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SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

Technology Demonstration Summary

DuPont/Oberlin Microfiltration System Palmerton, Pennsylvania

In April and May 1990, the U.S. Environmental Protection Agency (EPA), under the Superfund Innovative Technology Evaluation (SITE) program, demonstrated DuPont/Oberlin's microfiltration system at the Palmerton Zinc Superfund (PZS) site in Palmerton, Pennsylvania. The microfiltration system combines DuPont's Tyvek® T-980 filter media with Oberlin's automatic pressure filter and is designed to remove solids larger than 0.1 μ in diameter from liquid wastes. The microfiltration system demonstrated at the PZS site was evaluated primarily in terms of its ability to remove metals (mainly zinc) and particulates from the contaminated groundwater on site, while producing a dry filter cake and filtrate that meet applicable disposal requirements.

The results showed that the microfiltration system achieved zinc and total suspended solids (TSS) removal efficiencies of about 99.95%, and a filter cake solids content of 41%. The filter cake contained no free liquids, and a composite sample from all the demonstration runs passed both the extraction procedure (EP) toxicity test and the toxicity characteristic leaching procedure (TCLP) test. The filtrate met all National Pollutant Discharge Elimination System (NPDES) permit limits for metals and TSS, but not for pH. The filtrate pH was typically 11.5, while the NPDES upper pH limit is 9.

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 at back).

Introduction

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the EPA's Office of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) have established a formal program to accelerate the development, demonstration, and use of new or innovative technologies that offer permanent, long-term cleanup solutions for hazardous wastes. This program is called the SITE program. One component of the SITE program is the demonstration program, through which EPA evaluates field- or pilot-scale technologies that can be scaled up for commercial use. The main objective of the demonstration program is to develop performance, engineering, and cost information for innovative technologies. This information may be used to compare the technology's effectiveness and cost to other alternatives in order to make sound judgements regarding the applicability of the technology for a specific site.

In February 1988, E.I. DuPont de Nemours & Company, Inc. (DuPont), and Oberlin Filter Company (Oberlin) submitted to EPA a joint proposal to demonstrate their microfiltration technology under the SITE program. EPA selected the DuPont/Oberlin microfiltration technology for demonstration under the SITE program in June 1988.

The demonstration was conducted at the PZS site in Palmerton, Pennsylvania, during April and May 1990. During the last 70 yr, zinc smelter operations have resulted in 33 million tons of zinc residue accumulating and forming an extensive cinder bank at the site. The cinder bank has contaminated surrounding areas, including groundwater and surface water. The shallow groundwater at the PZS site was selected for evaluating the microfiltration system. The groundwater is primarily contaminated with high levels of zinc (400 to 500 mg/L) and trace levels ($\leq$ 1 mg/L) of cadmium, copper, lead, and selenium.

The technology demonstration had four objectives:

- Assess the technology's ability to remove zinc from the groundwater under different operating conditions
- Evaluate the microfiltration system's ability to dewater the metals precipitate from the treated groundwater
- Determine the system's ability to produce a filtrate and filter cake that meet applicable disposal requirements
- Develop information required to estimate the operating costs for the treatment system, such as electrical power consumption and chemical doses

Technology Description

DuPont/Oberlin's microfiltration technology is designed to remove solids from liquid wastes. It is suitable for treating landfill leachate, groundwater, and liquid industrial wastes containing metals. Since the microfiltration system is designed to remove particles down to 0.1 μ in diameter, dissolved contaminants must first be converted to a particulate form. For example, groundwater with dissolved metals must first be treated with a precipitating agent, such as lime, to convert the dissolved metals into particulate form, such as metal hydroxides. After the dissolved metals are converted to a particulate form, the liquid waste can be filtered through the microfiltration unit.

The microfiltration unit produces two end products: filter cake and filtrate. To produce a filter cake that has a low moisture content and a filtrate that has a low solids content, DuPont/Oberlin normally uses a filter aid or filter aid/cake stabilizing agent. For the SITE demonstration, DuPont selected a silicate-based filter aid/cake stabilizing agent known as ProFix, which is manufactured by EnviroGuard, Inc., of Houston, Texas.

