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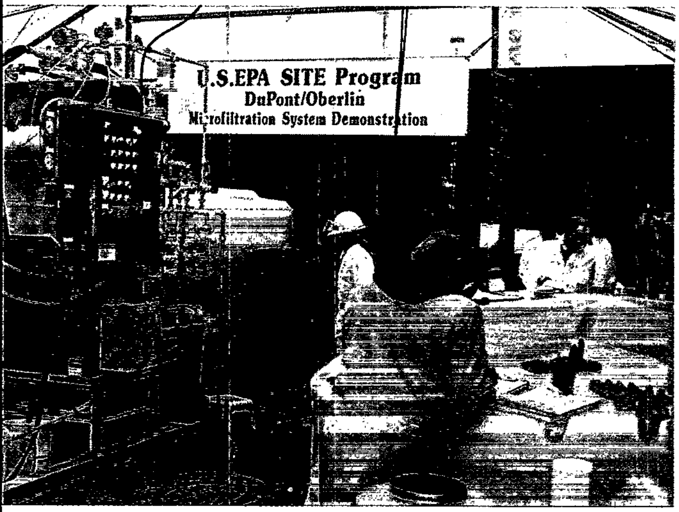
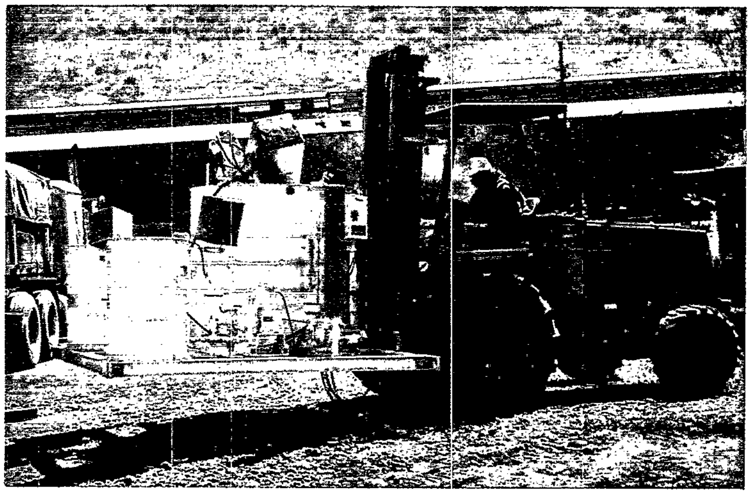
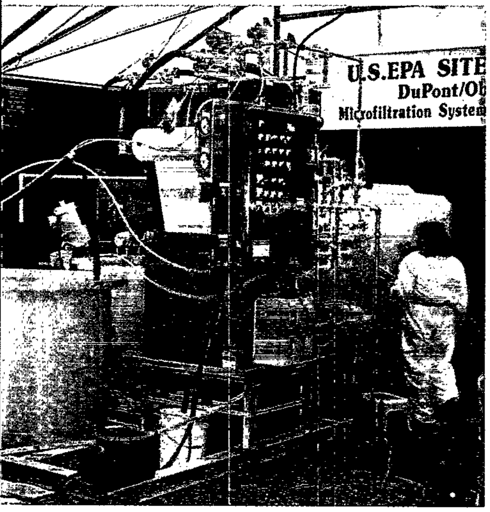
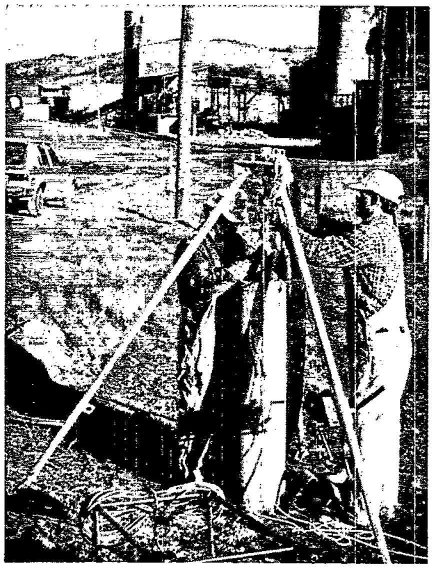
E. I. DuPont De Nemours & Company/Oberlin Filter Company Microfiltration Technology

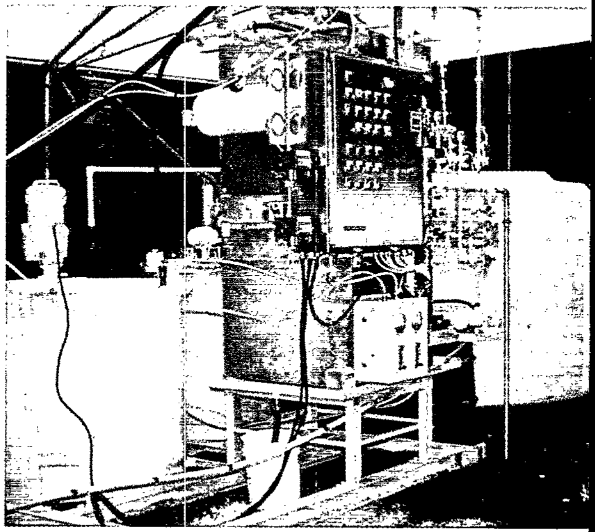
Applications Analysis Report











SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

EPA/540/A5-90/007
October 1991

DuPont/Oberlin Microfiltration Technology

Applications Analysis Report

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

The information in this document has been prepared for the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) program under Contract No. 68-C0-0047. This document has been subjected to the Agency's peer and administrative reviews and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

Foreword

The Superfund Innovative Technology Evaluation (SITE) program was authorized in the 1986 Superfund Amendments and Reauthorization Act (SARA). 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 which require greater reliance on permanent remedies. This is accomplished through technology demonstrations which are designed to provide engineering and cost data on selected technologies.

This project is a field demonstration under the SITE program and is designed to evaluate the DuPont/Oberlin microfiltration technology. The technology demonstration took place at a former zinc smelting facility in Palmerton, Pennsylvania. The demonstration effort was directed to obtain information on the performance and cost of the technology and to assess its use at this and other uncontrolled hazardous waste sites. Documentation consists of two reports: (1) a Technology Evaluation Report that describes the field activities and laboratory results; and (2) this Applications Analysis Report that provides an interpretation of the data and discusses the potential applicability of the technology.

A limited number of copies of this report will be available at no charge from EPA's Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268. Requests should include the EPA document number found on the report's cover. When the limited supply is exhausted, additional copies can be purchased from the National Technical Information Service, Ravensworth Building, Springfield, Virginia 22161, (703) 487-4600. Reference copies will be available at EPA libraries in the Hazardous Waste Collection. You can also call the SITE Clearinghouse hotline at (800) 424-9346 or (202) 382-3000 in Washington, D.C., to inquire about the availability of other reports.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

Abstract

This report evaluates the DuPont/Oberlin microfiltration technology's ability to remove metals (present in soluble or insoluble form) and particulates from liquid wastes while producing a dry filter cake and a filtrate that meet applicable disposal requirements. This report also presents economic data from the Superfund Innovative Technology Evaluation (SITE) demonstration and, as available, three case studies.

The DuPont/Oberlin microfiltration technology combines Oberlin's automatic pressure filter with DuPont's new microporous Tyvek® filter media. It is designed to remove particles that are 0.1 micron in diameter, or larger, from liquid wastes, such as contaminated groundwater. Groundwater with dissolved metals must first be treated to convert the dissolved metals into an insoluble form prior to microfiltration.

The DuPont/Oberlin microfiltration technology demonstration was conducted under the SITE program at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania, in April and May 1990. During the demonstration, the microfiltration system achieved zinc and total suspended solids (TSS) removal efficiencies of about 99.95 percent, and a filter cake solids content of 41 percent. The filter cake contained no free liquids, and a composite sample from all the demonstration runs passed both the extraction procedure toxicity test and the toxicity characteristic leaching procedure (TCLP) test. The filtrate met applicable National Pollutant Discharge Elimination System permit limits for metals and TSS but not for pH; the filtrate pH was typically 11.5 while the upper pH limit is 9.

The results from three case studies are also summarized in this report. All three facilities treated process wastewaters containing metals and TSS ranging from several parts per million to several percent. The filtrates at all three facilities met their respective discharge limits. Filter cake at one facility is a mixed waste and is further stabilized and solidified with cement prior to land disposal. At another facility, filter cake did not pass the TCLP test and is considered a hazardous waste. No filter cake information was available from the third facility.

Possible sites for applying this technology include Superfund and other hazardous waste sites that have groundwater and other liquid wastes contaminated primarily with metals and particulates. Sources of metal-bearing wastes include electroplating and metal finishing facilities, electronic component manufacturers, aluminum and other metal forming facilities, and uranium processing facilities. Economic data indicate that the capital costs for only the microfiltration unit and ancillary equipment are $48,000 for a 2.4-square foot unit and about $232,000 for a 36-square foot unit. Annual operation and maintenance (O&M) costs (including analytical, labor, and disposal costs) are estimated to be about $213,000 for the smaller unit and $549,100 for the larger unit, with corresponding annual throughputs of 525,600 gallons and 7,884,000 gallons.

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Acknowledgments

This report was prepared under the direction and coordination of Mr. John Martin, U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Project Manager and Demonstration Section Chief in the Risk Reduction Engineering Laboratory (RREL), Cincinnati, Ohio. Contributors and reviewers for this report were Ms. Linda Fiedler of EPA's Office of Solid Waste and Emergency Response, Washington, D.C.; Mr. Gordon Evans, Mr. Paul dePercin, and Mr. Robert Stenburg of EPA RREL, Cincinnati, Ohio; Dr. Ernest Mayer of E.I. DuPont de Nemours and Company, Inc., Newark, Delaware; and Dr. Thomas Oberlin of the Oberlin Filter Company, Waukesha, Wisconsin.

This report was prepared for EPA's SITE program by Dr. Kirankumar Topudurti, Mr. Stanley Labunski, Mr. Andrew Suminski, Ms. Carla Buriks, Mr. Michael Keefe, and Mr. Jack Brunner of PRC Environmental Management, Inc.

Section 1
Executive Summary

Introduction

The DuPont/Oberlin microfiltration technology was evaluated under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) program. The DuPont/Oberlin microfiltration technology demonstration was conducted at the Palmerton Zinc Superfund (PZS) site in Palmerton, Pennsylvania, during April and May 1990. This technology is designed to remove solids that are 0.1 micron in diameter, or larger, from liquid wastes. Liquid wastes with dissolved contaminants (for example, groundwater with dissolved metals) must first be treated with a precipitating agent to convert the dissolved contaminants into particulate form. The treated waste can then be filtered through the microfiltration unit, which produces two end products: filter cake and filtrate. Prior to filtration, a filter aid/cake stabilizing agent may be added to improve the filter cake's dewatering characteristics and bind the precipitated metals to the cake. The microfiltration unit can be manufactured as an enclosed unit, requires little attention during operation, is transportable, and can be trailer mounted.

The technology demonstration had the following four objectives:

1. Assess the technology's ability to remove zinc from the groundwater at the PZS site under different operating conditions
2. Evaluate the microfiltration system's ability to dewater the metals precipitate from the treated groundwater at the PZS site
3. Determine the system's ability to produce a filtrate and a filter cake that meet applicable disposal requirements
4. Develop information required to estimate the operating costs for the treatment system

The purpose of this report is to present information from the SITE demonstration and several case studies that are useful for implementing the DuPont/Oberlin microfiltration technology at Superfund and Resource Conservation and Recovery Act (RCRA) hazardous waste sites. Section 2 presents an overview of the SITE program, describes the DuPont/Oberlin microfiltration technology, and lists key contacts. Section 3 discusses information relevant to the technology's application, including pre- and post-treatment requirements, site characteristics, operating and maintenance requirements, potential community exposures, and potentially applicable environmental regulations. Section 4 summarizes the costs associated with implementing the technology. Appendices A through C include the following: the vendor's claims regarding the automatic pressure filter and microporous Tyvek® filter material, a summary of the SITE demonstration results, and three case studies.

Overview of the SITE Demonstration

The shallow groundwater at the PZS site was selected as the waste stream for evaluating the DuPont/Oberlin microfiltration system. This groundwater was primarily 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). The pH and alkalinity of the groundwater were about 4.5 and 15 mg/L as calcium carbonate, respectively.

During the SITE demonstration, the microfiltration system treated about 6,000 gallons of shallow groundwater from well RCRA-4. Lime was added to the groundwater to raise the pH and precipitate the dissolved metals. A filter aid/cake stabilizing agent, called ProFix, was also added to the pretreated groundwater prior to microfiltration.

The SITE demonstration was performed in four phases and was designed to evaluate the microfiltration system's ability to remove zinc from the groundwater, produce a dry filter cake, and produce a filtrate and a filter cake that met regulatory disposal requirements. Phases 1 and 2 involved nine runs each, and Phases 3 and 4 involved two runs each. In Phase 1, chemical operating parameters (pH and ProFix dose) were varied, while the filter operating parameters (blowdown pressure and blowdown time) were kept constant. In Phase 2, the filter operating parameters were varied, while the chemical operating parameters were kept constant. Phases 3 and 4 were performed at the overall optimum operating conditions determined during Phases 1 and 2. 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 material.

Results from the SITE Demonstration

The following operating conditions from Phases 1 and 2 were determined to be the overall optimum operating conditions for the demonstration: a precipitation pH of 9, a ProFix dose of 12 g/L, a blowdown pressure of 38 psig, and a blowdown time of 0.5 minute. At these optimum conditions, the microfiltration system achieved zinc and total suspended solids (TSS) removal efficiencies of about 99.95 percent and a filter cake solids content of 41 percent. The zinc and TSS removal efficiencies, and the filter cake solids content, were unaffected by the repeated use (six cycles) of the Tyvek® filter material. This indicates that the Tyvek® filter media could be reused without adversely affecting the microfiltration system's performance.

The filter cake passed the paint filter liquids test in all the demonstration runs. Also, a composite filter cake sample from the 22 demonstration runs passed both the extraction procedure toxicity and toxicity characteristic leaching procedure (TCLP) tests. This indicates that the filter cake could be disposed of in a non-hazardous waste landfill. ProFix comprised between 80 and 90 percent of the filter cake solids. The remaining solids consisted of precipitated metals, TSS from the groundwater, and any unreacted lime.

The filtrate met the applicable National Pollutant Discharge Elimination System (NPDES) permit limits, established for disposal into a local waterway, for metals and TSS at the 95 percent confidence level. However, the filtrate did not meet the NPDES limit for pH. The filtrate pH was typically 11.5, while the upper pH limit is 9. This indicates that the filtrate may require pH adjustment prior to disposal.

Results from the Case Studies

Information on the DuPont/Oberlin microfiltration technology's performance at three facilities was evaluated to provide additional performance data. These facilities were:

1. Westinghouse Savannah River Site, Aiken, South Carolina
2. DuPont Electronics Materials, Inc., Manati, Puerto Rico
3. DuPont Electronics, Sun Valley, California

Facility 1 treats process wastewaters from metal finishing and aluminum forming operations and from an autoclave testing operation. Wastewaters from the first two operations contain 3 mg/L of uranium, 180 mg/L of aluminum, 12 mg/L of nickel, and generally low levels of lead, chromium, copper, and zinc, mostly in dissolved form. These wastewaters undergo equalization, precipitation, flocculation, and microfiltration. Wastewater from the autoclave operation contains 16 mg/L of uranium oxides and undergoes only equalization and microfiltration. Prior to microfiltration, a filter aid (PerFLO 30SP) and a cationic polymer (Praestol K144L) are added to the pretreated waste. The filtrate meets all NPDES permit limits (uranium, other metals, pH, and TSS). The filter cake is a mixed waste containing both hazardous and radioactive material. Prior to disposal, the filter cake is stabilized and solidified with cement and is subject to land disposal restrictions.

Facility 2 produces about 2,000 gallons per day of wastewater containing 1,000 to 5,000 parts per million (ppm) of glass particulate matter, called frit, and 2,000 to 10,000 ppm of TSS. This wastewater does not require pretreatment; however, prior to microfiltration, a volcanic aluminum silicate filter aid and an organic polymer are added to the wastewater. After microfiltration, the filtrate passes through two cartridge filters arranged in series. These additional filters, rated at 10 microns and 1 micron, are provided to ensure high removal of particulates. According to the facility, the microfiltration system removes nearly all particulate matter.

