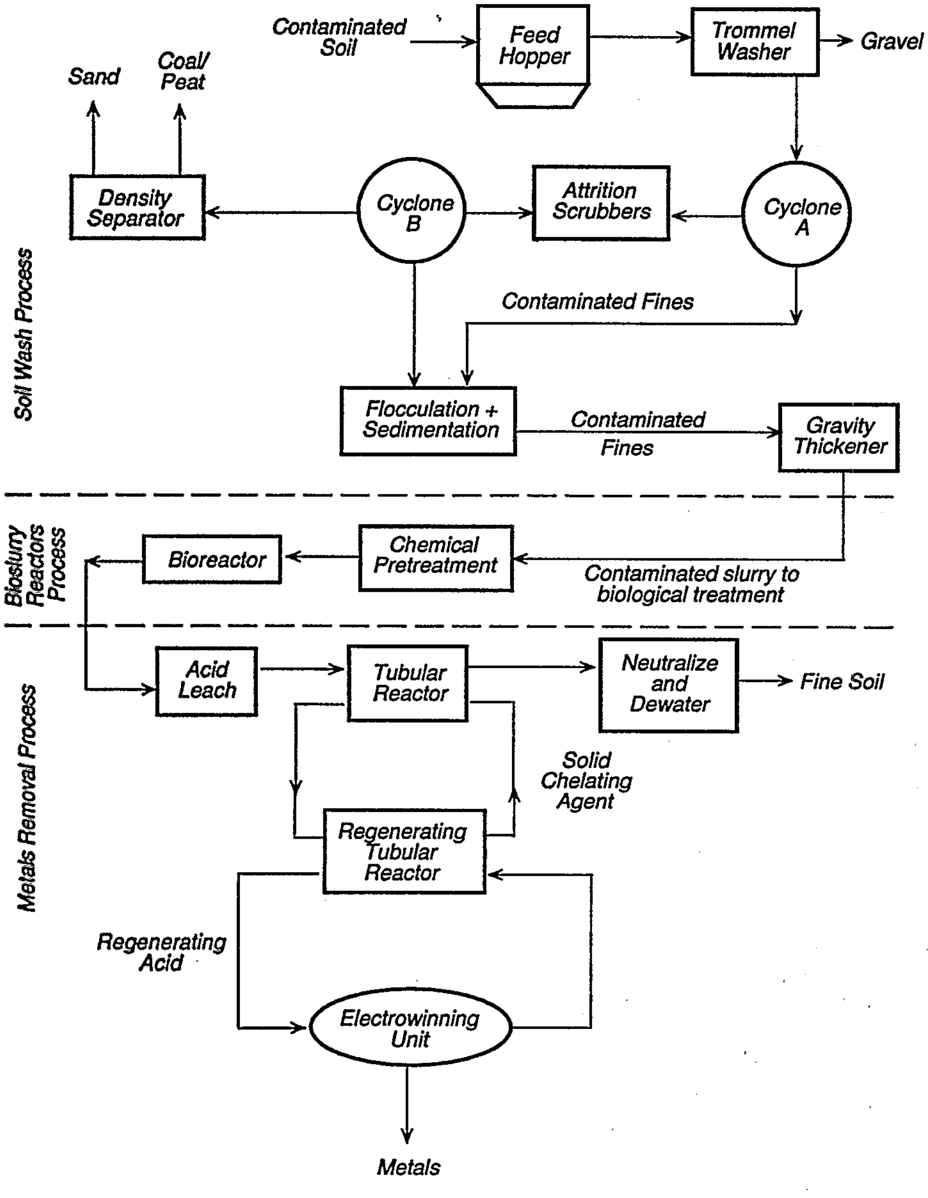

Figure 1. Simplified process flow diagram of the Toronto Harbour Commissioners' Soil Recycle Treatment train.

The THC claims that the treatment train technology will meet the following performance criteria:

1. Produce gravel (sized between 0.24 and 1.97 in.) and sand (sized between 0.0025 and 0.24 in.) from the soil washer that will meet the THC target criteria for coarse textured soils described in Table 1 for both organic and inorganic compounds independent of the initial contaminant levels.
2. Produce a fine soil fraction (sized less than 0.0025 in.) after metals removal or biological treatment or both that will meet the THC target criteria for fine textured soils described in Table 1 for both organic and inorganic compounds independent of the initial contaminant levels.

The THC criteria have been developed by THC by combining existing criteria for conventional pollutants and metals with a site-specific criterion developed for a contaminated soil associated with a refinery site.