A schematic of the DuPont/Oberlin microfiltration unit is shown in Figure 1. This microfiltration unit is an automatic pressure filter (APF) that operates on pressure signals and uses a low-cost, Tyvek® T-980 membrane filter (Tyvek®), a thin, durable spunbonded olefin fabric developed by DuPont. The APF, developed by Oberlin, has two chambers—an upper chamber for feeding waste through the filter media, and a lower chamber for collecting the filtrate. The Tyvek® filter lies between these two chambers. The APF unit used in the demonstration was 64 in. long, 33 in. wide, and 83 in. high. It weighed approximately 1,300 lb and had a filtering area of 2.4 sq ft. The system can be manufactured as an enclosed unit, requires little attention during operation, is mobile, and can be trailer-mounted. A typical configuration of the DuPont/Oberlin microfiltration system (including pretreatment of dissolved metals) is shown in Figure 2.

A typical microfiltration cycle consists of four steps: (1) initial filtration, (2) main filtration and cake forming, (3) cake drying, and (4) cake discharge. The process begins with liquid waste being pumped, usually from a waste feed tank, into the upper chamber. During the first minute of filtration, or the initial filtration step, the filtrate is usually recycled to the waste feed tank. At the end of 1 min, when filter cake buildup is sufficient to produce a clear filtrate, recirculation stops and the main filtration step begins. During the main filtration step, solids continue to accumulate and form a cake on the Tyvek® while filtrate drains from the lower chamber to a filtrate collection tank. When the pressure drop across the filter is about 45 psig, the waste feed valve closes, pumping of liquid waste feed to the microfiltration unit stops, and the cake drying step begins. Pressurized air (typically, at a blowdown

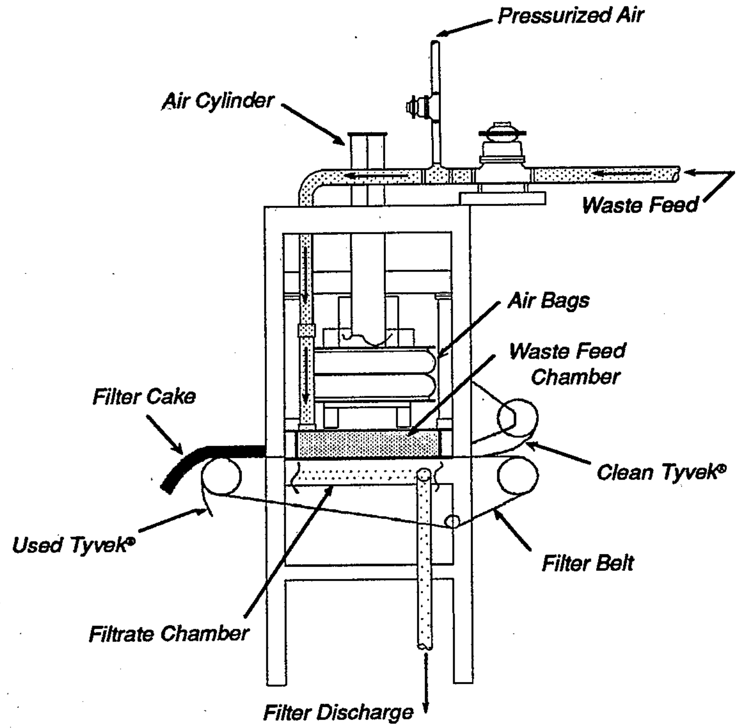

Figure 1. Schematic of DuPont/Oberlin microfiltration unit.