Facility 3 generates wastewater from its ceramic powder manufacturing process. Wastewater characteristics vary daily, depending on the specific operations performed. Generally, the wastewater contains, a mixture of metal oxides and titanates. Lead and TSS levels typically range from 0.5 to 5 percent. Pretreatment is not needed since most metals are in the form of suspended solids. However, prior to microfiltration, a diatomaceous earth filter aid and a polymer (Praestol K122L) are added to improve the cake solids content and its dewatering characteristics. The filtrate meets all local sewer discharge limits and contains typically 0.2 to 0.4 ppm of soluble lead and 5 ppm of TSS. The filter cake contains about 50 percent solids, but it is considered a hazardous waste based on TCLP test results. DuPont plans to use ProFix in lieu of diatomaceous earth to eliminate off-site stabilization and reduce operating costs.

Operating and maintenance costs are minimal at all three facilities, and no major operating problems have been cited.

Waste Applicability

The DuPont/Oberlin microfiltration technology can be applied to groundwater and industrial wastewaters containing metals in particulate form and other suspended solids. Metals in dissolved form must first be converted to an insoluble form prior to microfiltration. Potential sites for applying this technology to contaminated groundwater include Superfund and RCRA corrective action sites where groundwater is contaminated with metals from electroplating/metal finishing wastes, semiconductor and other electronic component manufacturing waste streams, metal forming and uranium manufacturing wastes, and other sources of metal-bearing wastes.

Economics

An economic analysis was performed that examined 12 separate cost categories for two microfiltration systems: a 2.4-square foot unit, similar to the unit used during the SITE demonstration, and a 36-square foot unit, the largest unit currently in use. This analysis assumed that the microfiltration systems would operate continuously (24 hours per day, 7 days per week) for 1 year. The economic analysis covered a 1-year period so that annual operation and maintenance (O&M) costs could be reliably estimated. Annual O&M costs were estimated to be $213,000 and $549,100 for the 2.4- and 36-square foot units, respectively, with corresponding annual throughputs of 525,600 gallons and 7,884,000 gallons. The cost analysis assumes that the filter cake and filtrate will be disposed of as non-hazardous wastes. One-time capital costs were $369,300 for the smaller unit and $1,251,200 for the larger unit. Minimal cost data were available from the case studies presented in Appendix C. However, one of the case study facilities provided an O&M cost of $5 per 1,000 gallons of wastewater treated. This cost included electricity and expenses for replacing polymer, filter aid, and filter media.

Section 2
Introduction

This section provides background information about the Superfund Innovative Technology Evaluation (SITE) program, discusses the purpose of this applications analysis report, and describes the DuPont/Oberlin microfiltration technology. The persons to be contacted for additional information about this technology, the SITE program, and the demonstration site are listed at the end of this section.

Purpose, History, and Goals of the SITE Program

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), EPA's Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER) established the SITE program to (1) accelerate the development, demonstration, and use of new or innovative technologies to clean up Superfund sites, (2) foster further investigation and development of treatment technologies that are still at the laboratory scale, and (3) demonstrate and evaluate new or innovative measurement and monitoring technologies.

The primary purpose of the SITE program is to enhance the development and demonstration, and thereby promote the commercial availability, of innovative technologies applicable to Superfund sites. Major goals of the SITE program are to:

- Identify and remove impediments to the development and commercial use of alternative technologies
- Demonstrate the more promising innovative technologies in order to establish reliable performance and cost information for site cleanup decision making
- Develop procedures and policies that encourage selection of available alternative treatment remedies at Superfund sites
- Structure a development program that nurtures emerging technologies

EPA recognizes that a number of forces inhibit the expanded use of alternative technologies at Superfund sites. One of the objectives of the program is to identify these impediments and remove them or develop methods to promote the expanded use of alternative technologies.

Another objective of the SITE program is to demonstrate and evaluate selected technologies. This is a significant ongoing effort involving ORD, OSWER, EPA Regions, and the private sector. The demonstration program serves to test field-ready technologies and provide Superfund decision makers with the information necessary to evaluate the use of these technologies for future cleanup actions.

Other aspects of the SITE program include developing procedures and policies that match available technologies with wastes, media, and sites for actual remediation, and providing assistance in nurturing the development of emerging innovative technologies from the laboratory- or bench-scale to the full-scale stage.

Technologies chosen for a SITE demonstration must be innovative, pilot- or full-scale applications and offer some advantage over existing technologies. Mobile technologies are of particular interest. Each annual round of demonstrations includes approximately 10 technologies.

Documentation of the SITE Demonstration Results

The results of each SITE demonstration are incorporated in two documents: the technology evaluation report and the applications analysis report. The technology evaluation report provides a comprehensive description of the demonstration and its results. A likely audience for the technology evaluation report are engineers responsible for performing an in-depth evaluation of the technology for a specific site and waste situation. These technical evaluators seek to understand, in detail, the performance of the technology during the demonstration and the advantages, risks, and costs of the technology for the given application. This information is used to produce conceptual designs in sufficient detail for evaluators to make preliminary cost estimates for the demonstrated technology.

The applications analysis report is intended for technical decision makers responsible for screening available remedial alternatives. The principal use of the applications analysis report is to assist in determining whether the specific technology should be considered further as an option for a particular cleanup situation. The report discusses the advantages, disadvantages, and limitations of the technology in its broadest application. Costs of the technology for different applications are estimated based on available data for pilot- and full-scale applications. The report discusses the factors, such as site and waste characteristics, that have a major impact on cost and performance. If the candidate technology appears to meet the needs of the site engineers, a more thorough analysis will be conducted, based on the technology evaluation report, applications analysis report, and information from remedial investigations for the specific site.

Purpose of the Applications Analysis Report

To encourage the general use of demonstrated technologies, EPA will provide information on the applicability of each technology to certain sites and wastes, other than those already tested, and will study the costs of these applications. Available information and data are presented through the applications analysis reports. These reports attempt to synthesize available information on the technology and draw reasonable conclusions as to its broad range applicability. The applications analysis report is useful to those considering the technology for Superfund and other hazardous waste site cleanups and represents a critical step in the development and commercialization of the treatment technology.

Each SITE demonstration will evaluate the performance of a technology in treating a particular waste found at the demonstration site. To obtain data with broad applications, attempts will be made to select waste frequently found at other Superfund sites. In many cases, however, the waste at other sites will differ in some way from the waste tested. Thus, the successful demonstration of a technology at one site does not ensure that it will work equally well at other sites. Data obtained from the demonstration may have to be extrapolated to estimate the total operating range over which the technology performs satisfactorily. This extrapolation should be based upon both demonstration data and other information available from case studies about the technology.

The amount of available data for the evaluation of an innovative technology varies widely. Data may be limited to laboratory tests on synthetic wastes or may include performance data on actual wastes treated at pilot- or full-scale treatment systems. In addition, there are limits to conclusions regarding Superfund applications that can be drawn from a single field demonstration. A successful field demonstration does not necessarily ensure that a technology will be widely applicable or fully developed to a commercial scale.

Technology Description

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

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 (in soluble or insoluble form) and particulates. Since the microfiltration system is designed to remove particles that are 0.1 micron or larger 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 conducted at the PZS site during April and May 1990, DuPont selected a silicate-based filter aid/cake stabilizing agent known as ProFix, which is manufactured by EnviroGuard, Inc. of Houston, Texas.

The microfiltration 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 and principal treatment operations) to treat groundwater contaminated with dissolved metals is shown in Figure 2-1. Since the pretreatment operations (for example, pH adjustment and filter aid addition) of the microfiltration technology vary from one application to another, these operations are not described in this section. However, a discussion on pretreatment operations is presented in Section 3 under "Factors Influencing Effectiveness." Principal treatment operations of the microfiltration technology and its innovative features are described below.

Principal Treatment Operations

A schematic of the DuPont/Oberlin microfiltration unit is shown in Figure 2-2. This microfiltration unit is an automatic pressure filter that operates on pressure signals and uses a low-cost membrane filter, Tyvek® T-980, a thin, durable spunbonded olefin fabric developed by DuPont. The microfiltration unit, 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 upper chamber moves vertically, while the lower chamber is fixed. The Tyvek® filter lies between these two chambers. These units are available in several sizes: the smallest unit has a filtering area of 2.4 square feet and the largest unit has a filtering area of 36 square feet. According to the technology developers, about 40 percent of the units in operation have the 2.4-square foot filtering area. The unit used in the SITE demonstration also has a filtering area of 2.4 square feet and is 64 inches long, 33 inches wide, 83 inches high, and weighs approximately 1,300 pounds.

A typical operating cycle of the microfiltration unit consists of four steps: (1) initial filtration/filtrate recirculation; (2) main filtration/cake forming; (3) cake drying; and (4) cake discharge. Figure 2-3 shows the steps involved in the operation of the microfiltration unit.

At the start of a typical filtration cycle, the upper chamber is lowered to form a liquid-tight seal against the Tyvek®. The liquid feed waste containing particulate matter is then pumped, at an initial air pressure of 10 psig, into the upper chamber and filtered through the Tyvek®. During this process, solids are deposited on the Tyvek® filter. This solids buildup increases resistance to liquid flow through the Tyvek®. To keep the filtration rate constant, air pressure to the pump is automatically increased throughout the filter cycle. During the initial 30 seconds to 1 minute of the cycle, the filtrate is recirculated to the precipitation tank to keep the quality of filtrate high. At the end of 1 minute, recirculation stops and the filtrate is drained to the filtrate collection tank.

Liquid waste is pumped to the microfiltration unit until the air pressure to the pump reaches 55 psig (a pressure drop of approximately 45 psig across the filter). Liquid feed waste to the microfiltration unit is then shut off, and pressurized air (30-45 psig) is fed into the upper chamber to dry the filter cake. The air forces any liquid remaining in the upper chamber and in the filter cake pores to pass through the Tyvek® into the lower chamber. The air pressure applied to drain the

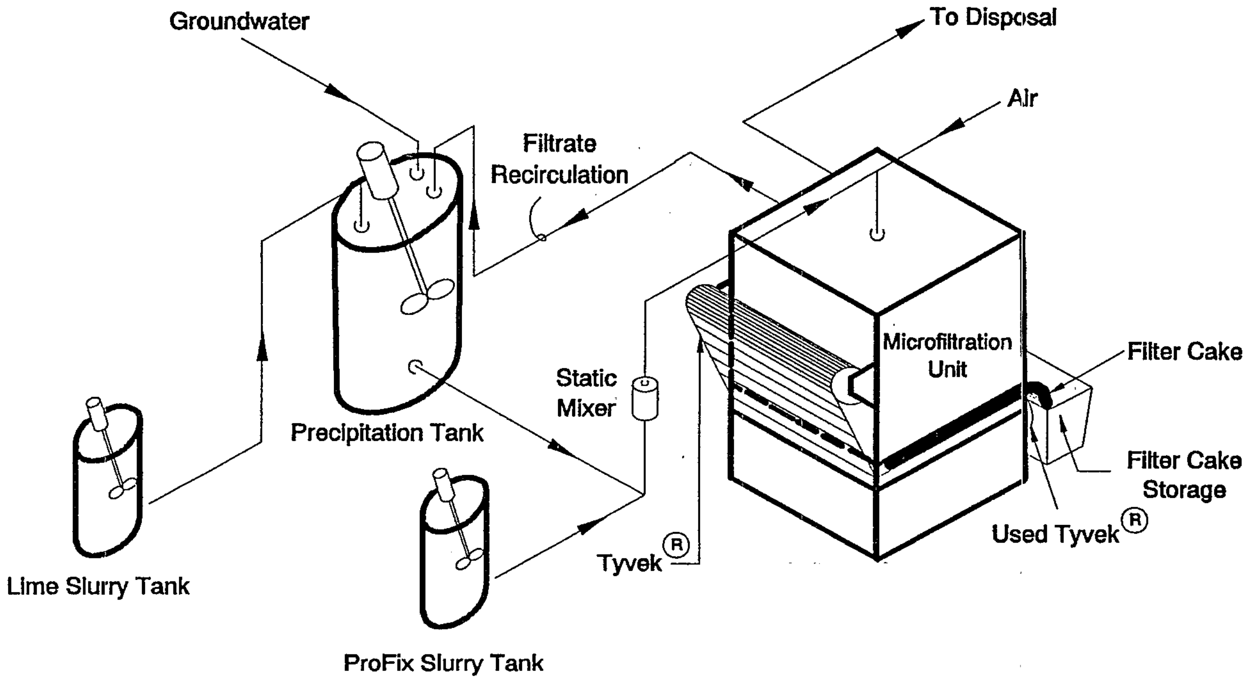


Figure 2-1. DuPont/Oberlin Microfiltration Treatment System.

liquid remaining in the upper chamber, and dry the filter cake, is called the blowdown pressure. Once the liquid is drained from the upper chamber and the filter cake, air breaks through the filter cake. After breakthrough occurs, air continues to be fed through the upper chamber for a preset time interval to further dry the cake. The preset time interval is called the blowdown time. During the cake drying period, the filtrate is sent back to the precipitation tank to keep the quality of filtrate high. At the end of the blowdown time, the air supply to the upper chamber is automatically shut off, the upper chamber is raised, and the filter cake is automatically discharged. Clean Tyvek® is then drawn from a roll into the microfiltration unit for the next cycle.

Innovative Features

The DuPont/Oberlin microfiltration technology uses a new, low cost membrane filter (Tyvek® T-980) that can be fed continuously to an automatic pressure filter to dewater sludges effectively. Through proper pretreatment, such as chemical precipitation, this technology can be used to remove dissolved metals from liquid wastes at a cost lower than several other treatment options, such as precipitation followed by clarification and conventional filtration, ion exchange, reverse osmosis, and electrolysis. When used in conjunction with a filter aid/cake stabilizing agent, the DuPont/Oberlin microfiltration technology produces a dry and stabilized cake that can be landfilled.

The DuPont/Oberlin microfiltration system has several innovative features that make it more effective than conventional microfiltration systems. The most significant of these features is DuPont's Tyvek® T-980 filter media, which is designed to remove particles that are 0.1 micron or larger in diameter. The high strength of this media, under both wet and dry conditions, permits continuous operation in the microfiltration unit. Also, the smooth, slick surface of the Tyvek® T-980 media facilitates cake release and separation.

Pressure filters such as the DuPont/Oberlin microfiltration units are becoming a more popular means of dewatering sludges and removing precipitated metals from liquid waste streams. Pressure filters generally produce a filter cake with a solids content high enough to meet landfill requirements,