The goals of this demonstration were to evaluate the technical effectiveness and economics of the treatment process sequence and to assess the potential applicability of the process to other waste and/or other Superfund and hazardous waste sites. These and other specific critical and noncritical objectives may be found in the Demonstration Plan [1]. This Project Summary summarizes the treatment train's ability to meet the THC target criteria.

Procedure

The demonstration took place while soil from a site that had been used for metals finishing and refinery and petroleum storage was processed in the pilot plant. This soil was expected to exhibit relatively high organic (oil and grease, PAH compounds) and inorganic (heavy metals) contaminants. EPA's sampling was of relatively short duration, but it was expected that when combined with results of THC evaluation, a sound basis for analysis of the technology would be obtained.

Soil was fed to the treatment train, and all solid products were sampled. Samples were also taken to allow separate assessment of the performance of each process technology, as required. In addition, samples of recycled water streams and air emission streams were obtained to determine the fate of contaminants. Process flow data were accumulated to allow the development of an estimated mass balance for the soil wash process.

The data collected during the demonstration were used to determine the following:

Table 1. *THC Target Criteria for Selected Parameters for Soils to be Used for Commercial/Industrial Lands*

Parameter	THC Target Course Textured Soil *	THC Target Medium & Fine Textured Soil	Feed + Soil	Gravel +	Sand +	Fine ‡ Soil
Conventional						
Oil and grease (%)	1	1	0.82	0.33	0.22	2.5
TRPH § (mg/kg)	-	-	2500	800	620	5400
Total Metals (mg/kg)						
Copper	225	300	18.3	6.4	13.8	84
Lead	750	1000	115.0	45.3	46.0	548
Zinc	600	800	82.5	46.0	34.0	343
Organic Compounds (mg/kg)						
Naphthalene	8.0 **	8.0 **	11.2	2.5	2.1	1.3 ++
Benzo(a)pyrene	2.4 #	2.4 #	1.9	0.6	0.5	(2.6) §§

* Defined as greater than 70% sand and less than 17% organic matter.
\+ Average of six composite samples.
‡ Average of six samples from bioslurry reactor batch 2.
§ Total recoverable petroleum hydrocarbons.
** If these trigger levels are exceeded, the Ministry of the Environment will make a determination on a case-by-case basis regarding the need for remediation.
++ Values reported are estimated detection limits for this parameter.
\# Cleanup levels are shown for organic compounds. If soils exceed these levels, then the soil is considered hazardous and remediation is required.
§§ Values shown are below quantitation limits for procedures. Values shown are estimated.

- the quality of the gravel, sand, and fine soil relative to the THC target criteria,
- the percent removal for organic contaminants (oil and grease, total recoverable petroleum hydrocarbons (TRPH), naphthalene, and benzo-(a)pyrene) from gravel, sand, and contaminated slurry for the attrition soil wash process,
- the percent removal of organic contaminants from a soil slurry for the bioslurry reactor process, and
- the percent removal of heavy metals (copper, nickel, lead, and zinc) for a soil slurry being processed in the metals removal process.

Soil Wash Process

Because the majority of contaminated soils encountered at the PID are sandy, silty soils, soil washing (Figure 1) is an economical and effective process to separate contaminants from the bulk of the soil. A scrubbing action and selected chemicals are used to separate contaminants from the larger soil particles. The rotary trommel washer removes particles larger than 0.24 in. as a gravel fraction. The contaminated soil particles less than 0.24 in. and the washwater pass through the screen in the trommel washer into a holding tank where belt-type oil skimmers remove free oil from the water. The remaining soil and washwater are pumped through a separation hydrocyclone where the contaminated fines (less than 0.0025 in.) are separated from the coarser soil particles. Larger sand particles are easily separated from the fines, where the contaminants are concentrated. The fines are pumped to a lamellar separator and then to a gravity thickener, while the coarse sand is pumped to the attrition scrubbers.

Three attrition scrubbing cells agitate the soil particles, causing them to rub against each other and scrub the fine particles and contaminants from the surfaces of the soil particles. Detergents or surfactants and acids or bases, if required, may be added to the third cell to aid in dislodging contaminants from the soil particles or in dissolving certain contaminants. The treatment processes subsequently used to treat the contaminated slurry restrict the types of chemicals that can be used in this treatment train.