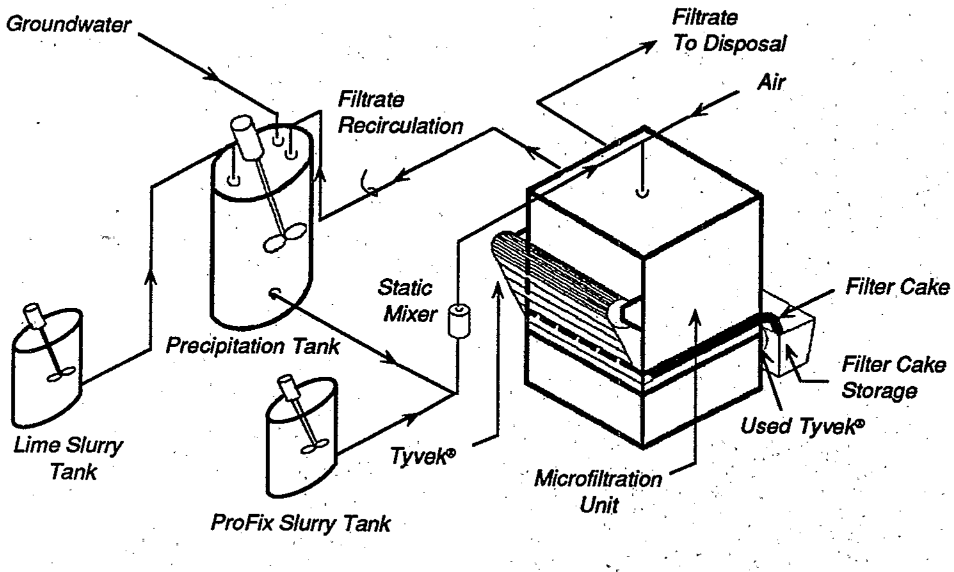

Figure 2. *DuPont/Oberlin microfiltration treatment system.*

pressure of 35 to 45 psig) is fed into the upper chamber to dry the cake. After air breaks through the cake, drying continues for a preset time, known as the blowdown time. During this step, any remaining liquid is forced through the Tyvek® and is recycled to the waste feed tank. Immediately following the cake drying step, the upper chamber is lifted, clean Tyvek® is drawn from a roll into the microfiltration unit for the next cycle, and the filter cake is discharged.

Demonstration Procedures

The procedures followed during the DuPont/Oberlin microfiltration technology demonstration were developed to evaluate the technology's effectiveness in treating contaminated groundwater from the PZS site. Groundwater samples from the PZS site were collected in June 1989 to characterize the groundwater and identify contaminants of concern for the technology demonstration. In July 1989, DuPont performed bench- and pilot-scale treatability studies. An additional study to refine the sampling and analytical techniques used during the pilot-scale study was conducted in October 1989. Based on the PZS site groundwater characteristics and the results of treatability tests, a demonstration plan was prepared detailing sampling, analytical, quality assurance, and health and safety procedures. Following EPA's approval of the demonstration plan, site preparation and equipment mobilization for the demonstration began in mid-March 1990. The actual demonstration of the DuPont/Oberlin microfiltration system began in April 1990. The demonstration was divided into three stages: (1) site preparation (2 weeks), (2) technology demonstration (4 weeks), and (3) site demobilization (2 weeks). The demonstration was completed in May 1990.

This section summarizes demonstration procedures, including the waste characterization, treatability studies, site preparation, and technology testing activities.

Waste Characterization

A detailed waste characterization was performed to (1) determine the metals concentration in the groundwater and (2) identify the levels of complexing agents (such as chloride, ammonia, cyanide, and sulfide) and oil and grease that could affect the microfiltration system's performance. Samples were collected from two onsite wells to characterize the groundwater. Groundwater samples indicated that the shallow groundwater was contaminated with high levels of zinc (400 to 500 mg/L) and trace levels of cadmium (1 mg/L), copper (0.02 mg/L), lead (0.015 mg/L), and selenium (0.05 mg/L). Neither complexing agents nor oil and grease were present at levels that could affect the microfiltration system's performance.

