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SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

Technology Demonstration Summary

EPA RREL's Mobile Volume Reduction Unit

A Superfund Innovative Technology Evaluation (SITE) demonstration of the mobile Volume Reduction Unit (VRU) was conducted in November 1992 at the Escambia Wood Treating Company Superfund Site in Pensacola, FL. The VRU is a soil washing technology that may be used to rid soils of organic contaminants. The VRU is designed to remove contaminants by suspending them in a wash solution and by reducing the volume of contaminated material through particle size separation.

For the SITE demonstration, the VRU was used to treat soil contaminated with wood-treating agents, pentachlorophenol (PCP) and creosote-fraction polynuclear aromatic hydrocarbons (PAHs). Demonstration test results indicate that the VRU soil washing system successfully separated the contaminated soil into two unique streams: washed soil and fines slurry. The washed soil was safely returned to the site following treatment. The fines slurry, which carried the majority of the pollutants from the feed soil, underwent additional treatment to separate the fines from the water.

An economic analysis was conducted to estimate costs for a commercial treatment system using the VRU technology. This analysis was based on the pilot-scale results from the SITE demonstration. The economic analysis was developed for a commercial unit projected to be capable of treating approximately 10 tons per hour (tph) of contaminated soil. The cost to remediate 20,000 tons of contaminated soil using this commercial unit is estimated to be $130 per ton if the system is online 90% of the time. Treatment costs appear to be competitive with other available technologies.

This 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 on back).

Introduction

In response to the Superfund Amendments and Reauthorization Act of 1986, EPA's Office of Research and Development and Office of Solid Waste and Emergency Response have established the SITE Program to accelerate the development, demonstration, and use of new or innovative technologies as alternatives to current treatment systems for hazardous wastes.

The major objective of the SITE Program is to develop reliable performance and cost information for innovative technologies. One such technology is EPA's mobile VRU, which was demonstrated over a 2-wk period beginning November 5, 1992, and ending November 13, 1992. The demonstration was conducted at the Escambia Wood Treating Company Superfund Site in Pensacola, FL.

The VRU is a soil washing technology designed to rid soils of organic contaminants through particle size separation and solubilization. The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind to fine clay and silt particles primarily by physical processes.

Critical and noncritical project objectives were established to evaluate the effectiveness of the process. Critical parameters provided data to support project objectives. Noncritical measurements provided additional information on the technology's applicability to other Superfund sites and allowed observation and documentation of any process performance anomalies. The following were the critical project objectives:

- Determine the system's ability to remove 90% of the PCP and creosote-fraction PAH contaminants from the feed soil.
- Determine the system's ability to return 80% of the solids in feed soil as washed soil.
- Perform mass balances on the following:
  - Total material: This is the ratio of the total mass of all output streams from the soil washing segment of the VRU to the total mass of all corresponding input streams.
  - Total dry solids: This is the ratio of the total mass of dry solids in all output streams from the soil washing segment of the VRU to the total mass of dry solids in all corresponding input streams.
  - PCP: This is the ratio of the total mass of PCP in all output streams from the soil washing segment of the VRU to the total mass of PCP in corresponding input streams.
  - PAHs: This is the ratio of the total mass of PAHs in all output streams from the soil washing segment of the VRU to the total mass of PAHs in all corresponding input streams.
- Verify VRU operating conditions: This includes measuring the pH of the wash water, the ratio of surfactant to wash water, and the temperature.

The noncritical project objectives of this demonstration were to determine the technology's general applicability and to document process performance. The noncritical project objectives were as follows:

- Determine removal efficiencies of the unit operations in the water purification system.
- Develop operating costs.

Process and Facility Description

The demonstration of the VRU was performed at the Escambia Wood Treating Company Superfund Site located in Pensacola, FL. The 26-acre facility, now closed, used PCP and creosote to treat wood products from 1943 to 1982. A typical VRU setup is shown in Figure 1. For this demonstration, the VRU was composed of two segments: soil washing and water treatment. The soil washing segment produces fines slurry and washed soil streams. The water treatment segment treats the fines slurry by separating the fines and removing pollutants from the wash water through a series of steps including sedimentation, flocculation, filtration, and carbon adsorption.

In this setup, the soil is fed to the miniwasher at a controlled rate of approximately 100 lb/h by the screw conveyor. Filtered wash water is added to the soil in the miniwasher and also sprayed onto an internal slotted trommel screen [with a 10-mesh (2-mm) slot opening] in the miniwasher. Two vibrascreens continuously segregate soil into various size fractions. For the demonstration, 10-mesh (2-mm) and 100-mesh (0.15-mm) screens were used.