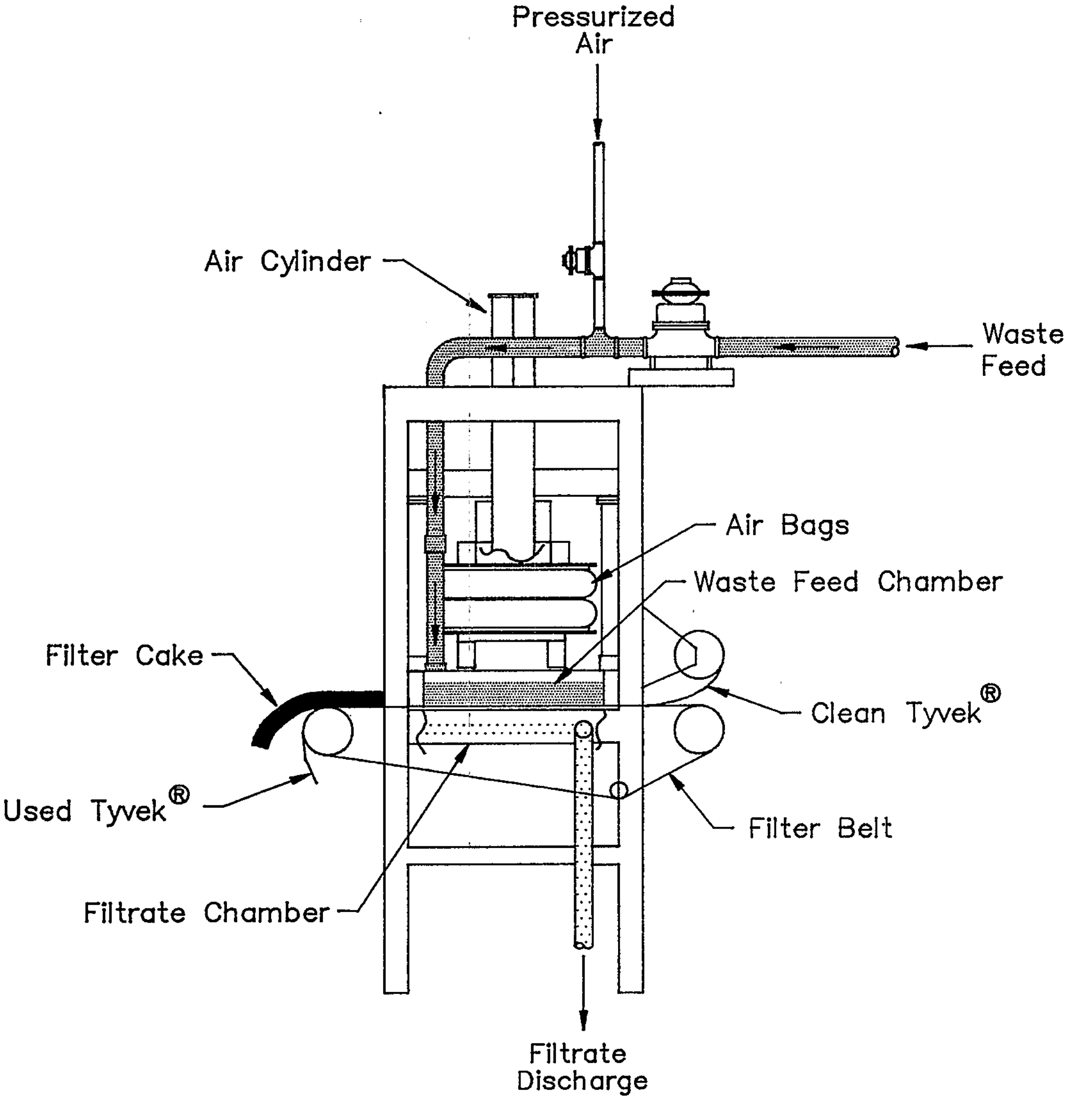
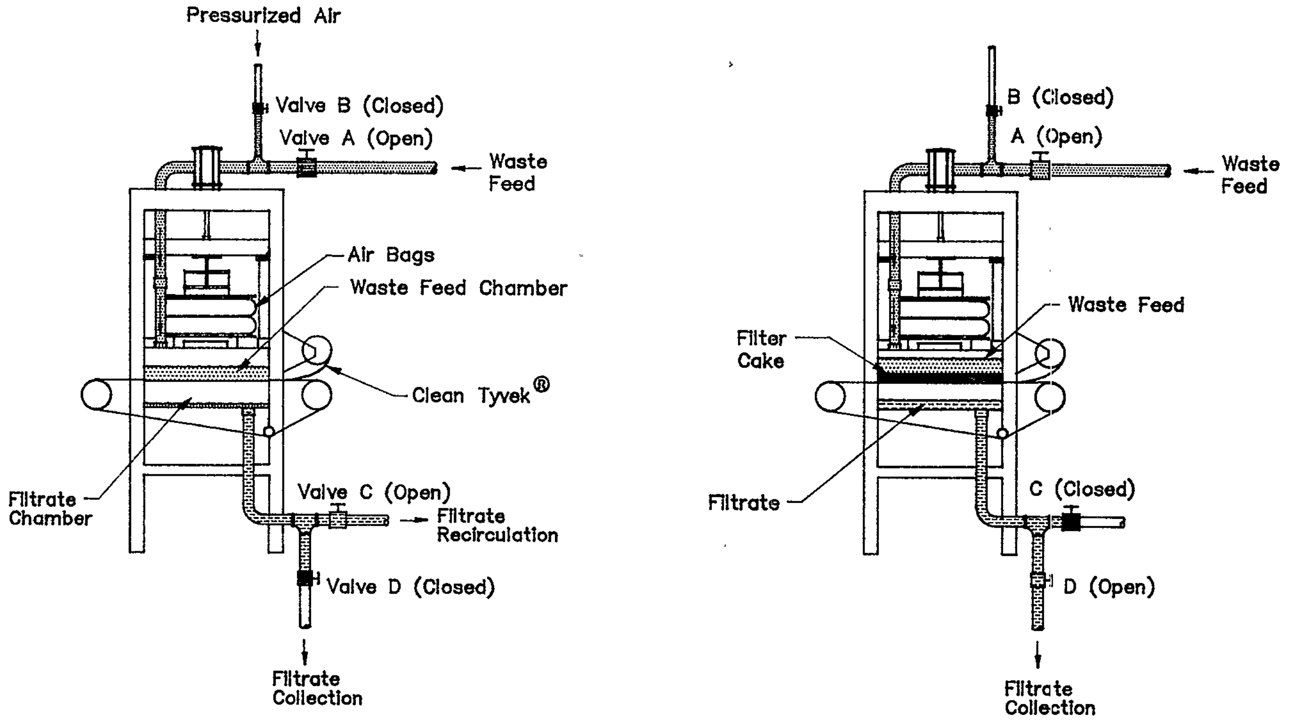


Figure 2-2. Schematic of DuPont/Oberlin Microfiltration Unit.

giving it a significant advantage over other dewatering methods. Also, automation makes pressure filters more appealing. Table 2-1 compares several sludge dewatering options.

The DuPont/Oberlin microfiltration technology uses Oberlin's automatic pressure filter, which has certain advantages over other conventional pressure filters. The microfiltration unit uses a continuous roll of filter media and automatically dispenses the filter cake, eliminating the need for add-on systems such as plate shifters and cake vibrators. When used in conjunction with the Tyvek® T-980 media, the system can effectively dewater sludge at a maximum pressure of 30 to 50 psig, requiring less energy than other pressure filters, which may operate at a maximum pressure above 200 psig. Also, the Tyvek® T-980 media is dispensed from a roll and the cake discharge is fully automated. The automatic cake discharge and electronic controls, based on either discrete relays and timers or programmable logic control, enable the microfiltration unit to run without significant operator attention, except for filter aid makeup, media roll replacement, and cake removal.

1. *INITIAL FILTRATION/FILTRATE RECIRCULATION* 2. *MAIN FILTRATION/CAKE FORMING*



3. *CAKE DRYING* 4. *CAKE DISCHARGE*

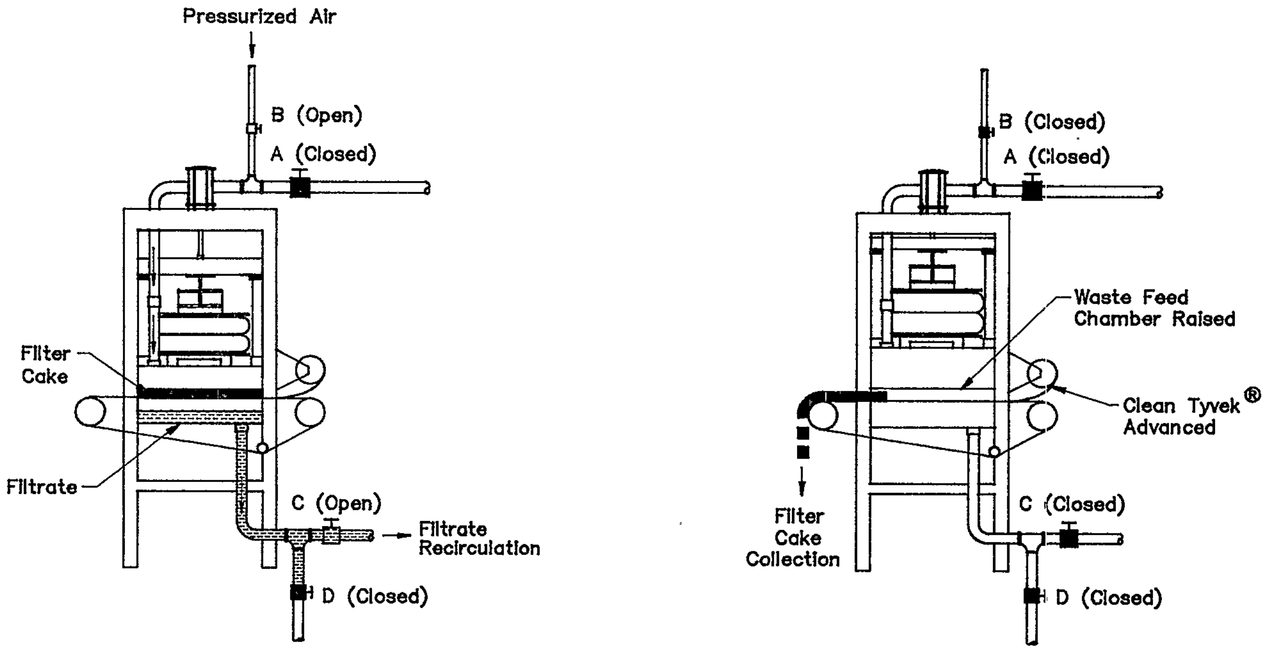


Figure 2-3. Steps in a Typical Microfiltration Unit Operating Cycle.

Table 2-1. Comparison of Sludge Dewatering Technologies

Technology	Advantages	Disadvantages
Basket Centrifuge	Low energy consumption; low chemical consumption; low labor requirements; prescreening not required	Low cake solids content
Solid Bowl Centrifuge	Low chemical consumption; low labor requirements	Low cake solids content; prescreening required; high energy consumption
Vacuum Filter	Low labor requirements	Low cake solids content; high energy consumption; high chemical consumption; prescreening required
Sludge Drying Bed	High cake solids content possible; low energy consumption; low chemical consumption; prescreening not required	High labor requirements; large land area requirements; climatic influences; aesthetically unpleasing
Gravity/Low Pressure Device	Low energy consumption; low labor requirements; prescreening not required	Low cake solids content; high chemical consumption
Belt Filter Press	High cake solids content; low energy consumption	Prescreening required; high chemical consumption; high labor requirements
Plate Filter Press	Very high cake solids content	Prescreening required; high chemical consumption; high labor requirements; high energy consumption
Pressure Filter	Very high cake solids content; low labor requirements	Prescreening required; high chemical consumption; high energy consumption

Note: Based on U.S. EPA, 1982.

Key Contacts

Additional information on the DuPont/Oberlin microfiltration technology, the SITE program, and the Palmerton Zinc Superfund site (demonstration site) can be obtained from the following sources:

The DuPont/Oberlin Microfiltration Technology

Ernest Mayer
E.I. DuPont de Nemours and Company, Inc.
Engineering Department L1359
P.O. Box 6090
Newark, DE 19714-6090
(302) 366-3652

Thomas Oberlin
Oberlin Filter Company
404 Pilot Court
Waukesha, WI 53188
(414) 547-4900

The SITE Program

John Martin
U.S. Environmental Protection Agency
Office of Research and Development
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7758

The Palmerton Zinc Superfund Site

Tony Koller
U.S. Environmental Protection Agency
Region 3 (3HW22)
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-6906

Section 3
Technology Applications Analysis

This section addresses the applicability of the DuPont/Oberlin microfiltration technology to treat liquid wastes containing particulate matter and metals in suspended or dissolved form. The technology's applicability is presented based on the results from the DuPont/Oberlin microfiltration system demonstration performed under the SITE program and other applications of the DuPont/Oberlin system presented in Appendix C. Since the results of the SITE demonstration provided an extensive database, evaluation of the technology's effectiveness and its applicability to other potential cleanup operations is mainly based on the SITE demonstration results presented in Appendix B. The vendor's claims regarding the applicability and performance of the DuPont/Oberlin microfiltration technology are included in Appendix A.

A summary of the effectiveness of the DuPont/Oberlin microfiltration technology is presented in this section, followed by a discussion of site characteristics, materials handling requirements, personnel requirements, potential community exposures, and potential regulatory requirements for the DuPont/Oberlin technology.

Effectiveness of the DuPont/Oberlin Technology

The effectiveness of the DuPont/Oberlin technology is presented based on the results from the SITE demonstration and three other case studies of the technology. After summarizing the results from the SITE demonstration and the case studies, this report describes factors influencing the effectiveness of the technology.

SITE Demonstration Results

The SITE demonstration was conducted at the Palmerton Zinc Superfund (PZS) site in Palmerton, Pennsylvania, during April and May 1990. During the SITE demonstration, the microfiltration system treated 6,000 gallons of groundwater 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).

The objectives of the DuPont/Oberlin microfiltration technology demonstration performed under the SITE program were to:

- Assess the technology's ability to remove zinc from the groundwater at the PZS site under different operating conditions
- Evaluate the microfiltration system's ability to dewater the metals precipitate from treated groundwater at the PZS site
- Determine the system's ability to produce a filtrate and a 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

The technology evaluation was performed in four phases. Phases 1 and 2 involved nine runs each, and Phases 3 and 4 involved two runs each. In Phase 1, chemical operating parameters (precipitation pH and ProFix dose) were varied, and the filter operating parameters (blowdown pressure and blowdown time) 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.

Appendix B summarizes information from the SITE demonstration, including (1) site characteristics, (2) contaminated groundwater characteristics, (3) microfiltration system performance, and (4) technology evaluation results. Key findings of the demonstration are given below.

- The DuPont/Oberlin microfiltration system achieved the following: (1) zinc and total suspended solids (TSS) removal efficiencies of 99.69 to 99.99 percent and (2) solids in the filter cake of 30.5 to 47.1 percent. At the overall optimum conditions (precipitation pH of 9, ProFix dose of 12 g/L, blowdown pressure of 38 psig, and blowdown time of 0.5 min.), the zinc and TSS removal efficiencies were about 99.95 percent, and the filter cake solids were about 41 percent.
- ProFix contributed a significant portion (80 to 90 percent) 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 (six 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 National Pollutant Discharge Elimination System (NPDES) permit

limits, established for discharge into a local waterway, for metals and TSS at the 95 percent confidence level. However, the filtrate did not meet the NPDES limit for pH. The filtrate pH was typically 11.5, while the upper discharge limit 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.

Other Case Studies' Results

Several other studies on the DuPont/Oberlin microfiltration system have been carried out. DuPont/Oberlin has made the results from three case studies available to EPA. These studies are summarized in Appendix C. A brief summary of the effectiveness of the DuPont/Oberlin microfiltration technology at the three facilities is presented below.

The first case study describes the effectiveness of two DuPont/Oberlin microfiltration units in treating wastewaters from a metal finishing and aluminum forming operation and from an autoclave process both at the Westinghouse Savannah River site in Aiken, South Carolina. The wastewater from metal finishing and aluminum forming operations contains about 3 mg/L of uranium, 180 mg/L of aluminum, 12 mg/L of nickel, and low levels of lead, zinc, copper, and chromium mostly in dissolved form. The wastewater from the autoclave process contains about 16 mg/L of insoluble uranium oxides.

At the Savannah River site, wastewater containing soluble metals is treated by equalization, precipitation, flocculation, and microfiltration, and wastewater containing insoluble metal oxides is treated by equalization and microfiltration. The Savannah River site used Tyvek® 1042B as the filter media for several years. However, during peak flow situations, the two DuPont/Oberlin systems could not provide adequate treatment. Therefore, DuPont conducted several tests to improve the treatment capacity of the filters. During these tests, DuPont's efforts to upgrade the microfiltration systems included using new filter media (Tyvek® T-980), filter aid, and polymer additive.

Performance of the microfiltration systems was maximized and their combined capacity was upgraded by using Tyvek® T-980 filter media, in conjunction with PerFLO 30SP filter aid and Praestol K144L cationic polymer. The volume of filter cake requiring disposal decreased by 15 percent. The filtrate and filter cake met both EP toxicity and TCLP tests. The filtrate also met all NPDES requirements. The filter cake is solidified and stabilized with cement prior to its disposal as a mixed waste.

The second case study describes the removal of particulate matter present in a wastewater slurry at the DuPont Electronics Materials, Inc. (DEMI) facility in Manati, Puerto Rico. DEMI produces a wastewater slurry at a rate of 2,000 gallons per day. The slurry contains 1,000 to 5,000 parts per million (ppm) of glass particulates and 2,000 to 10,000 ppm of TSS. The plant uses a filter aid and an organic polymer prior to microfiltration. The microfiltration unit uses Tyvek® T-980 filter media. After microfiltration, the filtrate passes through two cartridge filters arranged in series. These additional filters, rated at 10 microns and 1 micron, are provided to ensure high levels of particulate removal. According to DEMI, the microfiltration system removes nearly all particulate matter.

The third case study describes the removal of suspended metals from two liquid waste streams produced by the Component Materials Division of the DuPont Electronics facility located in Sun Valley, California. The compositions of the two waste streams vary according to daily operations at this facility. However, lead and TSS levels typically range from 0.5 to 5 percent. The facility uses two 7-square foot microfiltration units that are in two different locations 1/4 - mile apart. The microfiltration units use Tyvek® T-980 filter media, a filter aid, and a polymer.

The filtrate meets Los Angeles sewer effluent limits of 26 ppm and 5 ppm for TSS and zinc, respectively. The moisture content of the filter cake is about 50 percent. The filter cake is classified as hazardous waste because it fails the TCLP test. DuPont plans to use ProFix instead of diatomaceous earth to eliminate off-site stabilization and reduce operating costs.