Scrubbed particles and washwater from the attrition scrubbing units are pumped to a second hydrocyclone at the top of the plant, where sand particles (>0.0025 in.) are separated from the process water and the remaining fines. The sand stream from this separator is then put through a density separator to remove the light materials, such as coal, wood, and peat particles from the heavier soil particles. The coal and peat are collected separately, as a potentially contaminated waste stream. The sand is discharged by conveyor to a collection bin and is combined with the gravel from the trommel washer for return to the original site. This washed material is expected to include approximately 70% to 80% of the soil feed to the wash plant.

Contaminated fines with a grain size smaller than 0.0025 in. pass through the lamellar separator and sludge thickener to remove water. The contaminated slurry from the sludge thickener is fed into two large holding tanks at the front end of the metals removal system or directly to the bioslurry reactor process. The contaminated slurry is expected to represent approximately 15% to 30% of the soil feed to the wash plant.

The contaminated process water removed by the lamellar separator and sludge thickener is discharged to an outdoor storage pond for recycle. Any sludge recovered from the ponds is then added to the deep cone sludge thickener where it joins the slurry for further treatment.

Bioslurry Reactor Process

The bioslurry reactor process (Figure 1) involves a series of reactors (tanks) where organic contaminants are treated. Before introduction into the reactor, the slurry is pretreated with a proprietary inorganic oxidant.

The slurry to be treated is gently mixed in two surge tanks to prevent particles from settling and then pumped to one of three 20,000-gal upflow bioreactor tanks where submerged pumps and the upflow of air from the medium to fine bubble aerators provide constant mixing conditions and the suspension of fines.

The biological system is prepared for each soil to be treated by inoculating the system with bacteria that have developed in the soil; that is, a limited amount of fine slurry obtained from the soil wash process is pumped directly to the bioreactors without passing through the metals extraction process where the highly acidic conditions would destroy the desired bacteria. This allows a bacterial population in the bioreactor to develop—a population based on strains in the soil to be treated. Fine slurry is accumulated until a single reactor is fully charged.

Nutrients in the form of urea and phosphoric acid solutions are added periodically, and oxidants may be added.

Once the organics content of the slurry is reduced to a level below the THC guidelines for industrial soils, the slurry is returned to the excavation site since the dewatering process originally selected did not produce a solid product.

The developer of this treatment train had planned to use a continuous process for the biological treatment system, but earlier experience with the bioslurry reactor process disclosed variable analytical results. Because the developer had not moved beyond batch evaluations at the time of the SITE demonstration sampling, the discharge from two bioslurry reactor batches was extensively sampled.

Metals Removal Process

The contaminated slurry from the attrition wash plant or the bioslurry reactor process is fed into two large holding tanks in the central area of the facility, at the front end of the metals removal process (Figure 1). The slurry consists of approximately 24% solids by weight and 76% process water. Mild acid is added to the slurry from the acid storage tanks to desorb and solubilize any metal contaminants from the soil particles.

The contaminated slurry is then pumped into the first tubular reactor. This screw-type rotary reactor brings the slurry into countercurrent contact with solid metals chelating agents that have an affinity for specific metal contaminants. From here, the slurry, which now contains only soil particles, organic contaminants, residual metals not removed by the process, and process water, is pumped to a holding tank, where it is neutralized.

The solid chelating agent, which moves countercurrent to the slurry, now contains the extracted metals. The solid chelating material is selected from a family of metal-specific, ion-exchange chelating resins to preferentially remove heavy metals. It is washed to remove solid soil particles and is fed through a second tubular reactor where a mild acid breaks the bond between the chelating agent and the contaminant metals. The chelating agent is then recycled to the first reactor for reuse in the metals extraction process. Meanwhile, the metals/acid mixture is recycled in the second reactor until it becomes sufficiently rich in metal to be pumped to an electrowinning unit, where the metals are removed by electrolysis. The result of the buildup of metal concentration in the regenerating acid will somewhat reduce the absorption capacity of the resin beads being returned to the slurry contractor. The system has, however, been designed to provide excess absorption capacity of the chelating resin in relationship to the metals being absorbed. Little change in performance is expected. Another, more long-term deterioration of the resins absorption capacity is associated with the oxidation of the active sites on the resin bead. This reaction is expected to be measured in months to years and should not affect this demonstration. Nevertheless, resin replacement costs can be a significant cost factor in such a system. The metals may be removed singly or as one composite mass. During electrowinning, the metal-depleted acid is pumped back to the holding tanks for reuse as regenerating acid, or it may be neutralized and become a part of contaminated slurry.