Miniwasher overflow (the stream exiting the top of the washer), which contains the coarse soil fraction, falls onto the first 10-mesh (2-mm) vibrascreen. Solids that overflow the first vibrascreen [less than 1/4 in, greater than 10 mesh (0.15 mm)] flow by gravity down to a recovery drum. The underflow (the stream exiting the bottom) is pumped at a controlled rate to the second 100-mesh (0.15-mm) vibrascreen, where it is joined by the miniwasher underflow.

The overflow from the second vibrascreen [less than 10 mesh (2 mm), greater than 100 mesh (0.15 mm)] is gravity fed to the recovery drum containing the overflow from the first vibrascreen. The second vibrascreen underflow (a fines slurry) drains into a tank with a mixer.

Slurry from the 100-mesh (0.15-mm) screen (fines slurry) tank, which contains particles less than 100 mesh (0.15 mm) in size, is pumped to the Corrugated Plate Interceptor (CPI). Materials lighter than water (floatables such as oil) flow over an internal weir, collect in a compartment within the CPI, and drain by gravity to a drum for disposal. Solids settled in the CPI [particles less than 100 mesh (0.15 mm)] are discharged by the bottom auger to a recovery drum.

An aqueous slurry, which contains fines less than about 400 mesh (0.038 mm), overflows the CPI and gravity feeds into a tank with a mixer. The slurry is then pumped to a static mixer located upstream of the floc clarifier's mix tank. Flocculating chemicals, such as liquid alum and aqueous polyelectrolyte solutions, are metered into the static mixer tank to neutralize the electrostatic charges on colloidal particles (clay/humus) and promote coagulation. The slurry is then discharged into the floc chamber, which has a variable- speed agitator to stimulate floc growth. The floc slurry overflows into the clarifier (another CPI). Bottom solids are augured to a drum for disposal.

Clarified water is polished with the objective of reducing suspended solids and organics to low levels that permit recycling of spent wash water. Water is pumped from the floc settler overflow tank at a controlled rate through cartridge-type polishing filters operating in parallel to remove soil fines greater than 4×10^{-4} in. Water leaving the cartridge filter flows through activated carbon drums for removal of hydrocarbons. The carbon drums may be operated either in series or parallel. Hydrocarbon breakthrough is monitored by sampling; drums are replaced when breakthrough is detected.

Feed Soil Characteristics

PAH- and PCP-contaminated soil from the former Escambia Wood Treating Company site was excavated and then treated by the VRU. Contaminant levels in the excavated soil from the Escambia Wood Treating Company site ranged from the low parts per million (ppm) to percent levels. For the SITE demonstration, the excavated soil was homogenized and manually processed through a 1/4-in. screen before it was fed to the VRU. Contaminant concentrations in the feed soil after homogenization and screening are presented in Table 1.

Table 1. Contaminant Concentrations in the Feed Soil (ppm, dry weight basis)

	Average	Range
PAHs	920	480 to 1,500
PCP	130	43 to 200

Sampling and Monitoring

During the demonstration, the VRU operated at a feed rate of approximately 100 lb/h with wash water-to-feed (W/F) ratio of 6 to 1. The physical condition of the wash water was modified during the demonstration with combinations of surfactant, caustic, and temperature as follows:

- Condition 1: no surfactant, no pH adjustment, no temperature adjustment
- Condition 2: surfactant addition, no pH adjustment, no temperature adjustment
- Condition 3: surfactant addition, pH adjustment, temperature adjustment

The VRU operated under Conditions 1 and 2 three consecutive times; each run was 4 hr in duration. On the 7th day of testing, the generator that supplied the power to the test site failed, and consequently, testing was terminated and the data were not used. In order to remain on schedule and collect an equivalent amount of data for the third set of conditions, two 6-hr runs were conducted under Condition 3. Sample collection and flow measurements began when each run reached steady state. The unit ran for approximately 1 hr before reaching steady state conditions. The sampling locations, which are designated S1, S2, etc., are described in Table 2.