In summary, the DuPont/Oberlin microfiltration technology has been demonstrated to be effective in removing TSS and metals (soluble and insoluble) from liquid wastes. The technology has also been demonstrated to produce a filter cake of 40 to 50 percent solids that passes the paint filter liquids test, making the filter cake suitable for land disposal. However, whether the filter cake must be disposed of as a hazardous waste or non-hazardous waste has to be determined on a case-by-case basis. Also, in some cases, the filtrate may require post-treatment for pH adjustment prior to discharge into a waterbody.

Factors Influencing Effectiveness

Several factors influence the effectiveness of the DuPont/Oberlin microfiltration technology. These factors can be grouped into three categories: (1) waste characteristics, (2) operating parameters, and (3) maintenance requirements. Each of these is discussed below.

Waste Characteristics

The ability of the DuPont/Oberlin microfiltration system to remove dissolved metals depends on certain key waste characteristics. These include organic and inorganic ligands (a negatively charged ion or a molecule that forms a complex with positively charged metal ions), the oxidation state of metallic contaminants, and oil and grease. Several organic and inorganic ligands can complex with metals and make the metals less amenable to precipitation. Organic ligands such as amino acids and humic compounds are known to form complexes with several heavy metals (for example, with copper). Inorganic ligands such as ammonia, cyanide, and chloride are known to form stable complexes with zinc, iron, and mercury, respectively. Therefore, it is important to measure the ligand concentrations and properly design the pretreatment operations to precipitate metals effectively. Another key waste characteristic is the oxidation state of metallic contaminants. For example, hexavalent chromium is less amenable to precipitation than trivalent chromium. Therefore, if chromium is present in the hexavalent state, it needs to be reduced to the trivalent state prior to precipitation for effective removal. In addition to these waste characteristics, high levels of oil and grease may decrease the system's treatment efficiency.

Operating Parameters

Operating parameters are those parameters that are varied during treatment to achieve desired removal efficiencies. Typically, such parameters include precipitation pH, filter aid/cake stabilizing agent (for pretreatment, if required), blowdown time, and blowdown pressure (for microfiltration of sludge). In addition to these parameters, several other operating parameters become important depending on the type of pretreatment required. For example, if metals need to be oxidized or reduced prior to precipitation, the oxidant or reductant dose and the pH at which this pretreatment must be carried out will have to be controlled properly. Only the typical operating parameters are discussed in this report.

Precipitation pH depends on the metal to be precipitated and the type of solid phase formed during precipitation (hydroxide, carbonate, or sulfide). The solubility of most metals follows a U-shape curve because of the amphoteric nature of most solid phases formed during metal precipitation. This indicates that usually there is an optimum pH or pH range at which the solubility of a given metal is at its minimum. The removal of this metal from liquid wastes can be maximized by keeping the precipitation pH close to the optimum. In a real-world situation, however, the liquid wastes will have either multiple pH optima or an overall optimum pH range. Such situations may require conducting sequential precipitation of metals (in case of multiple optima) or setting the precipitation pH in the overall optimum range (in case of no multiple optima). Selection of precipitation pH could become more difficult, if the liquid waste contains ligands that form complexes with target metals. In such a case, the precipitation pH should be selected such that the metal complexation is minimized. However, if such an approach does not yield adequate metal removal, the ligand and/or complex should be removed prior to metal precipitation.

DuPont normally uses a filter aid to improve sludge dewatering characteristics or a filter aid/cake stabilizing agent to stabilize the cake and improve sludge dewatering characteristics. DuPont normally screens several commercial products for each application. Typically, higher chemical additive doses are required to meet TCLP limits. However, a higher dose also results in greater chemical costs and more dry solids handling.

Blowdown pressure is the pressure at which air is applied to drain residual liquid from filter cake pores during the cake drying step of a filtration cycle. Blowdown time is the time for which air is applied after it breaks through the filter cake. Since blowdown pressure and blowdown time control the filter cake dryness, these are the key operating parameters of the DuPont/Oberlin microfiltration unit. The higher the values of these parameters, the higher will be the filter cake dryness. However, it should be noted that as the target blowdown pressure increases, so will the required capacity and pressure rating of the air compressor. Also the filtration cycle time (processing time) will increase, if the blowdown time is increased.

Maintenance Requirements

The maintenance requirements for the DuPont/Oberlin system summarized here are based on a review of the operation and maintenance manual for the microfiltration unit (Oberlin, 1984) and other published literature (WPCF, 1984; Karassik, 1986). Regular maintenance by trained personnel is essential for the system's successful operation. The following components require routine maintenance: (1) microfiltration unit, (2) air compressor, (3) pumps, and (4) miscellaneous components. A brief summary of the maintenance requirements for each of these components is presented below.

The microfiltration unit has several components that require periodic maintenance. For example, the platen seals in both the upper and lower platens (chambers) will wear out and need replacement approximately once a year. Similarly, air bags will wear out and need replacement once every 3 to 5 years. Seals in the air cylinder (located on the top of the filter frame) will also age and leak air. If properly lubricated, these will require replacement approximately once every 5 years. Standard leak checks should be performed once a month to identify when platen seals or air bags need replacement. The Tyvek® filter media roll also needs to be replaced, as needed. Several moving parts, such as the air cylinder and pillow block bearings, should be lubricated with proper lubricants once every 6 months for smooth operation of the DuPont/Oberlin unit.

Oberlin normally uses a reciprocating type of compressor to supply pressurized air to the microfiltration unit. The compressor valves should be removed and inspected after the first 3 months of operation. The condition of the valves after this initial inspection will serve as a guide to the frequency of future inspections. It is generally recommended that the valves be inspected at least once a year. The compressor's shaft packing should also be inspected at frequent intervals, and this packing should be adjusted or replaced as often as required. Bearing and piston clearances, rod alignment, and cylinder bore condition should be checked at least annually and adjustments or replacements made to correct any abnormal conditions. Since the microfiltration unit has pneumatic controls, a moisture trap and an air dryer should be installed at the discharge end of the compressor to prevent malfunctioning of the microfiltration unit.

The operation of the DuPont/Oberlin microfiltration system typically requires three to four pumps. Since the type, size, design, and construction materials of these pumps may vary from one application to the other, the operators should review the manufacturer's instruction manuals before attempting to service any of the pumps. Only general guidelines regarding the maintenance of the pumps are outlined below. Pumps should be checked twice each shift (When the operators are on duty), and any irregularities in their operation should be addressed immediately following manufacturer's guidelines. This applies particularly to changes in the sound of a running pump, abrupt changes in bearing temperatures, and stuffing box leakage. The free movement of stuffing box glands should be checked semiannually, gland bolts should be cleaned and oiled, and the packing should be inspected to determine whether it requires replacement. The pump and driver alignment should be checked and corrected if necessary. Oil-lubricated bearings should be drained and refilled with fresh oil. Grease-lubricated bearings should be checked to see that they contain the correct amount of grease and that the grease is still of suitable consistency. During semiannual inspections, worn out bearings should be replaced. A complete overhaul of the pumps is required periodically for smooth operation. The frequency of complete pump overhauls will depend on the pump service, the pump construction and materials, the liquid pumped, and an evaluation of the costs of overhaul versus the cost of power losses resulting from increased clearances or of unscheduled downtime. Some pumps on very severe service may need a complete overhaul monthly, while other applications may require overhauls only every few years.

Other components of the DuPont/Oberlin microfiltration system, such as valves, flow meters, and pipelines, should be checked for leaks and clogging. The metals precipitation tank, lime slurry tank, filter aid/cake stabilizing agent slurry tank, and filtrate collection tank should also be checked for leaks. Finally, the electrical motors for the mixers used in tanks should be maintained following manufacturer's guidelines.

Site Characteristics

In addition to influent characteristics and effluent discharge requirements, site characteristics are important when considering the use of DuPont/Oberlin's microfiltration technology. Site-specific factors have both positive and negative impacts on the application of DuPont/Oberlin's technology, and these should be considered before this technology is selected for site remediation. These factors include site area, site preparation, site access, climate, utilities, and services and supplies.

Site Area

DuPont/Oberlin units are available in several sizes, with filtration areas ranging from 2.4 to 36 square feet. During the SITE demonstration, a 2.4-square foot unit was used. An area of 30 feet in length and 20 feet in width was adequate for the DuPont/Oberlin unit and associated equipment, excluding influent and effluent storage tanks. Larger units would require slightly larger areas. For example, for the 36-square foot unit, an area of 50 feet in length and 30 feet in width should be provided. Areas required for influent and effluent storage tanks, if needed, may vary depending on the flow rate and turnaround time for any effluent analysis required prior to disposal of the effluent. Also, an area of 20 feet in length and 15 feet in width is required for indoor office space and any on-site laboratory work.

Site Preparation

The area containing the DuPont/Oberlin system tanks should be relatively level. It can be paved or covered with compacted soil or gravel. The site geotechnical characteristics (for example, soil bearing capacity) should be evaluated to identify whether any foundation is required to support the microfiltration treatment system and storage tanks.

To clean up contaminated groundwater, extraction wells and a groundwater collection and transmission system should be installed so that the groundwater can be pumped to a central facility where the DuPont/Oberlin system will be located on-site. Unless the DuPont/Oberlin microfiltration system is designed for outdoor use, a temporary tent-like enclosure will be needed to protect the system from inclement weather. Tanks will likely be required for untreated and treated groundwater. Drums or other suitable containers will also be needed to store the filter cake. Also, an equipment and personnel decontamination facility should be provided, along with one or more portable chemical toilets or other suitable sanitary facilities.

Site Access

Site access requirements for the treatment equipment are minimal. The site must be accessible to tractor-trailer trucks of standard size and weight. The roadbed must be able to support such a vehicle delivering the DuPont/Oberlin system and tanks.

Climate

Below-freezing temperatures and heavy rain could have an adverse impact on the operation of the DuPont/Oberlin system. If below-freezing temperatures are expected for a long period of time, the DuPont/Oberlin system and influent and effluent storage tanks should be insulated or kept in a well-heated shelter, such as a building or shed. The DuPont/Oberlin system should also be protected from heavy rain.

Utilities

The DuPont/Oberlin system requires potable water and electricity. Potable water is required for preparation of lime and filter aid slurries, for equipment cleanup, and for personnel decontamination. In some applications, to conserve water, filtrate may be used instead of potable water.

The microfiltration unit typically requires 240-volt, 3-phase, 60-Hz electrical service. Additional electrical power (110-volt, single phase), is needed mainly for operating the mixers in the process tanks, lighting the office trailer, and operating the on-site laboratory and office equipment. Electricity is also needed to provide heat in the on-site trailer and equipment shelter area.

A telephone is required to order supplies, contact emergency services, and provide normal communications.

Services and Supplies

A number of services and supplies are required for the DuPont/Oberlin microfiltration technology. Most of these services and supplies can be readily obtained.

In case any of the pumps, mixers, or the air compressor malfunctions, or if any flow meters or pipelines crack, an adequate on-site supply of spare parts or access to a nearby industrial supply center is an important consideration.

An adequate supply of several materials is essential for the DuPont/Oberlin microfiltration system. These materials include (1) treatment chemicals (if needed), such as lime, to adjust pH and precipitate metals, (2) filter aid/cake stabilizing agent, such as ProFix, and (3) Tyvek® T-980 filter media.

Laboratory facilities to perform analyses, such as metals and TSS in liquids, and TCLP test and moisture content in the filter cake, are required to monitor the treatment system's performance. If such facilities are not available on-site, it would be prudent to enter into a contract with a local analytical laboratory for an ongoing monitoring program.

Materials Handling Required by the Technology

Materials handling requirements for the DuPont/Oberlin microfiltration technology would involve the handling of (1) pretreatment materials and (2) residuals. These are described below.

Pretreatment Materials Handling

Pretreatment materials handling requirements for the DuPont/Oberlin technology depend on the type of waste being treated. If the technology is applied to remove only particulate matter, minimal pretreatment is required. The pretreatment may involve addition of a filter aid to improve dewatering characteristics of the waste. However, if the technology is applied to remove dissolved metals, pretreatment generally involves metal precipitation (through addition of a hydroxide, carbonate, or sulfide source) and filter aid addition. The pretreatment could become more extensive if (1) the metals need to be oxidized or reduced prior to precipitation or (2) any metal complexing agents present in the waste require removal or destruction prior to metal precipitation.

Even if no pretreatment is needed, the liquid wastes may need to be pumped to an equalization tank to reduce flow and contaminant concentration fluctuations. The installation of an equalization tank would also require additional plumbing connections.

Residuals Handling

Two major types of residuals are generated from the DuPont/Oberlin microfiltration system: (1) treated water (filtrate) and (2) filter cake.

Filtrate could be disposed of either on- or off-site, once it meets the applicable regulatory requirements described at the end of this section. Examples of on-site disposal options for the filtrate include groundwater recharge and temporary storage on-site for sanitary use. Examples of off-site disposal options are discharge into rivers, creeks, storm sewers, and sanitary sewers. Bioassay tests may be required in addition to routine chemical and physical analyses before the filtrate is disposed. The pH of the filtrate may also need to be adjusted prior to its disposal depending on (1) the pH at which metal precipitation is done, (2) the filter aid added, and (3) the disposal site. During the SITE demonstration, the filtrate met the NPDES permit limits for disposal into a local waterway for metals and TSS. However, it did not meet the discharge limit for pH. The treated water pH was typically 11.5 while the upper discharge limit was 9. The filtrate pH was higher than the precipitation pH because of the addition of ProFix (filter aid/cake stabilizing agent).

The filter cake may be landfilled if it passes the paint filter liquids test. Whether the filter cake can be disposed of at a nonhazardous landfill depends on its ability to meet the applicable regulations described in the "Regulatory Requirements" section. During the SITE demonstration, the filter cake was disposed of as a nonhazardous waste. However, at the DuPont Electronics facility in Sun Valley, California, it is disposed of as a hazardous waste. DuPont plans to use ProFix instead of diatomaceous earth to eliminate off-site stabilization and reduce operating costs.

The DuPont/Oberlin system also generates spent Tyvek® filter media, which requires disposal. The spent Tyvek® media can also be disposed of at either a hazardous or nonhazardous landfill, depending on whether it meets the applicable regulations.

Personnel Requirements

Since DuPont/Oberlin's microfiltration unit is automated, little operator attention is required; one operator per shift would be adequate. This person should be capable of (1) preparing pretreatment chemical slurries, such as lime and filter aid, and adjusting their flow rates to achieve the desired doses, (2) operating the pneumatic and electronic controls on the microfiltration unit, (3) collecting solids and liquid samples and performing simple physical/chemical analyses and measurements (for example, measuring pH, temperature, flow rate, and TSS), and (4) troubleshooting minor operational problems. Analytical work requiring higher skills (for example, performing metals analysis and the TCLP test) can be performed by a local laboratory.

Each operator also should have an OSHA-required, initial 40-hour health and safety training and an annual 8-hour refresher course before operating DuPont/Oberlin's system at hazardous waste sites.

Potential Community Exposures

Contaminant exposure from the DuPont/Oberlin microfiltration system to the community is minimal. When treating wastes containing volatile contaminants, such as mercury, proper care should be taken to control the emissions from the metals precipitation tank. Other types of exposures include particulate emissions from lime and filter aid handling and significant noise (estimated to be 80 to 90 decibels) from the air compressor.