Treatability Studies

Treatability studies were conducted to evaluate treatment effectiveness and determine initial operating conditions for the microfiltration unit used for the SITE demonstration. Using groundwater from the PZS site, DuPont/Oberlin performed bench-scale treatability studies to (1) test several precipitating agents and filter aids that could be used to pretreat the groundwater and (2) develop initial operating conditions for pilot-scale studies. Groundwater from two onsite wells was mixed in equal volumes for the studies. During the bench-scale studies, a jar test apparatus precipitated the metals, and a vacuum filtration apparatus with a 0.45-μ membrane filter dewatered the metals precipitate. The results indicated that the DuPont/Oberlin process could meet applicable limits for filtrate discharge into a local waterway.

Following the bench-scale treatability studies, pilot-scale studies were performed using the same batch of groundwater. The purposes of the pilot-scale studies were to (1) select precipitating agent(s) and filter aid(s) and (2) develop initial operating conditions for the demonstration. The pilot-scale studies involved 10 experiments on a 0.0845-sq ft microfiltration unit, followed by two test runs using a 2.4-sq ft unit. The results showed (1) greater than 99% metals removal from groundwater, (2) a TSS concentration of 44 mg/L, and (3) 34% solids in the filter cake. Operating conditions were as follows: a precipitation pH of 10, a filter aid (EnviroGuard) dose of 11.1 g/L, a blowdown pressure of 45 psig, and a blowdown time of 2 min. These operating conditions were used to design an experimental matrix for the SITE demonstration.

Site Preparation

After a suitable location was selected for the demonstration at the PZS site, required support services, facilities, and equipment were ordered and installed. Specifically, EPA arranged utility connections, ordered and rented specialty equipment, and supervised and directed installation.

Approximately 10,000 sq ft of relatively flat area was needed for the microfiltration system and support facilities, such as storage tanks, an office and field laboratory trailer, and a parking area. Crushed gravel was laid and compacted on the existing ground to form a level surface and minimize muddy conditions resulting from rain or snow. A temporary enclosure covering approximately one half of the demonstration area was erected to provide shelter for the microfiltration system during inclement weather. To contain any spills during the demonstration, secondary containment was provided as needed. A 6-ft chain-link fence was constructed along the perimeter of the demonstration area to prevent unauthorized entry. Utilities required for the demonstration included water, electricity, and telephone service.

A week before the demonstration, about 6,000 gal of contaminated groundwater was collected for all the test runs to minimize variation in groundwater characteristics from run to run. The groundwater was stored in a 6,000-gallon waste feed tank located in the secondary containment area.

Technology Testing

After the site was prepared and the microfiltration unit and support facilities were installed, DuPont/Oberlin conducted startup testing of its demonstration equipment. During startup, the microfiltration system and connected support facilities were checked for leaks and proper operation.

The demonstration testing program involved evaluating (1) the performance of the microfiltration system by varying the chemical parameters (pH and filter aid/cake stabilizing agent dose) and filter parameters (blowdown pressure and blowdown time), (2) the reproducibility of the microfiltration system performance, and (3) the reusability of the Tyvek® filter media. The experimental program was carried out in four phases. In Phase 1, chemical operating parameters were varied, and the filter operating parameters were kept constant. In Phase 2, the filter operating parameters were varied, and the chemical operating parameters were kept constant. Phase 3 runs were performed to evaluate the reproducibility of the microfiltration system's performance. Phase 4 runs were performed to evaluate the reusability of the Tyvek® filter.

Figure 3 summarizes the operating conditions for the demonstration runs. During the demonstration, the optimum chemical operating conditions and filter operating conditions were determined in Phases 1 and 2, respectively. Run 5 conditions were selected as the optimum operating conditions for Phase 1; these were set as the chemical operating conditions for Phase 2. Phases 3 and 4 were performed at Run 13 conditions because these conditions were selected as the overall optimum chemical and filter operating conditions. This experimental design assumed that the chemical and filter operating parameters do not interact. Although this assumption is not critical to evaluating the microfiltration system based on the technology demonstration objectives, the technology developers agreed with this assumption based on their experience.