Results and Discussion

PCP removal efficiency was calculated for Conditions 1, 2, and 3. Under Condition 1, the average PCP removal efficiency was 81%, which is below the project objective of achieving at least 90%. Under Condition 2, which employed surfactant addition only, the average removal efficiency was 93%. This performance exceeds the project objective and reflects the surfactant's ability to pull hydrophobic PCP into the wash water. Under Condition 3, which employed surfactant addition and pH and temperature adjustment, 97% of the PCP was removed. These data illustrate that the PCP removal efficiency

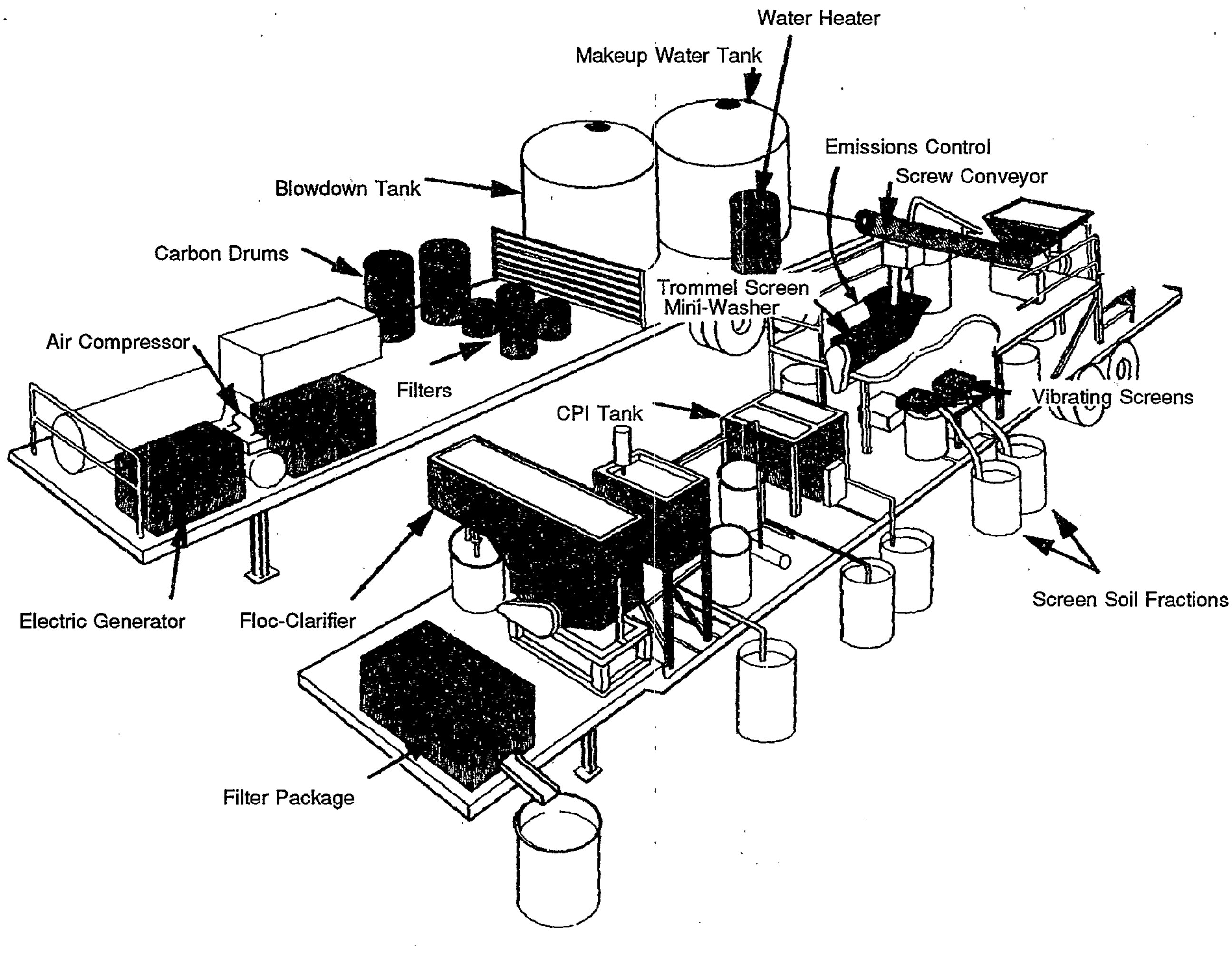

Figure 1. Typical VRU operational setup.