Potential Regulatory Requirements

This subsection discusses specific environmental regulations pertinent to the transport, treatment, storage, and disposal of wastes generated during the operation of the DuPont/Oberlin microfiltration system. The regulations that apply to a particular remediation activity will depend on the type of remediation site and the type of waste being treated. Table 3-1 provides a summary of regulations discussed in this subsection.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, provides for federal authority to respond to releases of hazardous substances, pollutants, or contaminants to air, water, and land (Federal Register, 1990a). Section 121 (Cleanup Standards) of SARA

Table 3-1. Regulations Summary

Act	Applicability	Application To DuPont/Oberlin Microfiltration System	Citation
CERCLA	Superfund Sites	The Superfund Program authorizes and regulates the cleanup of environmental contamination. Applies to all CERCLA site cleanups.	40 CFR Part 300
RCRA	CERCLA and RCRA Sites	RCRA defines and regulates the treatment, storage, and disposal of hazardous wastes.	40 CFR Parts 260-270
SDWA	Water Discharges Water Reinjection, and Sole Source/Wellhead Water Sources	Maximum contaminant levels and contaminant level goals would be appropriate standards to consider in setting water cleanup levels at RCRA corrective action and CERCLA response action sites. (Water cleanup levels are also discussed under RCRA and CERCLA.) Reinjection of treated water would be subject to underground injection control program and sole-source and wellhead water sources to their respective control programs.	40 CFR Part 141
CWA	Discharges to Surface Water Bodies	NPDES requirements of CWA would apply to both CERCLA and RCRA sites where treated water is discharged to surface water bodies.	40 CFR Parts 122-125
CAA	Ambient Air Quality	CAA emission standards might apply to fugitive air emissions, if any, from the DuPont/Oberlin microfiltration system (if the contaminant source and treatment technology are sufficiently similar to a source and technology regulated by the CAA). RCRA and CERCLA air emission requirements and any state programs will be the primary air requirements for use of the DuPont/Oberlin technology at CERCLA or RCRA sites.	40 CFR Parts 50, 60, and 61
TSCA	PCB Contamination	TSCA regulates PCB spill cleanups. If PCB-containing wastes are treated, TSCA requirements will generally be appropriate in determining cleanup standards and disposal requirements.	40 CFR Part 761
Other	Radioactive Wastes	Agencies regulating the treatment, storage, and disposal of radioactive wastes include: (1) the EPA, (2) the NRC, (3) the DOE, and (4) the states. Decisions regarding appropriate regulations should be based on: (1) the type of radioactive constituents present and how they were generated; (2) the jurisdiction a site is under; and (3) requirements that are most protective and appropriate for given site conditions.	40 CFR Parts 141, 440 (water); 10 CFR Parts 20, 30, 40, 61, 70 (air and water discharges, treatment and disposal, exposure limits); 40 CFR Part 190 (radiation doses); 40 CFR Part 192 (radon releases, cleanup standards); AEA(NRC licensees); DOE Orders
AEA and RCRA	Mixed Wastes	AEA and RCRA requirements apply to the treatment, storage, and disposal of wastes containing both hazardous and radioactive components. OSWER and DOE directives provide guidance for addressing mixed wastes.	AEA and RCRA
OSHA	All Remedial Actions	OSHA regulates on-site construction activities and the health and safety of workers at hazardous waste sites. Implementation and operation of the DuPont/Oberlin microfiltration system at CERCLA or RCRA sites must meet OSHA requirements.	29 CFR Parts 1900-1926 29 CFR Part 1910.120 (hazardous waste operations and emergency response)

Note: Abbreviations included above are spelled out in this subsection's text requires that selected remedies be protective of human health and the environment and be cost-effective. SARA states a preference for remedies that are highly reliable, provide long-term protection, and employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants. The DuPont/Oberlin microfiltration technology is one such remedy. Section 121 also requires that remedies selected at Superfund sites comply with federal and state applicable or relevant and appropriate requirements (ARAR), and it provides only six conditions under which ARARs for a remedial action may be waived: (1) the action is an interim measure and the ARAR will be met at completion, (2) compliance with the ARAR would pose a greater risk to health and the environment than noncompliance, (3) it is technically impracticable to meet the ARAR, (4) the standard of performance of an ARAR can be met by an equivalent method, (5) a state standard has not been consistently applied elsewhere, and (6) ARAR compliance would not provide a balance between the protection achieved at a particular site and demands on the Superfund for other sites. These waiver options apply only to Superfund actions taken on-site, and justification for the waiver must be clearly demonstrated (U.S. EPA, 1988).

Generally, contaminated water treatment using the DuPont/Oberlin microfiltration system will take place on-site, while treated water discharge, filter cake disposal, and filter media disposal may take place either on-site or off-site. On-site and off-site actions must meet the substantive requirements (for example, emission standards) of all ARARs; off-site actions must also meet permitting and any other administrative requirements of environmental regulations.

Resource Conservation and Recovery Act (RCRA)

RCRA regulations define hazardous wastes and regulate their transport, treatment, storage, and disposal. Wastes defined as hazardous under RCRA include characteristic and listed wastes.

Criteria for identifying characteristic hazardous wastes are included in 40 CFR Part 261 Subpart C. Listed wastes from non-specific and specific industrial sources, off-specification products, spill cleanups, and other industrial sources are itemized in 40 CFR Part 261 Subpart D. For RCRA regulations to apply, evidence (for example, manifests, records, and knowledge of processes) must affirm that the waste is hazardous. Site managers may also test the waste or use their knowledge of its properties to determine if the waste is hazardous.

Contaminated water to be treated by the DuPont/Oberlin microfiltration system will probably be hazardous or sufficiently similar to hazardous waste so that RCRA standards will be requirements. Because the DuPont/Oberlin microfiltration system includes waste storage in tanks, 40 CFR Part 265 standards for tank storage (Subpart J) should be met. Also, RCRA treatment requirements must be met.

Filter cake and spent filter media generated during treatment must be stored and disposed of properly. If the water treated is a listed waste, treatment residues will be considered listed wastes (unless RCRA delisting requirements are met). If the treatment residues are not listed wastes, they should be tested to determine if they are RCRA characteristic hazardous wastes. Treatment residues should also be tested using EPA Method 9095 (paint filter liquids test) to determine if they contain free liquids. Wastes containing no free liquids are excluded from various leak detection and secondary containment requirements for disposal. Usually, the DuPont/Oberlin treatment residues will not contain free liquids. If the residuals are not hazardous and do not contain free liquids, they can be disposed of at a nonhazardous waste landfill. If the filter cake or filter media is hazardous, the following RCRA standards apply.

40 CFR Part 262 details standards for generators of hazardous waste. These requirements include obtaining an EPA identification number, meeting waste accumulation standards, labeling wastes, and keeping appropriate records. Part 262 allows generators to store wastes up to 90 days without a permit and without having interim status as a treatment, storage, and disposal facility. If treatment residues are stored on-site for 90 days or more, 40 CFR Part 265 requirements apply.

Any facility (on-site or off-site) designated for permanent disposal of hazardous wastes must be in compliance with RCRA. Disposal facilities must fulfill permitting, storage, maintenance, and closure requirements contained in 40 CFR Parts 264 through 270. In addition, any authorized state RCRA requirements must be fulfilled. If treatment residues are disposed off-site, 40 CFR Part 263 transportation standards apply.

For both CERCLA actions and RCRA corrective actions, the treatment residuals generated by the DuPont/Oberlin microfiltration system will be subject to land disposal restrictions (LDR) if they are hazardous and land disposed (U.S. EPA, 1989a). Several LDR compliance alternatives exist for disposing of the filter cake and spent filter media if they are hazardous: (1) comply with the LDR that is in effect, (2) comply with the LDRs by choosing one of the LDR compliance alternatives (for example, treatability variance, no migration petition), or (3) invoke an ARAR waiver (this option would only apply to on-site CERCLA disposal).

40 CFR Part 264, Subparts F (promulgated) and S (proposed) include requirements for corrective action at RCRA-regulated facilities. In addition, these subparts generally apply to remediation at Superfund sites. Subparts F and S include requirements for initiating and conducting RCRA corrective actions, remediating groundwater, and ensuring that corrective actions comply with other environmental regulations. Subpart S also details conditions under which particular RCRA requirements may be waived for temporary treatment units operating at corrective action sites (Federal Register, 1990b).

Clean Water Act (CWA)

The NPDES permitting program established under the CWA issues, monitors, and enforces permits for direct discharges to surface water bodies. Discharges to off-site receiving waters or to publicly owned treatment works (POTW) must comply with applicable federal, state, and local administrative and substantive requirements. Effluent limits are contained in the NPDES permit issued for direct discharges to off-site receiving waters. No NPDES permits are issued for on-site discharges or off-site discharges to POTWs, but all substantive requirements (such as discharge limits) should be identified and achieved.

Safe Drinking Water Act (SDWA)

The SDWA, as amended in 1986, includes the following programs: (1) drinking water standards, (2) underground injection control (UIC) program, and (3) sole-source aquifer and wellhead protection programs.

SDWA drinking water primary (health-based) and secondary (aesthetic) maximum contaminant levels will generally be appropriate cleanup standards for water that is, or may be, used as a source of drinking water. In some cases, alternate concentration limits will be appropriate (for example, in cases where multiple contaminants are present). Decision makers should refer to CERCLA and RCRA standards for guidance in establishing alternate concentration limits.

Water discharge through injection wells is regulated under the UIC program. This program categorizes injection wells as Classes I through V, depending on their construction and use. Reinjection of treated water involves Class IV (reinjection) or Class V (recharge) wells and should meet the appropriate requirements for well construction, operation, and closure.

The sole-source aquifer protection and wellhead protection programs are designed to protect specific drinking water supply sources. If such a source is to be remediated, appropriate program officials should be notified, and any potential problems should be identified before treatment begins.

Clean Air Act (CAA)

Pursuant to the CAA, EPA has set national ambient air quality and pollutant emissions standards. CAA requirements will generally not apply to the DuPont/Oberlin microfiltration system, although they may apply on a source-specific basis (see radioactive waste regulations discussion). However, air emissions should be monitored to ensure that they comply with CAA standards.

RCRA air standards generally must be met for CERCLA response actions and RCRA corrective actions. Forthcoming RCRA regulations (40 CFR Part 269) will address air emissions from hazardous waste treatment, storage, and disposal facilities. When promulgated, these requirements will include air emission standards for equipment leaks and process vents, a category that will cover any fugitive air emissions from a DuPont/Oberlin microfiltration system. In addition, states' programs to regulate toxic air pollutants, when established, will be the most significant regulations for environmental remediation activities. Generally, air emissions from the DuPont/Oberlin microfiltration system will be minimal, and complying with air emission regulations should not be a problem. To minimize air emissions, however, pretreatment might be required for water containing volatile organic contaminants.

Toxic Substances Control Act (TSCA)

The DuPont/Oberlin microfiltration system has the capability to handle wastes containing polychlorinated biphenyls (PCB), although PCBs are not removed by the system. TSCA requirements set standards for PCB spill cleanups and PCB disposal which should be achieved if PCB waste is treated. The EPA document CERCLA Compliance with Other Laws Manual, Part II: Clean Air Act and Other Environmental Statutes and State Requirements discusses TSCA as it pertains to Superfund actions (U.S. EPA, 1989b). The proposed RCRA corrective action regulations (Federal Register, July 1990) state that PCB waste should be handled in accordance with TSCA PCB spill cleanup policy. As TSCA does not regulate direct spills to surface water or drinking water, cleanup standards for these sites are established by EPA regional offices.

Radioactive Waste Regulations

The DuPont/Oberlin microfiltration system has the capability to treat water contaminated with radioactive materials. Decisions concerning what is an appropriate requirement for a site contaminated with radioactive waste should be based on the following factors: (1) what type of radioactive constituents are present and how they contaminate the site, (2) whose regulatory jurisdiction the site falls under, and (3) which regulation is most protective or appropriate. The primary agencies that regulate the cleanup of radioactively contaminated sites are EPA, the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the states. In addition, nongovernmental agencies may issue advisories or guidance, which should also be considered in developing a protective remedy.

The SDWA has established maximum contaminant levels for radionuclides in community water as a concentration limit for alpha-emitting radionuclides and as an annual dose limit for the ingestion of beta/gamma-emitting radionuclides. These standards are appropriate in setting cleanup standards for radioactively contaminated water. Discharge of treated water from radioactively contaminated sites could be subject to 40 CFR Part 440 Subpart C, which establishes radionuclide concentration limits for liquid effluent from facilities that extract and process uranium, radium, and vanadium ores. The DuPont/Oberlin microfiltration system has the potential to treat water to well within the radioactivity limits established by these regulations. However, treated water should be tested to ensure that such limits are not being exceeded.

Any fugitive radioactive air emissions that result from the DuPont/Oberlin microfiltration system must achieve radionuclide emissions standards promulgated under the CAA (codified in 40 CFR Part 61).

The Environmental Radiation Protection Standards (40 CFR Part 190) promulgated under the authority of the Atomic Energy Act (AEA) set standards for radiation doses to the general public caused by normal operations within the uranium fuel cycle. These requirements should be considered at sites where such contamination is being treated or disposed. Standards regulating the stabilization, control, and disposal of uranium and thorium mill tailings are included in 40 CFR Part 192. These regulations set cleanup, control, and release standards for radioactive materials.

NRC regulations cover the possession and use of source, by-product, and special nuclear materials by NRC licensees. These regulations apply to sites where radioactive contamination exists. 10 CFR Parts 20, 30, 40, 61, and 70 cover protection of workers and the public from radiation, discharges of radionuclides to air and water, and waste treatment and disposal requirements for radioactive waste. The filter cake and spent filter media generated by microfiltration of radioactive water might be regulated under these parts if they contain residual radioactivity.

DOE requirements are included in a series of internal DOE orders that have the same force as regulations at DOE facilities. These DOE directives should be considered when developing protective remedies at CERCLA sites or RCRA corrective action sites, although they apply directly only to DOE sites. DOE orders address exposure limits for the public, concentrations of residual radioactivity in soil and water, and management of radioactive wastes (U.S. DOE, 1988).

Mixed Waste Regulations

Use of the DuPont/Oberlin microfiltration system at sites with radioactive contamination might involve the treatment or generation of mixed waste. Mixed waste contains both radioactive and hazardous components (as defined by the AEA and RCRA) and is subject to the requirements of both acts. When the application of both regulations results in a situation that is inconsistent with the AEA (for example, an increased likelihood of radioactive exposure), AEA requirements supersede RCRA requirements.

EPA's Office of Solid Waste and Emergency Response (OSWER), in conjunction with the NRC, has issued several directives to assist in the identification, treatment, and disposal of low-level radioactive mixed waste. Various OSWER directives include guidance on defining, identifying, and disposing of commercial mixed low-level radioactive and hazardous waste (U.S. EPA, 1987). If the DuPont/Oberlin microfiltration system is used to treat low-level mixed wastes, these directives should be considered. If high-level mixed waste or transuranic mixed waste is treated, DOE internal orders should be considered when developing a protective remedy (U.S. DOE, 1988).

Occupational Safety and Health Act (OSHA)

CERCLA response actions and RCRA corrective actions must be performed in accordance with OSHA requirements detailed in 29 CFR Parts 1900 through 1926, especially Part 1910.120, which provides for the health and safety of workers at hazardous waste sites. On-site construction activities at Superfund or RCRA corrective action sites must be performed in accordance with Part 1926 of OSHA (Safety and Health Regulations for Construction). For example, construction of electric utility hookups for the DuPont/Oberlin microfiltration system would need to comply with Part 1926, Subpart K (Electrical). Also, any more stringent state requirements would need to be met.

Section 4
Economic Analysis

The costs associated with the DuPont/Oberlin microfiltration technology have been placed into the 12 cost categories that are applicable to typical cleanup activities at Superfund and Resource Conservation and Recovery Act (RCRA) corrective action sites (Evans, 1990). These cost categories are defined and discussed in this section as they apply to the DuPont/Oberlin microfiltration technology, thereby forming the basis for the estimated costs presented in Table 4-1. The annual operating and maintenance costs, as well as one-time costs presented in Table 4-1, are for two microfiltration systems with filtration areas of 2.4 square feet (demonstration unit) and 36 square feet (largest unit available). The costs presented in this analysis are order-of-magnitude (-30 to +50 percent) estimates, as defined by the American Association of Cost Engineers (Humphreys, 1984).

Site-Specific Factors Affecting Cost

A number of factors affect the estimated cost of a DuPont/Oberlin microfiltration system. These factors are highly site-specific and rather difficult to identify if accurate site location and site data are unavailable. The factors that will affect the cost generally include: volume of groundwater or other type of liquid waste to be treated; type and concentration of contaminants in the water; physical site conditions (such as site access and availability of utilities); required support facilities, extraction wells for contaminated groundwater, auxiliary equipment, and buildings; geographical location (availability of supplies and consumables, availability of service for equipment); treatment goals to be met; discharge permit requirements; and frequency of equipment repair and replacement.

Basis of Economic Analysis

The DuPont/Oberlin technology can be applied to treat several types of liquid wastes including contaminated groundwater, landfill leachate, and industrial wastewater. For the purpose of this economic analysis, contaminated groundwater was selected as the liquid waste since it represents (1) a waste commonly found at Superfund and RCRA corrective action sites and (2) a waste treatment scenario that covers several cost categories. It should be noted that all the categories for the contaminated groundwater scenario may not apply to other types of liquid waste. Therefore, when estimating the costs for a given scenario, only applicable categories should be used.

For the purpose of this economic analysis, it is assumed that a DuPont/Oberlin microfiltration system will treat contaminated groundwater on a batch cycle, 24 hours per day, 7 days per week for 1 year. The average time of each cycle is assumed to be 20 minutes. The total volume of groundwater treated during each cycle is difficult to estimate since it depends on the (1) concentration of the contaminants of concern in the groundwater, (2) amount of filter aid used, and (3) size of the microfiltration unit. During the technology demonstration, a 2.4-square foot microfiltration unit treated approximately 20 gallons of groundwater during each cycle. Therefore, it is assumed that the 36-square foot microfiltration unit will be capable of treating 300 gallons of groundwater during each cycle.