Liquid and solid samples were collected from several locations in the treatment system. Sampling locations for liquids included the (1) influent (raw groundwater) line to the precipitation tank; (2) influent line to the microfiltration unit; and (3) filtrate line from the collection tank. The filter cake solids were sampled directly from the microfiltration unit. EPA-approved sampling, analytical, quality assurance and quality control procedures were followed to obtain reliable data. Details on these procedures are presented in the Demonstration Plan.

Table 1 identifies critical parameters measured during the demonstration. Metals and TSS were measured to estimate the removal efficiencies and determine whether the filtrate met the applicable discharge limits. Free liquids and moisture content of the filter cake were measured to determine whether the filter cake passed the paint filter liquids test (that is, it contained no free liquids) and to determine the percent solids in the filter cake, respectively. In addition, pH was measured to control the precipitation pH and determine whether the filtrate met applicable discharge limits.

Results

This section summarizes the analytical results for critical parameters for the overall optimum condition runs (13, 19, 20, 21, and 22).

The total zinc concentration in the untreated groundwater in Runs 19 and 20 (reproducibility runs performed at Run 13

Table 1. *Critical Parameters*

Solids	*Liquids*
• *Free Liquids*	• *Metals (total and dissolved)*
• *Metals (total zinc)*	• *Total Suspended Solids*
• *Moisture Content*	• *pH*

Run No.	*Precipitation pH*	*ProFix Dose (g/L)*	*Blowdown Time (min)*	*Blowdown Pressure (psig)*
Phase 1 Chemical Parameter Runs				
1	8	6	*Blowdown Time = 2*	*Blowdown Pressure = 45*
2	9	6		
3	10	6		
4	8	12		
5	9	12		
6	10	12		
7	8	14		
8	9	14		
9	10	14		
Phase 2 Filter Parameter Runs				
10	*pH = 9*	*ProFix Dose = 12*	0.5	30
11			2	30
12			3	30
13			0.5	38
14			2	38
15			3	38
16			0.5	45
17			2	45
18			3	45
Phase 3 Performance Reproducibility Runs*				
19	*pH = 9*	*ProFix Dose = 12*	*Blowdown Time = 0.5*	*Blowdown Pressure = 38*
20				
Phase 4 Tyvek® Reusability Runs*				
21	*pH = 9*	*ProFix Dose = 12*	*Blowdown Time = 0.5*	*Blowdown Pressure = 38*
22				

* *Performed at Run 13 Conditions*

Figure 3. *Operating conditions for the demonstration runs.*

operating conditions) was 465 mg/L. Following treatment, zinc concentrations were reduced by 99.95% and 99.94%, resulting in 0.24 and 0.28 mg/L of zinc in Runs 19 and 20, respectively. These removal efficiencies agree with the removal efficiency achieved in Run 13 (99.95%), indicating that the microfiltration system's performance in removing zinc was reproducible.

The TSS concentrations in the influent to the microfiltration unit were 14,300 and 14,000 mg/L in Runs 19 and 20, respectively. Following treatment, these concentrations were reduced by 99.95%, resulting in 7.7 and 6.8 mg/L of TSS in Runs 19 and 20, respectively. This removal efficiency also agrees with the TSS removal efficiency observed in Run 13 (99.91%), indicating that the system's performance in removing TSS was reproducible.

Figure 4 compares regulatory thresholds with (1) the 95% upper confidence limits (UCL) for filtrate metals (cadmium, lead, and zinc) and TSS and (2) the filtrate pH level most frequently measured for Runs 13, 19, and 20. The regulatory thresholds are those that would need to be met for discharge into a local waterway (Aquashicola Creek) if a NPDES permit were required. The UCLs were calculated using the one-tailed Student's t-test. To calculate UCLs for cadmium and lead, which were present below detection limits, mean concentrations were estimated using standard statistical procedures. Figure 4 shows that the filtrate met the NPDES limits for metals and TSS. However, the NPDES upper limit for pH was not met.