Table 2. Sampling Locations for VRU Demonstration Test

Process Stream (Sample Location)	Matrix
Feed Soil (S1)	Solid
Feed Water (S2)	Liquid
Surfactant (S3)	Liquid
Caustic (S4)	Liquid
Washed Soil (S5)	Solid
Fines Slurry (S6)	Slurry
Water Floatables (S7)	Liquid
CPI Fines (S8)	Slurry
Flocculant Fines (S9)	Slurry
Clarified Water (S10)	Liquid
Post-Filtration Water (S11)	Liquid
Post-Carbon Adsorption Water (S12)	Liquid

is clearly enhanced by surfactant addition and pH and temperature adjustment.

PAH removal efficiency was calculated for Conditions 1, 2, and 3. Under Condition 1, the average PAH removal efficiency was 76%, which is again below the project objective of achieving at least 90%. Under Condition 2, the average removal efficiency was 86%. This performance is also below the project objective; however, the large rise in removal efficiency reflects the surfactant's ability to transfer PAHs into the wash water. The average PAH removal efficiency for Condition 3 increased to 96%. These data illustrate that the PAH removal efficiency is clearly enhanced by surfactant addition and pH and temperature adjustment.

As soil travels through the VRU, the sand and gravel fraction of the soil are separated from the contaminated fines (i.e., fines particles). The relatively nonhazardous sand and gravel fraction exits the system as washed soil. By comparing the mass of dry solids in the feed soil with the mass of dry solids in the washed soil, solids recoveries of 96%, 95%, and 81% were calculated for soils treated under Conditions 1, 2, and 3. These recoveries exceed the project objective that at least 80% of the solids present in the feed soil would be returned to the site as washed soil.

Washed soil recovery was also determined on a normalized basis, which compares the mass of dry solids in washed soil to the combined mass of dry solids in washed soil and fines slurry. Normalized data minimize the effect that potential biases in the total solids balance could have on this evaluation. Average washed soil recoveries on a normalized basis of 90%, 88%, and 86% were determined for Conditions 1, 2, and 3, respectively. These recoveries exceed the project objectives that at least 80% of the solids present in the feed soil would be returned to the site as washed soil.

Mass balances are obtained by comparing the mass entering a system to the mass exiting the system. The mass balance closures calculated for the VRU demonstration are summarized in Table 3.

For the total material balance, the recovery is the percentage of the material entering the system as feed soil and wash water that was recovered from the system as washed soil and fines slurry. The project objective for the total material balances was that closures would be between 90% and 110%. A review of balance closures reveals that acceptable performance criteria were met for Conditions 1 (104%) and 3 (98%) but not Condition 2 (113%). During Condition 2, it was noted that the mass flow rate measurement of the fines slurry may have been affected by sampling procedures employed during the demonstration. This resulted in inflated mass flow rates. The procedure was modified and the percent closures dropped to the acceptable range. Dry solids recoveries during the VRU demonstration were 107%, 109% and 94% for Conditions 1, 2, and 3, respectively, which meet project objectives of recoveries between 85% and 115%.

Under Condition 1, the average mass balance closures for PCP and PAHs were 101% and 87%, respectively. The average PCP and PAH recoveries for Conditions 2 and 3 were below 80% and therefore did not meet the project objectives. Because low PCP and PAH closures were experienced when surfactant was added to the wash water, it seems probable that the surfactant interfered with the PCP and PAH analyses.

The VRU's effectiveness is based on its ability to separate soil fines [less than 100 mesh (0.15 mm)] from the coarser gravel and sand fraction of the soil [greater than 100 mesh (0.15 mm)]. Significant contaminant concentration reductions can be realized by the VRU, provided the majority of the contaminants present in the feed soil concentrate in the fines. Table 4 indicates the percentage of fines and coarse sand and gravel fraction from the feed soil recovered in the washed soil and fines slurry. The data indicate the majority of the small particles were partitioned to the fines slurry.

Pollutants were removed from the fines slurry stream by a water treatment sequence that included settling, flocculation, filtration, and carbon adsorption. Following treatment in the CPI, where the fines were separated by gravity, the overflow was pumped to a flocculation/clarification system for additional fines partitioning. CPI and floc tank underflow streams were collected and were to be analyzed for PCP and PAHs; however, problems with the analysis produced data of limited usefulness. Clarified water from floc tank overflow was pumped through cartridge polishing filters operated in parallel to remove soil fines greater than 4×10^{-4}. Water exiting these filters then passed through activated carbon drums for hydrocarbon removal. The clarified water was analyzed for total organic carbon (TOC) and total residue (TR), which is the sum of total suspended solids (TSS) and total dissolved solids (TDS). Table 5 lists the TOC levels of the clarified water, water from the filters and activated carbon, and feed water. Table 6 lists the TR levels from the clari-