During a 1-year period, the 2.4-square foot unit will treat approximately 525,600 gallons, and the 36-square foot unit will treat approximately 7,884,000 gallons. A 1-year period of time was chosen for this analysis so that an estimated annual operation and maintenance cost could be developed. It should be noted, however, that most groundwater remedial actions cover a significantly longer period of time (such as 10 to 30 years) and may require multiple treatment units.

For this analysis, the following assumptions were made regarding the untreated groundwater, operating conditions, and filtrate. The groundwater is acidic (has a pH of less than 7), has negligible ligands and organic contaminants, and is primarily contaminated with heavy metals (such as lead or zinc) at levels of up to 500 mg/L. The microfiltration system operating conditions are as follows: a precipitation pH of 9 (a lime dose of 1.5 g/L to raise the pH from 4.7); a filter aid dose of 12 g/L; a blowdown time of 0.5 minute; and a blowdown pressure of 38 psig. The contaminated groundwater will be treated to meet National Pollutant Discharge Elimination System (NPDES) requirements for discharge into a nearby surface water.

The following is a list of other assumptions used for this analysis:

- The site is located in the Midwest.
- Utilities such as electricity and telephone lines will be overhead.
- Suitable access roads are available.
- Contaminated groundwater is in a shallow aquifer.
- A heated temporary tent-like enclosure will be required to house equipment.
- The installation cost of the microfiltration system at the site is assumed to be 3 to 5 percent of the capital equipment cost (depending on size) and is included in the capital cost.
- One technician will be required per shift to operate and maintain the equipment, collect all required samples, and perform equipment maintenance and minor repairs.

Table 4-1. Estimated Costs Associated with DuPont/Oberlin Microfiltration Systems

Cost Categories	Estimated Costs (1990 $) 2.4 sq. ft.[a]	Estimated Costs (1990 $) 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
Supply and Consumable [c]	16,900	220,000
Utility [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 one-year period, it is assumed that the 2.4-sq. ft. unit will treat about 525,600 gallons and the 36-sq. ft. unit will treat about 7,884,000 gallons.
b One-time costs.
c Annual operation and maintenance costs.

- Labor costs associated with major equipment repairs or replacement are not included.
- The filter cake and used filter media will be considered nonhazardous wastes, and will be disposed of in a permitted sanitary landfill.
- A composite sample will be taken weekly from the filtrate discharge and analyzed for heavy metals and pH.
- Filter aid will be purchased in sacks for the 2.4-square foot unit and in bulk for the 36-square foot unit.
- No pretreatment other than lime addition and filter aid addition is required.
- The filtrate will require pH adjustment (post-treatment) to meet applicable discharge limits (typically 6 to 9).
- Site demobilization does not include transportation of the microfiltration equipment.

A discussion of each of the 12 cost categories and the elements associated with each category is provided in Table 4-1.

Site Preparation Costs

The costs associated with site preparation include planning and management, system design (as well as design of auxiliary systems and controls), legal searches, access rights, construction work, emergency and safety equipment, shakedown, and start-up.

Site preparation costs will vary depending on the type, condition, and geographical location of the site. Sites that require major clearing or sites that are located in the northern part of the country will have significantly increased site preparation cost. Utilities must be installed in accordance with national codes and local ordinances.

In addition to the above items, site preparation costs include an untreated groundwater storage tank, an office/laboratory trailer, an air compressor, a temporary tent-like structure for the microfiltration system, a pH adjustment system, and treated groundwater discharge piping.

For this analysis, site preparation costs are estimated to be approximately $209,200 for the 2.4-square foot microfiltration unit and $843,200 for the 36-square foot microfiltration unit (R.S. Means Co. Inc., 1989; McArdle, *et al.*, 1988). Installation of a groundwater extraction and transmission system, which was not included in this analysis, may considerably increase the site preparation cost. The cost for this system was not estimated because it is highly site-specific.

Permitting and Regulatory Costs

Permitting and regulatory costs will vary depending on whether treatment is performed on a Superfund or a RCRA corrective action site and on how the effluent, filter cake, and filtrate are disposed. Section 121 (d) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), requires that remedial actions be consistent with applicable or relevant and appropriate requirements (ARAR) of environmental laws, ordinances, regulations, and statutes. ARARs include federal standards and criteria, as well as more stringent standards or criteria promulgated under state or local jurisdictions, and must be determined on a site-specific basis.

At RCRA corrective action sites, analytical protocols and annual monitoring records will have to be kept, which will increase the regulatory costs. For these situations, an additional 5 percent should be added to the cost estimated for this category. Contaminated soil removed during the installation of monitoring and extraction wells will have to be disposed of in compliance with RCRA or state requirements. Soil that will be disposed of at a permitted landfill will have to meet federal or state land disposal restriction requirements.

Permitting and regulatory costs are assumed to be approximately 5 percent of the capital equipment costs for a treatment operation that is part of a Superfund remedial action.

Capital Equipment Costs

Capital equipment costs include the cost of the microfiltration system and the required auxiliary equipment, as well as the installation cost. Based on information provided by Oberlin, these costs are $45,500 for the 2.4-square foot unit and $225,000 for the 36-square foot unit. Installation costs are assumed to be approximately 3 to 5 percent of the capital cost (depending on size). The total capital cost is, therefore, estimated to be $47,800 for the 2.4-square foot unit and $231,800 for the 36-square foot unit. These costs include only the equipment furnished by the microfiltration system manufacturer.

Startup and Fixed Costs

Startup costs include those costs required to establish operating procedures, train operators, perform initial shakedown of equipment and analysis procedures, and initiate an environmental monitoring program.

To ensure safe, economical, and efficient operation of the system, an operator training program will be required. The costs associated with developing the operator training program will include developing a health and safety program and associated documents, providing health and safety training, and providing operation and maintenance training for the microfiltration system.

All new operators will need health and safety training. In addition, since all operators will be responsible for daily monitoring and operation of the equipment, operation and maintenance training will be required and will be provided by equipment manufacturers and the engineer responsible for designing the system. Startup training costs are estimated to be approximately $30,000. This estimate is based on four 40-hour health and safety training courses, 4 weeks of operation and maintenance training (including "hands-on"), and one week follow-up training for equipment troubleshooting.

Mobilization and shakedown costs include transportation of the equipment to the site, initial setup, initial startup and trial runs, and equipment optimization. These costs are site-specific and will vary depending on the location of the site, complexity of controls, and the degree of automation. For this analysis, mobilization, shakedown, and equipment startup are assumed to be $50,000. Total startup and fixed costs are estimated to be approximately $80,000.

Labor Costs

After the construction, equipment installation, initial startup, and optimization are completed, the operators will assume operation of the system. The system will operate on a batch cycle, with an operator monitoring operation of all auxiliary equipment and making necessary adjustments to compensate for changes in metal concentration, pH, and temperature of the groundwater. The operator will also prepare the required chemicals, such as lime slurry for pH adjustment and filter aid, and will collect the required samples, dispose of filter cake, and operate auxiliary equipment. This analysis assumes that four operators will operate this system on a shift basis 7 days per week, 24 hours per day. It is assumed that the operators will be paid $15 per hour (fringe benefits are not included). The annual operating labor cost will be $131,400 for the operators. All operators will require an annual health and safety refresher course, which is estimated to cost $2,000 annually. Total annual labor costs are estimated to be $133,400.

Supply and Consumable Costs

Supplies and consumable costs for the DuPont/Oberlin microfiltration system include filter aid, lime for pH control, filter media, hydrochloric acid for effluent pH adjustment, and other miscellaneous supplies. The quantities of filter aid, lime, filter media, and hydrochloric acid used will depend on the size of the system and the concentrations of the metallic contaminants in the groundwater. These costs are estimated to be approximately $16,900 for the 2.4-square foot unit and $220,000 for the 36-square foot unit. Except for hydrochloric acid, costs are based on the average cost of supplies and consumables incurred during the SITE demonstration of the DuPont/Oberlin system. Hydrochloric acid costs are estimated based on lowering the filtrate (effluent) pH from 11.5 to between 6 and 9.

Utility Costs

The DuPont/Oberlin system operates on 240/480V three-phase electric power. In addition to electric power, the system requires high pressure air at approximately 100 psig. Since the air compressor is driven by an electric motor, only total electric power requirements will be evaluated. The system also requires potable water at 40 psig for equipment washing and preparation of lime and filter aid slurries. About 150 gallons of potable water should be adequate per 1,000 gallons of water treated. In some applications, to conserve water filtrate may be used instead of potable water.

The total electric power requirements will greatly depend on the total quantity of groundwater treated as well as the size of the microfiltration unit used, the size of the compressor used, and the size of all auxiliary equipment, which is also electrically driven. It is estimated that the electric power cost will be approximately $8.46 per 1,000 gallons treated. For this analysis, it is assumed that the power cost is $.10 per kilowatt-hour. It should be noted that the cost of power can vary by as much as 50 percent, depending on the local utility company rates.

The cost of water required is estimated to be about $2.00 per 1,000 gallons treated. It should be noted that this cost can vary by as much as 1,000 percent depending on geographic location, availability of water, distance to the nearest water main, and other factors. If water is to be delivered by truck, this cost will be higher yet.

The cost of heating and ventilation of the required tent-like enclosure for the microfiltration equipment and office/laboratory space is not included in this analysis. This cost will greatly depend on geographic location, availability of natural gas (cost of electric heat is much higher), and many other factors.

Effluent Monitoring Costs

This cost category covers effluent monitoring for compliance with NPDES permit limits. Effluent monitoring will be performed by the microfiltration system operators. Effluent will be discharged to a nearby surface water or reinjected into the groundwater if permitted by local and state regulations. The cost estimate for effluent monitoring will greatly depend on local and state requirements. For this analysis, it is assumed that the effluent will be discharged to a nearby surface water by gravity, and the cost associated with monitoring is $15,000 per year.

Residuals and Waste Shipping, Handling, and Transportation Costs

The DuPont/Oberlin microfiltration system produces considerable amount of filter cake, which requires special handling and disposal. Used filter media also needs to be disposed of. For this analysis, all these materials are assumed to be nonhazardous and, therefore, may be disposed of in a permitted sanitary landfill. These costs will depend on geographic location, distance to the permitted landfill from the site, as well as other factors such as the concentrations of regulated metallic contaminants in the groundwater, the degree of treatment, and the quantity of filter aid used.

Waste shipping, handling, and transportation costs are based on the generation of 70 pounds of filter cake per 1,000 gallons of groundwater treated and an estimated disposal cost of $200 per ton. The annual handling, shipping, and disposal costs are estimated to be $3,700 for the 2.4-square foot unit and $55,200 for the 36-square foot unit.

Analytical Costs

Analytical costs include sample shipment, laboratory analysis, data reduction and tabulation, quality assurance and quality control (QA/QC), and reporting. Monthly laboratory analysis costs are estimated to be approximately $2,000, while data reduction and tabulation, QA/QC, and reporting should cost approximately $1,000 per month. This analysis assumes that four treated water samples will be taken every month and analyzed for metals. Total estimated analytical costs, therefore, are approximately $36,000 per year.

Equipment Repair and Replacement Costs

During the course of operation, some parts of the system may require repair or replacement. Since insufficient data is available on the long-term reliability of a microfiltration system, no cost can be assigned. For this analysis, it is assumed that the annual equipment repair and replacement cost is $2,500 for the 2.4-square foot microfiltration unit system and $7,000 for the 36-square foot unit system. This cost, however, does not include any major repairs or replacements.

Site Demobilization Costs

Site demobilization will include operation shutdown and decommissioning of equipment, site cleanup and restoration, disconnection of utilities, closing of groundwater extraction wells, and disposal of decontamination waste and any other wastes. Site demobilization costs will vary depending on whether the treatment operation was conducted at a Superfund site or at a RCRA corrective action site. Demobilization at a RCRA corrective action site will require detailed closure plans and permits, which are not required at a Superfund site. This analysis assumes site demobilization costs will only cover costs of disassembling and transporting all equipment and removing all exposed piping and electrical lines. This estimated cost is based on previous similar projects. The estimated demobilization cost for the 2.4-square foot unit is $30,000 and $85,000 for the 36-square foot unit. Decommissioning and disposal of buildings, permanent tanks, and extraction/monitoring wells is not included in this cost estimate.

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Appendix A
Vendor's Claims for the Technology

Introduction

Many industries face the challenge of removing heavy metals from groundwaters and industrial wastewaters to meet stringent discharge or disposal limits. Conventional technologies, such as chemical precipitation followed by clarification and sand filtration, are generally unsuitable to meet the stringent limits, while advanced technologies such as ion exchange, ultrafiltration, and reverse osmosis are expensive options for heavy metal removal. The metals precipitate generated during the chemical precipitation process is usually landfilled. However, the Resource Conservation and Recovery Act (RCRA) requires that the precipitate pass the paint filter liquids test before it can be landfilled. RCRA also requires that the precipitate pass the toxicity characteristic leaching procedure (TCLP) test for its disposal at a nonhazardous waste landfill. For these reasons, the metals precipitate must be adequately dewatered (to pass the paint filter liquids test) and stabilized (to pass the TCLP test).

The DuPont/Oberlin microfiltration technology can treat metal-bearing wastewaters to meet regulatory requirements at a reasonable cost. The use of this technology has solved many problems found in the metal forming and metal working industries, eliminating many disadvantages of conventional treatment technologies, particularly chemical precipitation followed by clarification and sand filtration. A description of the DuPont/Oberlin microfiltration technology and its applications are presented below.

DuPont/Oberlin Microfiltration Technology

The DuPont/Oberlin microfiltration technology is a physical separation process for removing submicron particles from liquid wastes. The submicron particles from liquid wastes are removed using a spunbonded olefin filter media, known as Tyvek® T-980 (developed by E.I. DuPont de Nemours and Company, Inc.), and an automatic pressure filter (developed by Oberlin Filter Company). The Tyvek® filter media has a high tensile strength (wet and dry) and is manufactured and sold in rolls, making it suitable for use with the Oberlin filter, which uses a roll feed and discharge. Another important feature of the Tyvek® media is its smooth and slick surface which facilitates excellent separation of filtered solids from its surface. Tyvek® can remove submicron particles at a cost almost 97.5 percent less than other competitive filtration media, such as microporous membranes (Lim and Mayer, 1989).

When liquid wastes contain dissolved metals, DuPont/Oberlin pretreats the wastes to convert the metals into an insoluble form (precipitate) using chemicals, such as lime, caustic, sodium carbonate, or sodium sulfide. After the metals are precipitated, a filter aid/stabilizing agent, known as ProFix (manufactured by EnviroGuard, Inc. of Houston, Texas), is added to the metals precipitate prior to microfiltration to produce a dry and stabilized filter cake.

A brief description of the Oberlin pressure filter and its capabilities are presented below.

Oberlin Pressure Filter Equipment

The Oberlin pressure filter is a versatile, rugged, and industrial-scale solid/liquid separation unit. A schematic of the Oberlin pressure filter is shown in Figure 2-1. The filter has two compartments—an upper compartment, or filter platen; and a lower compartment, or filter chamber. The platen moves while the chamber is fixed in place. The filter media lies between these two compartments.

At the beginning of a filtration cycle, airbags lower the filter platen against the filter chamber. Platen seals on the perimeter of the compartments form a liquid-tight seal around the filter media. The liquid waste containing solids is pumped into the platen and forced by the pump pressure through the filter media. The filtered liquid is collected in the lower compartment and drained out.

When the pressure inside the filter reaches 30-50 psig (maximum, depending on the model), the feed pumping stops, and pressurized air is fed into the platen forcing the remaining liquid through the filter cake and media. After the cake is dried (as determined by back pressure and time elapsed), the platen is lifted by an air cylinder. The cake is then automatically discharged either by using an endless conveyor belt or by simply pulling the spent filter media by a motor driven reroller. After the cake discharge, the filter platen automatically descends and a new filtration cycle starts.

The filter is made of carbon steel. All parts can be lined with 304/316 stainless steel or coated with Halar or other metals such as Alloy 20, if required. The filter does not require a special foundation; a flat area is adequate. Electrical controls are based on either discrete relays and timers or programmable logic controllers (PLC). Filters with explosion proofing option (for treating munitions wastes) are also available.