The filter cake passed the paint filter liquids test for all test runs. Average percent solids in the filter cake ranged from 41.2 in Run 19 to 42.1 in Run 20. Of these solids, about 80% to 90% were from the filter aid/cake stabilizing agent, ProFix, and the remaining were from (1) TSS present in the untreated groundwater, (2) metals precipitated during pretreatment, and (3) any unreacted lime from pH adjustment.

As a quality control check, a mass balance was performed for zinc and TSS in Runs 19 and 20. The difference between zinc entering and leaving the system was about 15%, which is within the analytical precision for zinc measurement (± 25%). Similarly, TSS measurements were also found to be within analytical precision (± 30%).

The results for zinc, TSS, and cake solids for Runs 21 and 22 (Tyvek® reusability runs) are presented in Figure 5. In these runs, the same portion of Tyvek® was used repeatedly for six cycles. Samples were composited after the first three cycles (Run 21) and the last three cycles (Run 22). Figure 5 shows that the microfiltration unit's performance was unaffected even after multiple uses of the Tyvek®.

Costs

The costs associated with the DuPont/Oberlin microfiltration technology have been estimated for the 12 cost categories typically applicable to cleanup activities at Superfund and Resource Conservation and Recovery Act (RCRA) corrective action sites. These costs are presented in Table 2 for a 2.4-sq ft unit (demonstration unit) and a 36-sq ft unit (largest available), along with annual operating and maintenance costs and one-time costs. The costs presented in Table 2 are considered order-of-magnitude (-30% to +50%) estimates.

Conclusions

Based on the results from the SITE program demonstration of DuPont/Oberlin's microfiltration system, the fol-