Table 3. Average Mass Balance Closures (%)

	Total Material	Dry Solids	PCP	PAHs
Condition 1	104	107	94	88
Condition 2	113	109	19	28
Condition 3	98	94	13	14

Table 4. Distribution of Fines and Coarse Gravel and Sand (%, dry weight basis)

	Fines			Coarse Sand and Gravel		
Condition	1	2	3	1	2	3
Washed Soil	31	41	54	104	102	82
Fines Slurry	75	83	110	1	2	2
Closure	106	124	164	105	104	84

fied water, water from the filters and activated carbon, and feed water.

TOC reduction was affected significantly when surfactant was introduced into the system during Conditions 2 and 3. The efficiency was affected because surfactant was adsorbed on the carbon along with the contaminants. Instead of having the carbon available to adsorb the contaminants, many of the adsorption sites were occupied by the surfactant. Unadsorbed contaminants exited the carbon drum, which caused an increase in TOC. TOC efficiency could be improved by removing the surfactant before it enters the carbon canisters or by using another organic removal technology. The TR reduction from the filter unit was minimal, indicating that a finer-sized filter is needed.

An economic analysis has been developed to estimate costs (not including profits) for a commercial treatment system. The analysis is based on the results of the SITE demonstration, which used the pilot- scale EPA VRU, operating at approximately 100 lb/h.

It is projected that the commercial unit will operate at 10-tph. The cost to remediate 20,000 tons of contaminated soil using a 10-tph VRU is estimated at $130 per ton if the system is online 90% of the time. Treatment costs increase as the percent online factor decreases. Projected unit costs for a smaller site (10,000 tons of contaminated soil) are $163 per ton; projected unit costs for a larger site (200,000 tons) are $101 per ton.

Conclusions and Recommendations

The VRU soil washing system successfully separated the contaminated soil into two unique streams: washed soil and fines slurry. The washed soil was safely returned to the site following treatment. The fines slurry, which carried the majority of the pollutants from the feed soil, underwent additional treatment to separate the fines from the water.

The demonstration was divided into three phases (Conditions 1, 2, and 3) that evaluated the performance of the VRU under varying wash water conditions. Under Condition 1, using only ambient temperature wash water with no additives, average PCP and PAH removal efficiencies were 80% and 75%, respectively. Under Condition 2, with the addition of surfactant to ambient temperature wash water, average PCP and PAH removal efficiencies improved to 92% and 85%, respectively. Under Condition 3, with the addition of surfactant and caustic (for pH adjustment) to the wash water at an elevated temperature, average PCP and PAH removal efficiencies of 98% and 96%, respectively, were achieved, exceeding the project objective of 90% removal.

The results show the positive impact that surfactant, pH adjustment, and increased temperature have on PCP and PAH removal efficiency. However, from these data it is not possible to determine whether pH adjustment, temperature, or both these factors caused the increased removal efficiency in Condition 3.

The ability of the VRU to produce washed soil that meets the target cleanup levels of 30 ppm PCP, 50 ppm carcinogenic creosote, and 100 ppm total creosote was also evaluated. The average washed soil contaminant concentrations for Condition 1 were 29 ppm PCP, 17 ppm carcinogenic creosote, and 240 ppm total creosote. Under Condition 2, washed soil contaminant concentrations improved to 12 ppm PCP, 10 ppm carcinogenic creosote, and 130 ppm total creosote. Under Condition 3, washed soil contaminant concentrations further improved to 3 ppm PCP, 2.8 ppm carcinogenic creosote, and 38 ppm total creosote.

Another primary objective of this SITE demonstration was to determine whether the VRU could recover 80% of the contaminated feed soil as clean washed soil. Washed soils recoveries of 96%, 95%, and 81% were calculated for Conditions 1, 2, and 3, respectively.