Oberlin Pressure Filter Capabilities

The Oberlin pressure filter has a few unique capabilities to produce a high quality filtrate and a dry cake while treating liquid wastes. These capabilities are listed below:

- It operates at a relatively high pressure (up to 50 psig) to ensure long operating cycles.
- It is truly an automatic filtration system designed for unattended operation (except for filter aid slurry preparation, cake removal, and filter media roll replacement). Its operation is precisely controlled through a PLC to minimize operator attention.
- It has a horizontal filtering area to allow relatively thick filter cake to form. Also, the cake formed in this process is dry because the moisture present in the cake is forced out by pressurized air or nitrogen.
- The filter is skid-mounted for easy transportation.
- The operating costs are kept low through the use of standard industrial controls for the filter.

Applications of the DuPont/Oberlin Microfiltration Technology

The DuPont/Oberlin microfiltration technology has been used to:

- Treat wastewater containing uranium, aluminum, lead, cadmium, nickel, copper, and zinc to meet fairly stringent National Pollutant Discharge Elimination System limits at metal forming operations in uranium manufacturing processes.
- Treat lead-bearing wastewaters from a ceramics manufacturing plant.
- Remove heavy metals from a battery manufacturing facility's wastewater.
- Remove lead solids from an electronics manufacturing plant's wastewater.
- Remove lead from a munitions plant's wastewater.
- Remove copper, zinc, cadmium, and lead from another munitions plant's wastewater.
- Remove iron, lead, chromium, nickel, copper, and zinc from contaminated groundwater prior to volatile organic compounds removal by stripping.
- Remove iron, lead, chromium, copper, zinc, silver, and nickel from a chemical plant's wastewater prior to discharge. Discharge limits are very low for this application (for example, 13 ppb for copper).

Details on some of these applications can be found in a paper presented at the Second U.S. EPA Forum on Innovative Hazardous Waste Treatment Technologies, Philadelphia, Pennsylvania (Mayer, 1990). As can be seen from these applications, the technology is well suited for a variety of wastewaters and groundwaters, if the metals can be converted into an insoluble form prior to filtration.

Summary

Over the past 8 years, the DuPont/Oberlin microfiltration technology has evolved into a viable technique for removing heavy metals from contaminated groundwaters and industrial wastewaters. It is basically a submicron filtration process that removes practically all suspended metals much more effectively than conventional techniques (such as precipitation followed by clarification, and sand filtration). It also produces a dry cake that will pass the paint filter liquids test and the TCLP test. It accomplishes this in a simple, one-step operation that is totally automatic except for media replacement, filter aid makeup, and cake removal. Systems are now available that can also automate these steps, if desired.

References

Lim, H.S., and E. Mayer, 1989. Tyvek for Microfiltration Media, *Fluid Particle Separation Journal*, 2:1:17-21.

Mayer, E., 1990. DuPont/Oberlin Microfiltration System for Hazardous Wastewaters, presented at the *Second U.S. EPA Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International,* Philadelphia, Pennsylvania.

Appendix B
SITE Demonstration Results

Introduction

In February 1988, E.I. DuPont de Nemours and Company, Inc. (DuPont) and Oberlin Filter Company (Oberlin) submitted a joint proposal for their microfiltration technology to U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER) under the Superfund Innovative Technology Evaluation (SITE) program. EPA selected the DuPont/Oberlin microfiltration technology and identified the Palmerton Zinc Superfund (PZS) site as an appropriate site for the technology demonstration. The technology was demonstrated at the PZS site in April and May 1990 through a cooperative effort between ORD, OSWER, EPA Region 3, DuPont, and Oberlin. This appendix briefly describes the PZS site and summarizes the SITE demonstration activities and demonstration results.

Site Description

The site is located in the Lehigh Valley along the Aquashicola Creek in the town of Palmerton, Pennsylvania. Figure B-1 is a map of the site. The site includes all areas of possible contamination resulting from operations at the Zinc Corporation of America (ZCA) industrial complex. The ZCA complex consists of two zinc smelting plants. West of the town is the West Plant, located where the Lehigh River meets the Aquashicola Creek. The East Plant is located on the southern bank of the Aquashicola Creek.

Zinc smelting operations at the PZS site began in 1898 and 1915 at the West and East Plants, respectively. In 1980, primary zinc smelting at the ZCA facility ceased and the West Plant was shut down. Secondary metal refining and processing operations continue in the East Plant.

During the last 70 years, zinc smelter operations have resulted in 33 million tons of zinc residue accumulating and forming an extensive cinder bank along the southern boundary of the East Plant. This cinder bank has contaminated the surrounding areas, including the groundwater and surface water. Because of the contamination, the cinder bank was placed on the National Priorities List (NPL No. 339) in December 1982. Under an Administrative Order of Consent dated September 24, 1985, ZCA agreed to conduct a remedial investigation/feasibility study (RI/FS) of the on-site surface water and groundwater, as well as the cinder bank. The RI/FS work was carried out by ZCA's contractor, R.E. Wright Associates, Inc.

Site Contamination Characteristics

Air emissions from smelting operations at the East and West Plants, and the cinder bank, have contaminated the surrounding environment. The primary constituents of concern are cadmium, copper, lead, and zinc. Cadmium, copper, and lead commonly occur as minor constituents in zinc sulfide ore, which was the primary raw material used in smelting operations at the Palmerton smelting plants. Previous studies as well as the RI/FS have shown heavy metals in measurable amounts in soils in the surrounding Palmerton area, with the highest concentrations present in soils immediately surrounding the East and West Plants. Emissions from the smelters also caused the defoliation of approximately 2,000 acres on Blue Mountain.

Data from the draft RI report (ZCA, 1987) was used to select the shallow aquifer at the site as the candidate waste stream for the technology demonstration. Groundwater samples collected by EPA in June 1989 indicated that the shallow groundwater is 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).

Review of SITE Demonstration

The SITE demonstration was divided into three phases: (1) site preparation; (2) technology demonstration; and (3) site demobilization. These activities and a review of technology and equipment performance during these phases are described below.

Site Preparation

Approximately 10,000 square feet of relatively flat ground surface was used for the microfiltration system and support equipment and facilities, such as a filtrate storage tank, nonhazardous and potentially hazardous waste storage containers, office and field laboratory trailer, and a parking area. A temporary enclosure covering approximately one-third of the demonstration area was erected to provide shelter for the microfiltration system during inclement weather. A secondary containment area was provided for the tanks holding treated and untreated groundwater to collect any spills or leakage. Site preparation included setting up major support equipment, on-site support services, and utilities.

Major Support Equipment

Support equipment for the microfiltration system included storage tanks for untreated and treated groundwater, storage tanks for equipment washdown and decontamination rinse waters, equipment for treated effluent disposal, a dumpster, a forklift with operator, a bulldozer with operator, pumps, sampling equipment, health and safety-related gear, and a van. Specific items include:

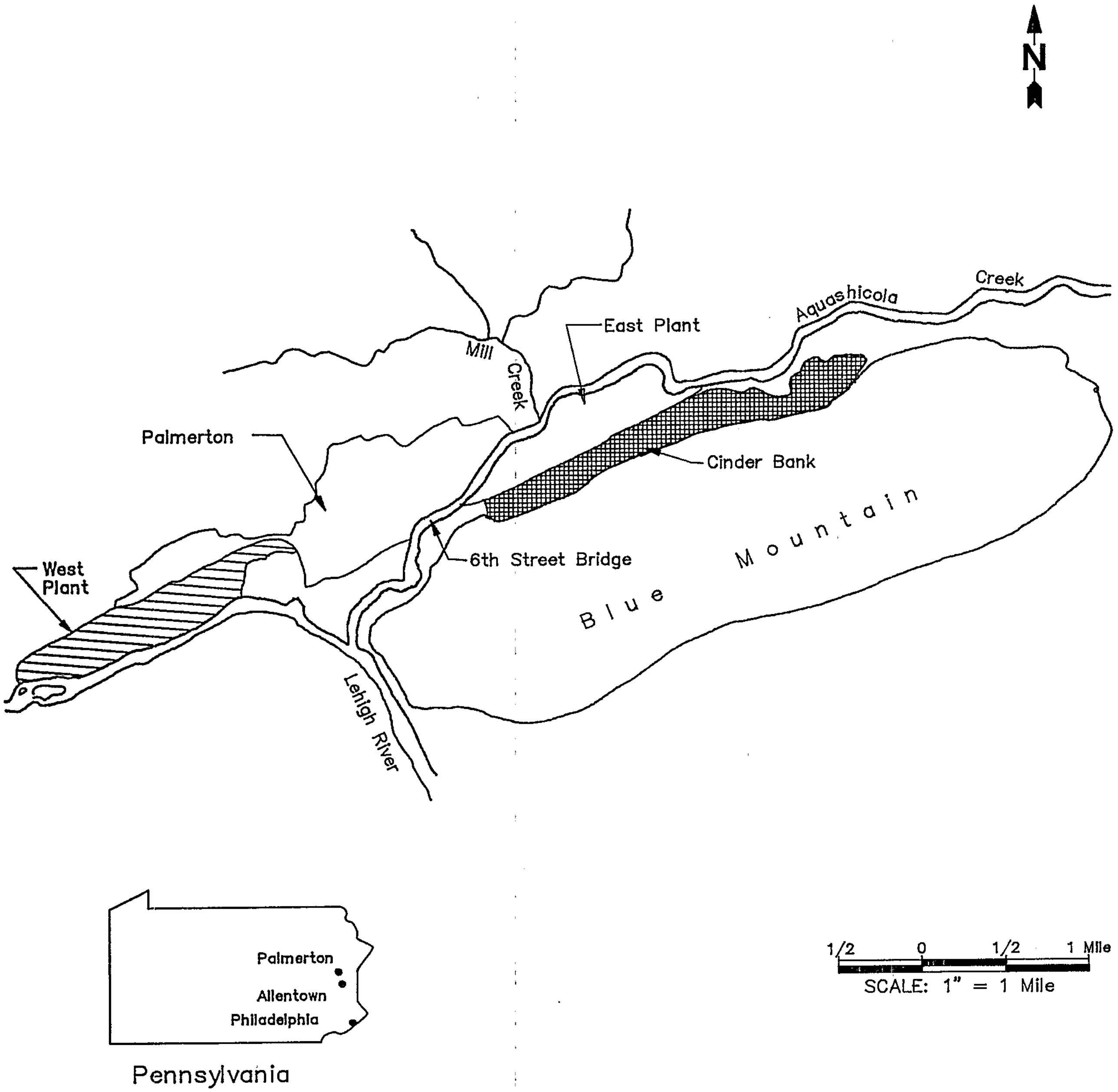


Figure B-1. PZS Site Location Map.

- One 1,600-gallon tank mounted on a truck to transport the groundwater required to perform all test runs. Groundwater was collected from well RCRA-4, transported to the demonstration area, and pumped into a 6,000-gallon storage tank.
- One 6,000-gallon filtrate storage tank sized to contain the filtrate from all test runs.
- One 4,500-gallon storage tank to contain the equipment washdown and decontamination rinse waters.
- One 1,000-gallon storage tank to store tap water required for equipment and personnel decontamination.
- One 1,000-gallon storage tank to store deionized water required for equipment decontamination.
- One 1,600-gallon storage tank to temporarily store (1) the metals precipitate sludge remaining at the end of each run, (2) filtrate collected during the cake drying cycle, and (3) equipment washwater. This waste was temporarily stored in this tank until it was treated and pumped to the 4,500-gallon storage tank for appropriate disposal.
- One solid waste dumpster to store nonhazardous wastes prior to disposal.
- A number of 55-gallon drums to contain filter cake, used filter media, and used disposable health and safety gear prior to disposal.
- A high-pressure steam cleaner for decontaminating the storage tanks and sampling equipment at the end of the demonstration.
- A bulldozer with operator to clear and grade the demonstration area.
- A forklift with operator for setting up equipment and for moving drummed wastes.
- One pump for transferring the contaminated shallow groundwater from well RCRA-4 to the tank truck, and from the tank truck to the untreated groundwater storage tank. An additional pump was needed to transfer the filtrate from the filtrate storage tank to a tank truck.
- An air compressor and related equipment for generating compressed air at 90 psig minimum and 40 scfm capacity. This compressed air was used in operating the microfiltration unit.
- Sampling equipment to sample filter cake and aqueous media.
- Analytical equipment for measuring field parameters at the demonstration site.
- Health and safety-related equipment, such as a first-aid kit and protective coveralls, latex or similar inner gloves, nitrile outer gloves, steel-toe boots and disposable overboots, safety glasses, and a hard hat.
- A van to transport oversight personnel and supplies.

On-Site Support Services

On-site laboratory analyses were conducted in a field trailer measuring 12 by 44 feet. The field trailer also served as an office for field personnel and provided shelter and storage for small equipment and supplies. A personal computer and printer were used for data processing. Two chemical toilets were located near the trailer.

Utilities

Utilities required for the demonstration included water, electricity, and telephone service. Water was required for the equipment and personnel decontamination and for drinking purposes. During operation of the demonstration unit, personnel and equipment decontamination required about 50 gallons per day (gpd) of tap water. Deionized water needs for final equipment decontamination were approximately 50 gpd. Drinking water needs were 5 to 10 gpd.

Electricity was needed for the microfiltration system, the office trailer, and the laboratory equipment. The microfiltration system required 240-volt, 3-phase, 60-Hz, and 20-amp electrical service. Additional electrical power (110-volt, single-phase) was needed mainly for operating the microfiltration system's agitators, lighting the office trailer, and operating the on-site laboratory and office equipment. A portable generator was used during the initial 2 weeks of the demonstration because Pennsylvania Power and Light Company could not provide the electrical connection due to rainy weather.

Telephone service was required mainly for ordering equipment, parts, reagents and other chemical supplies; scheduling deliveries; and making emergency communications.

Technology Demonstration

This section discusses operational and equipment problems and health and safety issues associated with the SITE demonstration.

Operational Problems

The SITE team experienced a few operational problems during the demonstration. Some of these problems resulted in changes in the demonstration schedule and duration, while the others required making field decisions to solve the problems. These operational problems and their resolutions are described below.

- Pennsylvania Power and Light Company could not provide electrical power connection for onsite operations during the first 2 weeks of demonstration. The SITE team rented a portable generator to perform the field work during this period. Although the generator could provide adequate power supply, field personnel had to make frequent trips to diesel fuel stations to obtain diesel for the generator. Sometimes, the voltage fluctuations by the generator resulted in minor problems in the operation of field analytical instruments.
- According to the technology developers, several additional dry runs had to be performed because the groundwater characteristics during the demonstration were slightly different from those for the treatability studies performed in June

1989. In the dry runs, it was found that the volume of filtrate generated in each filtration cycle was significantly less than the quantity the developers anticipated. Because of this, the filtrate collection and recirculation tanks were too large to implement the sampling procedures planned for the demonstration. To solve this problem, significant modifications were made to the tanks used, the sampling approaches, and the number of cycles per run. This resulted in equipment modifications and demonstration schedule changes.

Equipment Problems

The SITE team experienced a few equipment problems during the demonstration. These problems resulted in (1) repeating the demonstration runs, (2) onsite equipment maintenance, and (3) changes in the demonstration schedule and duration. These equipment problems and their resolutions are described below.

- At the beginning of the demonstration, the filter aid pump did not deliver the rated flow rate due to cold weather. For example, when the pump was set at its maximum, it delivered only 16 gallons per hour (gph) instead of 40 gph. After the hydraulic oil in the pump warmed up and the filter pump was recalibrated onsite, the pump was able to deliver the desired flow rate.
- The filter feed pump flow rate could not be controlled properly because of the excessive air supply to the pump. The developer replaced the 0.5-inch air line with 0.25-inch air line and this solved the problem.
- The moisture trap of the compressor was not adequate to dry compressed air for proper functioning of the microfiltration system. Because of this, the pneumatic controls of the microfiltration system malfunctioned, and the pump flow rates could not be controlled properly in some runs. The moisture in the air lines had to be removed every few hours to minimize moisture accumulation. The demonstration runs impacted by this problem had to be repeated.
- The ProFix pump and the lines clogged frequently. To minimize this problem, ProFix was sieved through a Number 10 mesh size screen and also ProFix slurry was diluted from 9 percent to 6 percent. According to the developer, all commercially available ProFix is now screened to eliminate this problem.
- In one run, the filter media reroller did not function properly. The filter media did not reroll automatically at the end of some filtration cycles because the reroller did not have adequate tension. The developer discovered that it was because the clutch on the reroller slipped. The clutch was then repaired for proper functioning of the microfiltration unit.
- During the latter runs, it was found that the scraper bar on the microfiltration unit punctured the filter media because the scraper bar surface was not smooth. This problem was resolved by removing the scraper bar and using a new segment of filter media. This run was also repeated. The developer states that most commercially available filters have smooth scraper bars.