Results and Discussion

Soil Product Criterion

- The gravel (sized between 0.24 and 1.97 in.) and sand (sized between 0.0025 and 0.24 in.) products met the THC target criteria.
- Fine soil did not meet the THC target criteria because oil and grease and benzo(a)pyrene levels exceeded the criteria.

Soil Wash Process

- For gravel, removal rates for organic contaminants (oil and grease, TRPH, naphthalene, and benzo(a)pyrene) were 67% or greater. This gravel accounted for 11.5% of total process mass output and 4% or less of the organic contaminants in the product streams.
- For sand, removal rates for organic contaminants (oil and grease, TRPH, naphthalene, and benzo(a)pyrene) were 78% or greater. This sand accounted for about 68% of the process output and 15% or less of the organic contaminants in the product stream.
- The process concentrated the organic contaminants into a contaminated fine slurry (<0.0025 in.) which accounted for about 19% of the process output mass and 74% or more of the organic contaminants.
- The process also produced a contaminated coal/peat product (<0.24 in; >0.00025 in) that represented about 1.6% of the process output and 6% or more of the organic contaminants. This waste stream will require disposal (most likely by incineration).
- The feed soil exhibited low heavy-metals contaminant levels (copper, 18 ppm; lead, 115 ppm; and zinc, 83 ppm). The wash process concentrated these contaminants in the fine slurry (19% of the process mass output and 59% or more in the process output streams).

Data from the soil wash process that were developed during the SITE demonstration are presented in Table 2.

Bioslurry Reactor Process

- When inlet samples were compared with outlet samples, the oil and grease reduction from the bioslurry process was limited.
- A similar comparison for other parameters yielded the following reduction: TRPH, 52%; naphthalene, at least 97%; and benzo(a)pyrene, approximately 70%.

Results for the bioslurry reactor process are shown in Table 3.

Metals Removal Process

- The levels of metal contamination actually encountered eliminated the need to use the metals removal process for this soil. Limited data were developed for the efficiency of the metals removal process by sampling a process run of a metal-rich slurry from another soil. The reactor achieved the following removal efficiencies based on metals concentrations in the inlet versus the outlet samples: copper, 96%; lead, 71%; nickel, 71%; and zinc, 63%.
- Because the metals removal process became fouled with oil and grease, the operation shut down prematurely. This may be a limitation on the process in that slurries with free oil and grease cannot be processed.

Results for the metals removal process are shown in Table 4.

Fine Product Dewatering

- Because the hydrocyclone device used for final dewatering of the fine soil was not successful, the final product from the process was a slurry. Dewatering will require further evaluation by the developer or the application of other technology.

Emissions Assessment

- Emission sampling of the ventilation system serving the biological treatment system did not detect PAH compounds, but detection limits were very high due to a high concentration of light hydrocarbons in the exhaust stream. These light hydrocarbons were tentatively identified as a petroleum distillate in the range between diesel oil to Stoddard solvent (C_9 - C_{16} paraffins). Total gaseous, nonmethane organic compounds were detected at levels that indicated 220 lb/day of emissions. (The data illustrate that significant air stripping is occurring in the bioreactor, and this must be accounted for in the design.) The facility has a biological filter system and carbon adsorption bed in place to control these emissions.

Table 2. *Selected Feed and Product Characteristics of the Attrition Soil Wash Process*

Characteristic	Feed Soil *	THC Criteria	Gravel, * <1.97 in. >0.24 in.	Coal/Peat Fraction, + <0.24 in.	Sand, * <0.24 in. >0.0025 in.	Contam. Fines, * <0.0025 in.
Percent of output based on site demo data		—	11.5	1.6	68.1	18.8
Percent of output based on THC overall analysis	—	—	10.5	2.5	70.2	16.7
Oil, grease (mg/kg)	8,200 (6,708-9,700)‡	10,000	3,300 (1,200-10,400)	38,000 (17,600-51,600)	2,200 (1,400-3,900)	40.000 (26,900-50,500)
TRPH (mg/kg)	2,500 (2,270-3,430)	—	800 (270-1,370)	11,900 (4,760-16,280)	620 (380-960)	14.000 (8,500-19,800)
Copper (mg/kg)	18.3 (9.2-42.2)	225	6.4 (0.7-12.1)	32.9 (22.8-41.7)	13.8 (32-32.4)	83.1 (48.2-135)
Lead (mg/kg)	115 (63.3-127)	750	45.3 (3.2-117)	406 (12.9-749	46 (23.6-82.9)	522 (421-680)
Zinc (mg/kg)	82.5 (40.4-181)	600	46 (2.3-98.6)	210 (46.8-406)	34.1 (15.9-71.4)	344 (192-593)
Naphthalene (mg/kg)	11.2 (5.3-18)	8	2.5 (0.9-2.9)	64 (34-110)	2.1 (1.5-3.1)	51.7 (17-82)
Benzo(a)pyrene (mg/kg)	1.9 (0.9-2.9)	2.4	0.6 (0.2-1.0)	14.5 (9.6-23)	0.5 (0.2-1.2)	10.0 (9.0-12.0)