Washed soil recovery was also determined on a normalized basis that compared the mass of dry solids in washed soil to the combined mass of dry solids in washed soil and fines slurry. Average washed soil recoveries on a normalized basis of 89%, 88%, and 86% were determined for Conditions 1, 2, and 3. This indicates steady performance of the VRU in treating a uniform feed soil. The system consistently segregated the feed solids

Table 5. TOC Levels in Water Streams (ppm)

	Feed Water	Clarified Water	Post-Filtration Water	Post-Carbon Adsorption Water
Condition 1	<1.0	11.5	11	<1.0
Condition 2	<1.5	1,045	1,075	283
Condition 3	<1.02	825	697.5	305

Table 6. TR Levels in Water Streams (ppm)

	Feed Water	Clarified Water	Post-Filtration Water	Post-Carbon Adsorption Water
Condition 1	70	260	247.5	115
Condition 2	73	2,200	2,025	557.5
Condition 3	62	6,075	5,075	2,550

into washed soil and fines slurry, appearing to be unaffected by fluctuations in feed rate, W/F ratio, wash water additives, or other operating parameters.

Mass balances were calculated for total materials, total dry solids, total PCP, and total PAHs for each condition. Closure rates between 90% and 110% were achieved for Conditions 1 and 3 for total mass. Sampling procedures contributed to a less than acceptable total materials closure rate of 113% for Condition 2. Closure rates between 85% and 115% were achieved for Conditions 1, 2, and 3 for total dry solids. Mass balances for PCP and PAHs achieved closure rates of between 85% and 175% for Condition 1 only. Mass balances for Conditions 2 and 3 were considered invalid and attributed to surfactant addition that adversely affected the analyses.

The VRU is designed to return feed soil that is greater than 100 mesh (0.15 mm) in size as washed soil. The data from the demonstration indicate this soil is an ideal candidate for treatment by the VRU. Excellent results for partitioning the greater than 100- mesh (0.15-mm) particles (coarse sand and gravel) to the washed soil were achieved. Only 1% to 2% of these particles was detected in the fines slurry. A majority of less than 100-mesh (0.15-mm) particles (fines) were isolated in the fines slurry stream; however, the partitioning was not as complete.

PCP and PAH solid fraction data confirm that material from the CPI and floc/clarifier was highly contaminated. A more complete partitioning of the less than 100-mesh (0.15-mm) particles to the fines slurry may lead to decreased contaminant levels in washed soil and to increased removal efficiency. An additional series of unit operations, such as a trommel washer and dispersing agent (e.g., sodium hexametaphosphate) employed after the vibrascreens, may help reduce the level of fines in washed soil. The VRU was designed with the ability to recycle water treatment subsystem effluent to the miniwasher; however, water quality criteria for recycling have not been defined. Although the developer claimed that the effluent after water treatment would be of sufficient quality to permit recycling into the water tank for reuse as wash water, this claim was not evaluated during the demonstration. Prior to the demonstration, the developer chose to operate the VRU without recycling. The developer indicated that the CPI/floc tank did not settle out as much as expected, allowing more solids and TOC to pass through the filters and carbon. Based on the data presented in Tables 5 and 6, the treated water produced during Condition 1 is considered potentially suitable for recycling. The treated water produced during Conditions 2 and 3 contained significantly higher levels of TOC and TR and would likely require further treatment before it could be recycled. If the treated water cannot be reused as wash water, then it must be disposed of. Disposal options may include discharge to a local publicly-owned treatment works (POTW). Discharge to a POTW will typically be regulated according to the industrial wastewater pretreatment standards of the POTW. These standards are specified by EPA for certain industries. Depending on the site, the treated wash water may fall into one specific industrial category. If it does not, the pretreatment standards for the wash water will be determined by the POTW and will depend on site-specific parameters such as flow rate of the wash water, contaminants present, design of the POTW, and receiving stream water quality standards. The developer indicated that solids did not settle out in the CPI and floc/clarifier as much as expected, allowing more solids and organics to pass through the filters and carbon. Excessive solids may adversely affect the process by plugging water lines. The commercial-scale VRU proposed by EPA appears to be suited to the remediation of soils and other solid wastes contaminated with organic compounds. Treatment costs appear to be competitive with other available technologies. The cost to remediate 20,000 tons of contaminated soil using a 10-tph VRU is estimated at $130 per ton if the system is on-line 90% of the time. Treatment costs increase as the percent online factor decreases. Projected unit costs for a smaller site (10,000 tons of contaminated soil) are $163 per ton; projected unit costs for a larger site (200,000 tons) are $101 per ton.

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The complete report, entitled "Technology Evaluation Report: SITE Program Demonstration EPA RREL Mobile Reduction Unit"
(Order No. PB94-136264; 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 "Applications Analysis Report EPA RREL Mobile Volume Reduction Unit" (EPA/540/AR-93/508) is available as long as supplies last from:

ORD Publications
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