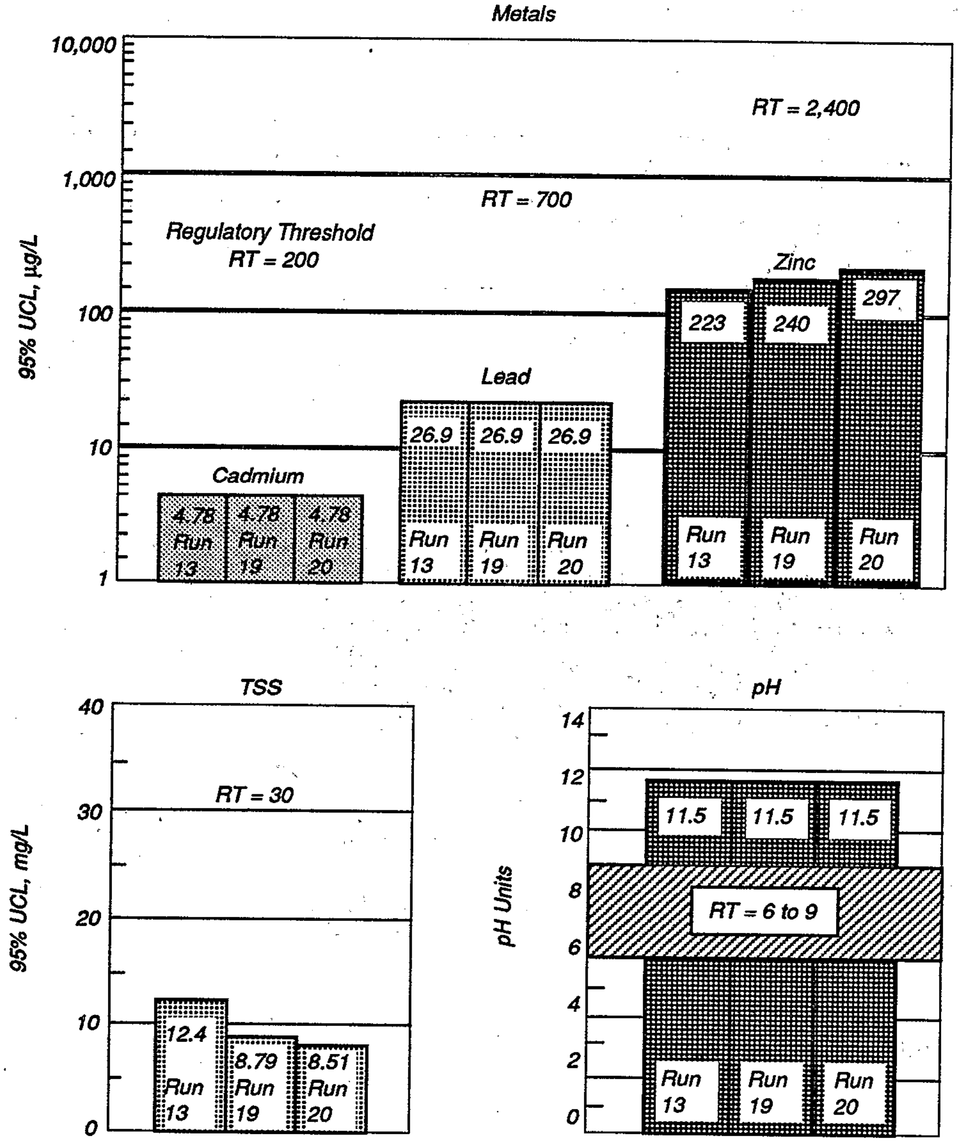

Figure 4. *Comparison of filtrate quality for reproducibility runs with regulatory thresholds.*