* Average of six composite samples.
\+ Average of three composite samples.
‡ Range of results.

Conclusions

The results of the SITE Demonstration Test showed that

- Soil washing effectively produced clean, coarse soil fractions and concentrated the contaminants in the fine slurry.
- The chemical treatment process and biological slurry reactors achieved at least a 90% reduction in simple PAH compounds such as naphthalene but fell just short of the approximately 75% reduction in benzo(a)pyrene required to achieve the THC criteria.
- The biological process discharge did not meet the THC criteria for oil and grease, and the process exhibited virtually no removal of this parameter. The developer believes that the high outlet oil and grease values are the result of the analytical extraction of the biomass developed during the process.
- The hydrocyclone dewatering device did not achieve significant dewatering. Final process slurries were returned to the excavation site in liquid form. The development of an acceptable dewatering process will require further evaluation of alternative technologies.
- The metals removal process equipment and chelating agent were fouled by free oil and grease contamination, forcing the premature curtailment of sampling. This establishes a limitation for this technology since biological treatment or physical separation of oil and grease will be required to avoid such fouling.

Table 3. *Selected Feed and Product Characteristics of the Bioslurry Reactor Process*

Characteristic	MOE Criteria	Contaminated Fine Slurry *	Bioslurry Reactor Batch 1 +	Bioslurry Reactor Batch 2 +	Removal Efficiency % ‡
Oil, grease	1.0%	4.00% (2.7-5.4) §	4.98% (3.96-6.08)	2.53% (3.98-2.17)	6
TRPH	—	1.4% (.85-1.98)	.78% (68-.95)	.54% (.39-.76)	52
Naphthalene	8 mg/kg	51.7 mg/kg (17-82)	<14 ** mg/kg	<13 ** mg/kg <16-<11	97 ++
Benzo(a)pyrene	2.4 mg/kg	10 mg/kg (8.4-12)	3.1 mg/kg (2.0-5.1)	2.6 mg/kg (2.3-3.4)	71

* Average of six composite samples.
\+ Average of 6 samples taken at 20-min intervals during discharge of batch.
‡ Removal efficiency based on average value for both batches.
§ Range of results.
** Value reported is average of quantitation limit reported. Detection limit is at least a factor 10 less than the quantitation limit.
++ Removal efficiency calculated from detection limit; estimated by dividing quantitation limit by 10.

Table 4. Selected Heavy Metals Data for Removal of Metals from the Liquid Stream by the THC Metals Removal Process

Metal	Influent mg/kg	Effluent mg/kg	Removal %
Copper	51.1 (49.2-53.2)*	1.8 (0.9-3.0)	96
Lead	100.5 (94.2-112)	29.0 (13.5-46)	71
Nickel	11.7 (10.7-12.7)	3.3 (0.9-7.3)	71
Zinc	277 (264-294)	101 (53-183)	63

* Range of values.

References

1. Science Applications International Corporation. March 16, 1992. "Demonstration Plan for the Toronto Harbour Commissioners (THC) Soil Recycle Treatment Train."

☆U.S. GOVERNMENT PRINTING OFFICE: 1993 - 750-071/80051

*The EPA Project Manager, **Teri Richardson**, is with the Risk Reduction Engineering Laboratory, Cincinnati, OH 45268 (see below)*

The complete report, entitled "Technology Evaluation Report; Toronto Harbour Commissioners (THC) Soil Recycle Treatment Train," (Order No. PB93-216067; Cost: $27.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

A related report, entitled "Toronto Harbour Commissioners (THC) Soil Recycle Treatment Train; Applications Analysis Report," EPA/540/AR-93/517, discusses application and costs.

The EPA Project Manager can be contacted at:

Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use
$300

EPA/540/SR-93/517