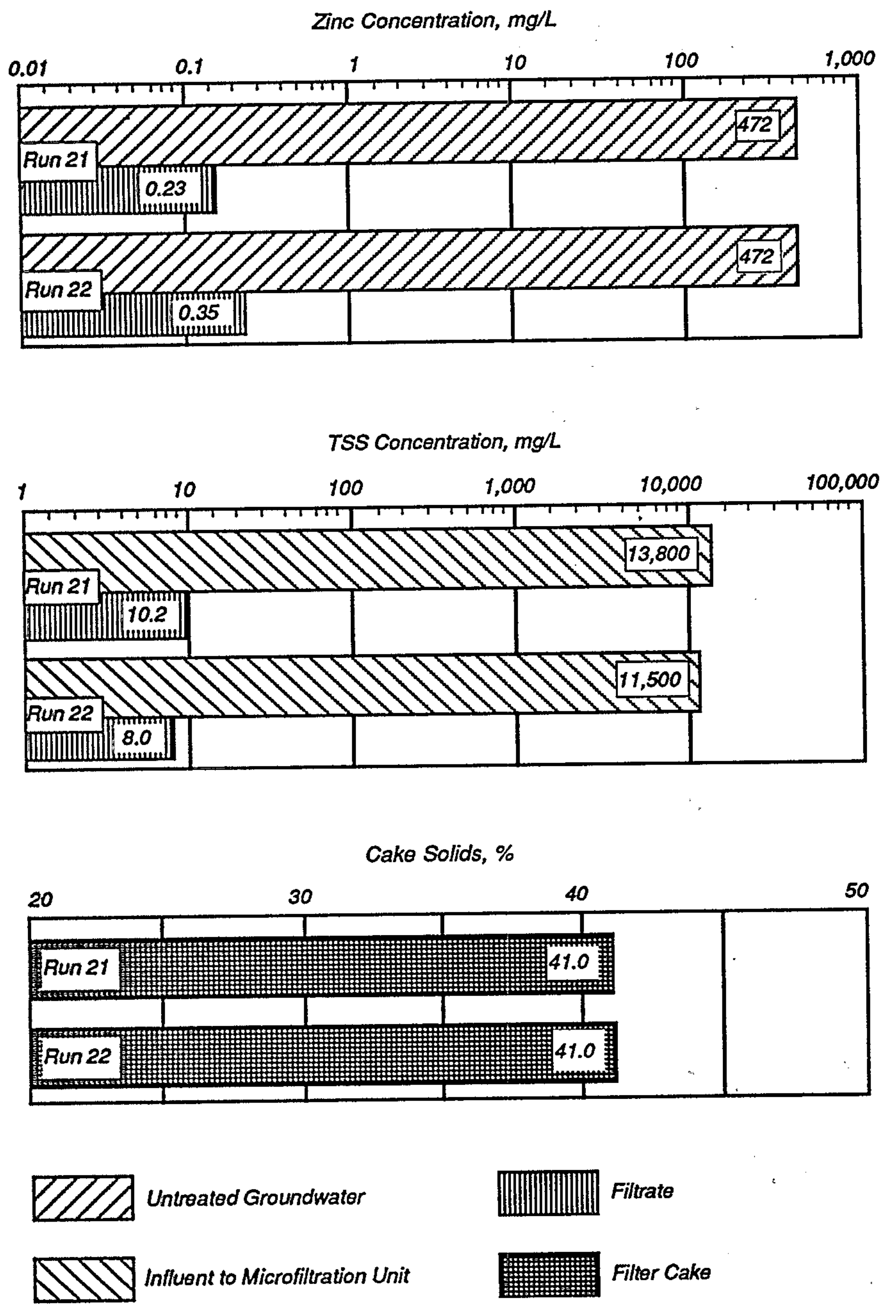

Figure 5. Tyvek performance for reusability runs.

lowing conclusions about the technology's ability to treat groundwater at the PZS site were drawn.

- The DuPont/Oberlin microfiltration system achieved zinc and TSS removal efficiencies of 99.69% to 99.99% and produced filter cakes with 30.5% to 47.1% solids. Under optimum conditions, zinc and TSS removal efficiencies were about 99.95% and the filter cake solids were about 41%.
- The filter aid/cake stabilizing agent, ProFix, contributed a significant portion (80% to 90%) of solids to the filter cake. The remaining solids were due to precipitated metals, TSS from the untreated groundwater, and any unreacted lime.
- The zinc and TSS removal efficiencies and the filter cake percent solids were unaffected by the repeated use (6 cycles) of the Tyvek® filter media. This indicates that the Tyvek® media could be reused without adversely affecting the microfiltration system's performance.
- The filtrate met the applicable NPDES permit limits for metals and TSS at the 95% confidence level. However, the filtrate did not meet the NPDES upper permit limit for pH. The filtrate pH was typically 11.5, while the upper permit limit for pH is 9.
- The filter cake passed the paint filter liquids test for all runs. Also, a composite filter cake sample from the demonstration runs passed the extraction procedure (EP) toxicity and toxicity characteristic leaching procedure (TCLP) tests.

Table 2. Estimated Costs Associated with DuPont/Oberlin Microfiltration Systems

Cost Categories	Estimated Costs (1990 $) 2.4 sq ft[a]	36 sq ft[a]
Site Preparation[b]	209,200	843,200
Permitting and Regulatory[b]	2,300	11,200
Capital Equipment[b]	47,800	231,800
Startup and Fixed[b]	80,000	80,000
Labor[c]	133,400	133,400
Supplies and Consumables[c]	16,900	220,000
Utilities[c]	5,500	82,500
Effluent Monitoring[c]	15,000	15,000
Residuals and Waste Shipping, Handling, and Transporting[c]	3,700	55,200
Analytical[c]	36,000	36,000
Equipment Repair and Replacement[c]	2,500	7,000
Site Demobilization[b]	30,000	85,000
Total One-Time Costs	369,300	1,251,200
Total Annual Operation and Maintenance Costs	213,000	549,100

Notes: [a] During a 1-yr period, it is assumed that the 2.4-sq ft unit will treat about 525,600 gal and the 36-sq ft unit will treat about 7,884,000 gal.
[b] One-time costs.
[c] Annual operation and maintenance costs.

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The complete report, entitled "Technology Evaluation Report: SITE Program Demonstration of the DuPont/Oberlin Microfiltration Technology" (Order No. PB92-153 410; Cost: $26.00, subject to change) discusses the results of the SITE demonstration.

This report 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: DuPont/Oberlin Microfiltration Technology" (EPA/540/A5-90/007 dated October 1991), discusses the applications and costs.

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