Health and Safety Considerations

In general, health hazards associated with the demonstration resulted from the possibility of exposure to the contaminated groundwater. Although the treatment system was entirely closed, the potential routes of exposure during the demonstration were inhalation, ingestion, and skin and eye contact from possible splashes or spills during sample collection.

All personnel working in this area had, at a minimum, 40 hours of health and safety training and were under routine medical surveillance. Personnel were required to wear protective equipment appropriate for the activity being performed. Steel-toe boots were required in the exclusion zone. Personnel working in direct contact with contaminated groundwater were in modified Level D protective equipment, including safety shoes, latex inner gloves, nitrile or Viton outer gloves, and safety glasses.

Site Demobilization

Decontamination was necessary for the DuPont/Oberlin demonstration unit, untreated groundwater storage tank, treated effluent storage tank, and sampling equipment.

The storage tanks were steam-cleaned at the end of the demonstration program. Filtrate collected during the demonstration was tested and discharged into an on-site treatment facility. Filter cake, along with disposable protective clothing such as coveralls, was collected in 55-gallon drums and disposed of at a permitted nonhazardous waste landfill.

After the demonstration program was completed and onsite equipment was disassembled and decontaminated, equipment and site demobilization activities began. Equipment demobilization included loading the skid-mounted units on a flat-bed trailer and transporting them off-site, returning rented support equipment, and disconnecting utilities.

Experimental Design

The objectives of the technology demonstration were to: (1) assess the technology's ability to remove zinc from the groundwater at the PZS site under different operating conditions, (2) evaluate the system's ability to dewater the metals precipitate from treated groundwater at the PZS site, (3) determine the system's ability to produce a filtrate and a filter cake that meet applicable disposal requirements; and (4) develop the information required to estimate the operating costs for the treatment system, such as electrical power consumption and chemical doses.

Testing Approach

The technology evaluation was performed in four phases. Phases 1 and 2 involved nine runs each, and Phases 3 and 4 involved two runs each. In Phase 1, chemical operating parameters (precipitation pH and ProFix dose) were varied, and the filter operating parameters (blowdown pressure and blowdown time) 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.

Table B-1 summarizes the operating conditions for the demonstration runs. For Phase 1 runs, the initial operating conditions (Run 1) were based on a pilot-scale treatability study performed by DuPont/Oberlin on the PZS site groundwater. During the demonstration, the chemical operating conditions and the filter operating conditions were optimized in Phases 1 and 2, respectively. Since Run 5 conditions were selected as the optimum operating conditions for Phase 1, these were set as the initial conditions for Phase 2. Phases 3 and 4 were performed at Run 13 conditions because these conditions were selected as the overall optimum operating conditions. This experimental design assumes that there is no interaction effect between the chemical and filter operating parameters. 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.

Sampling and Analytical Procedures

Solids and water samples were collected from the microfiltration system at the locations shown on Figure B-2. The following measurements were considered critical to evaluating the microfiltration system: (1) zinc in the untreated groundwater and filtrate, (2) total suspended solids (TSS) before and after the microfiltration unit, (3) free liquids (paint filter liquids test) and moisture content in the filter cake, and (4) pH of the untreated groundwater and filtrate. Several noncritical measurements were also performed, including the extraction procedure (EP) toxicity test and toxicity characteristic leaching procedure (TCLP) test for the filter cake, and particle size distribution for the filtrate. For the critical measurements, about three to six replicate samples were collected depending on the data variability. Duplicate samples were collected for noncritical measurements.

EPA-approved sampling, analytical, quality assurance, and quality control (QA/QC) procedures were followed to obtain reliable data. Details on QA/QC procedures are presented in the demonstration plan (PRC, 1990). Table B-2 summarizes analytical and measurement methods.

Review of Treatment Results

This section summarizes the results of both critical and noncritical parameters for the DuPont/Oberlin microfiltration system demonstration and evaluates the microfiltration technology's effectiveness in treating groundwater contaminated with zinc.

Summary of Results for Critical Parameters

Results for the critical parameters were evaluated for each of the four phases.

Phase 1 Results

The total zinc concentrations in the untreated groundwater and filtrate are presented in Figure B-3 for varying precipitation pH and ProFix doses. The zinc concentrations in the untreated groundwater, ranging from 417 to 493 mg/L, were reduced to about 0.1 mg/L (except in Run 6), yielding a typical removal efficiency of greater than 99.9 (3 logs) percent. In Run 6, the filtrate zinc concentration was an order of magnitude higher than the typical filtrate zinc level; this increased concentration cannot be explained. No definite trend was identified for effluent zinc levels or zinc removal efficiencies with varying pH or ProFix dose.

During the demonstration, a sample of the influent to the microfiltration unit was filtered through a standard 0.45-µm membrane filter (commonly used to measure dissolved) metals) to compare the resulting filtrate with T-980 filtrate. In all cases, the zinc concentration was less in the T-980 filtrate, indicating the possible superior performance of Tyvek® T-980 filter media.

Figure B-4 presents the TSS concentration profiles for influent and filtrate. These data show that the influent TSS concentrations ranged from 6,560 to 18,900 mg/L, and the filtrate TSS concentrations ranged from 8.4 to 31.5 mg/L. The TSS removal efficiencies ranged from 99.69 to 99.95 percent. Neither filtrate TSS levels nor TSS removal efficiencies seemed to follow a definite trend with varying pH or ProFix dose.

The filter cake solids levels are presented on Figure B-5. This figure shows that cake solids ranged from 30.5 to 47.1 percent. This figure also shows that the cake percent solids increased as the pH or ProFix dose increased. The filter cake passed the paint filter liquids test in all runs, making it suitable for landfilling.

The filtrate pH was typically about 11.5, irrespective of the precipitation pH due to the high pH (about 12.6) of the ProFix slurry added at the influent to the microfiltration unit.

At the end of Phase 1, Run 5 conditions were selected as the optimum chemical operating conditions based on (1) zinc and TSS removals, (2) zinc and TSS levels in the filtrate, (3) percent solids in the filter cake, and (4) the cost of treatment chemicals (lime and ProFix).

Phase 2 Results

Figures B-6, B-7, and B-8 present the concentrations profiles for zinc, TSS, and filter cake solids, respectively. These results are similar to Phase 1 results. The filter cake passed the paint filter liquids test in all Phase 2 runs, and the filtrate pH was typically about 11.5 (same as that in Phase 1 runs).

A dissimilarity was noted between the Phase 1 and Phase 2 results for Tyvek® T-980 filtrate and 0.45-µm filtrate. In the Phase 2 runs, the zinc concentrations in the Tyvek® T-980 filtrate were not always less than the 0.45-µm filtrate. This dissimilarity cannot be explained.

At the end of the Phase 2 runs, Run 13 conditions were selected as the optimum operating conditions based on the criteria discussed for Phase 1, plus waste processing time (which includes blowdown time).

Table B-1. Operating Conditions for the Demonstration Runs

Phase	Run No.	Precipitation pH	ProFix Dose (g/L)	Time (Min)	Pressure(psig)
1	1	8	6	2	45
	2	9	6	2	45
	3	10	6	2	45
	4	8	12	2	45
	5	9	12	2	45
	6	10	12	2	45
	7	8	14	2	45
	8	9	14	2	45
	9	10	14	2	45
2	10	9	12	0.5	30
	11	9	12	2	30
	12	9	12	3	30
	13	9	12	0.5	38
	14	9	12	2	38
	15	9	12	3	38
	16	9	12	0.5	45
	17	9	12	2	45
	18	9	12	3	45
3	19	9	12	0.5	38
	20	9	12	0.5	38
4	21	9	12	0.5	38
	22	9	12	0.5	38

Phase 3 Results

The total zinc concentration in the untreated groundwater in Runs 19 and 20 (reproducibility runs performed at Run 13 operating conditions) was 465 mg/L. This was reduced by 99.95 and 99.94 percent, 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 percent), 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. These were reduced by 99.95 percent, 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 percent), indicating that the system's performance in removing TSS was reproducible.

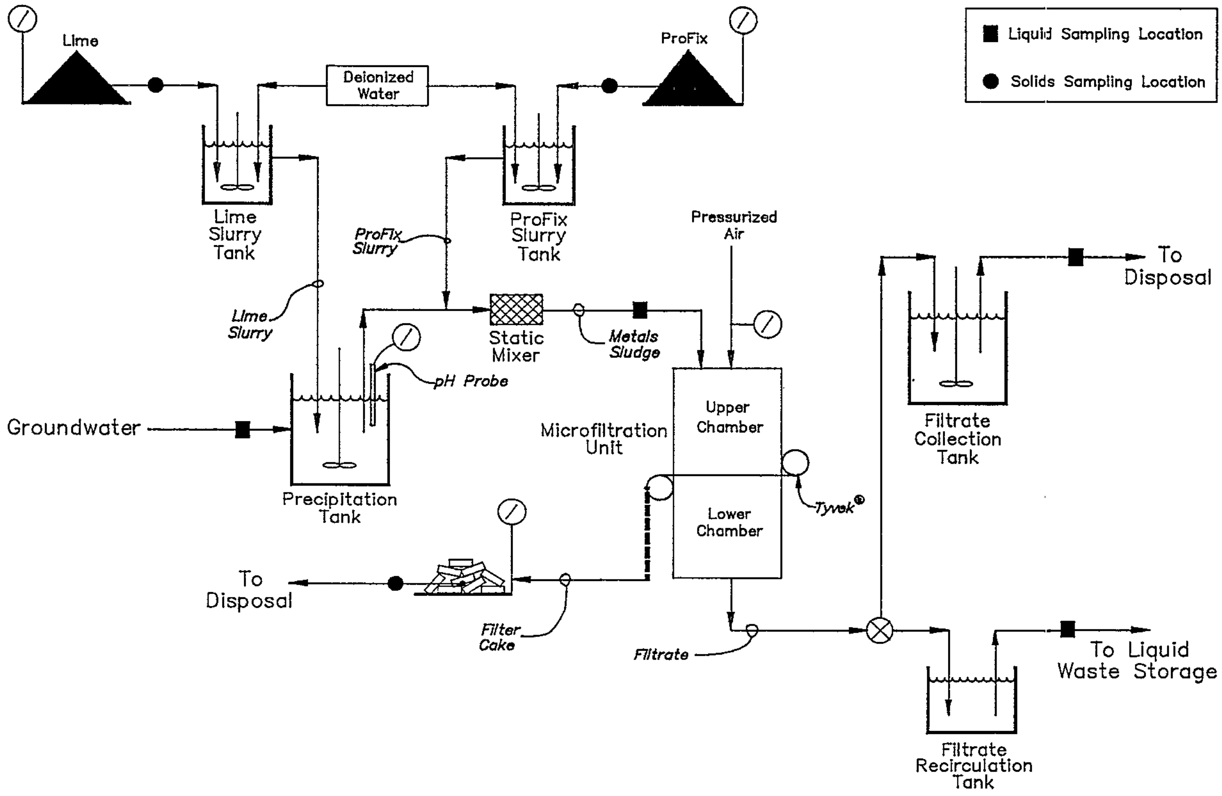


Figure B-2. Microfiltration System Sampling Locations.

Table B-2. Analytical and Measurement Methods

Parameter	Matrix[a]	Method Type	Method	Reference	Title
Metals (total)	L	Lab	SW-846	3010/6010[b]	Metals by ICP
Metals (dissolved)	L	Lab	SW-846	3005/6010[b]	Metals by ICP
EP Toxicity	S	Lab	SW-846	1310[b]	Extraction
			SW-846	3010/6010[b]	Metals by ICP
TCLP	S	Lab	40 CFR	Part 268[c]	Toxicity Characteristic Leaching Procedure
Metals (total)	S	Lab	SW-846	3050/6010	Metals by ICP
Free Liquids	S	Field	SW-846	9095[b]	Paint Filter Liquids Tests
Moisture Content	S	Field	SM 209F[d]		Percent Solids
TSS	L	Field	MCAWW	160.2[e]	Residue (filterable)
Acidity	L	Field	MCAWW	3051[e]	Acidity (Titrimetric)
Particle Size	L	Lab	Coulter Corporation Manufacturer Spec.		Particle Size Analysis
Temperature	L	Field	MCAWW	170.1[e]	Temperature
pH	L	Field	MCAWW	150.1[e]	pH
Turbidity	L	Field	MCAWW	180.1[e]	Turbidity
Volume	S, L	Field	NA[f]		Volume
Mass	S	Field	NA[f]		Mass
Electricity Consumption	O	Field	NA[f]		Electricity Consumption

Notes
a L = Liquids
S = Solids
O = Others
b U.S. EPA, 1986.
c. 40 CFR, 1988
d APHA, AWWA, and WPCF, 1989.
e U.S. EPA, 1983
f NA = Not available

Figure B-9 compares regulatory thresholds with (1) the 95 percent upper confidence limits (UCL) for filtrate metals Cadmium, lead, and zinc) and TSS and (2) the average filtrate pH value. the regulatory thresholds are those that would be required for discharge into a local waterway (Aquashicola Creek) if an 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, their mean concentrations were estimated using standard statistical procedures. Figure B-9 shows that the filtrate met the NPDES limits for metals and TSS. However, the NPDES limit for pH was not met.

Figure B-10 presents the composition of the filter cake in the reproducibility runs. Percent solids in the filter cake was about 41. Of these solids, about 80 to 90 percent were from ProFix, and the remaining were from (1) TSS present in the untreated groundwater: (2) metals precipitated during the treatment; 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 mass balance results for zinc showed that the difference between zinc in and zinc out was about 15 percent, which is within analytical precision (± 25 percent). Similarly, TSS measurements were also within analytical precision (± 30 percent).

Phase 4 Results

The results for the Tyvek® reusability runs (Runs 21 and 22) are presented on Figure B-11. 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 B-11 shows that the microfiltration unit's performance was unaffected even after multiple uses of Tyvek®.

Summary of Results for Noncritical Parameters

The demonstration also evaluated the results for noncritical parameters such as filter cake toxicity characteristics and the filtrate particle size distribution. Toxicity characteristics were considered a noncritical parameter because EP and TCLP metals were present at very low levels in the untreated groundwater. The particle size distribution measurement was included primarily to evaluate the developers' claim that the Tyvek® filter can remove particles down to 0.1 micron (µm). The filter cake toxicity characteristics were determined using EP and TCLP tests. A composite filter cake sample collected from the demonstration runs passed both these tests, indicating that the filter cake could be disposed of as a nonhazardous waste.

Figure B-12 presents the filtrate particle size distribution and TSS results for the reproducibility runs. The particle size was measured using a Coulter counter with a 0.5-to 500-µm measurement range. The data presented on this figure indicate that the majority of particles present in the filtrate were 1 to 4 µm in size. The TSS data for these runs were used together with the particle size distribution to estimate the particle concentration in each size range. In Run 13 for example, filtrate particles ranging from 1 to 2 µm and greater than 8 µm were present at 6.3 mg/L and 0.63 mg/L, respectively. These results do not support the developers' claim that the Tyvek® filter can remove particles down to 0.1 µm. Similar observations were made for Runs 19 and 20.

After reviewing the particle size distribution and TSS data, DuPont stated that the TSS measured in the filtrate was the result of postprecipitation of calcium carbonate solids. DuPont provided X-ray diffraction data for the TSS collected on a 0.45-µm filter by processing the filtrate from the microfiltration unit in Phase 1 runs. The X-ray diffraction data showed a much stronger peak for calcium carbonate solids than for zinc solids; however, quantitative data were not available. DuPont also stated that the filtrate turbidity it measured immediately after sample collection typically ranged from 0.1 to 0.3 NTU and that TSS values were about 0.2 mg/L. These levels are lower than those observed by EPA, although EPA analyzed its samples well within the holding times specified by EPA-approved analytical methods. DuPont observed that both turbidity and TSS levels in the filtrate samples increased overnight, indicating postprecipitation effects. Such observations were not made during the pilot-scale tests performed before the demonstration, perhaps because the batch of groundwater used during the pilot-scale testing was different from that used during the demonstration.

Conclusions

The DuPont/Oberlin microfiltration system achieved the following: (1) zinc and TSS removal efficiencies of 99.69 to 99.99 percent and (2) solids in the filter cake of 30.5 to 47.1 percent. At the optimum conditions (Run 13), the zinc and TSS removal efficiencies were about 99.95 percent and the filter cake solids were about 41 percent.

ProFix contributed a significant portion (80 to 90 percent) 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 (six 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, established for disposal into a local waterway, for metals and TSS at the 95 percent confidence level. However, the filtrate did not meet the NPDES permit limit for pH. The filtrate pH was typically 11.5, while the permit limit is 6 to 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 EP toxicity and TCLP tests.

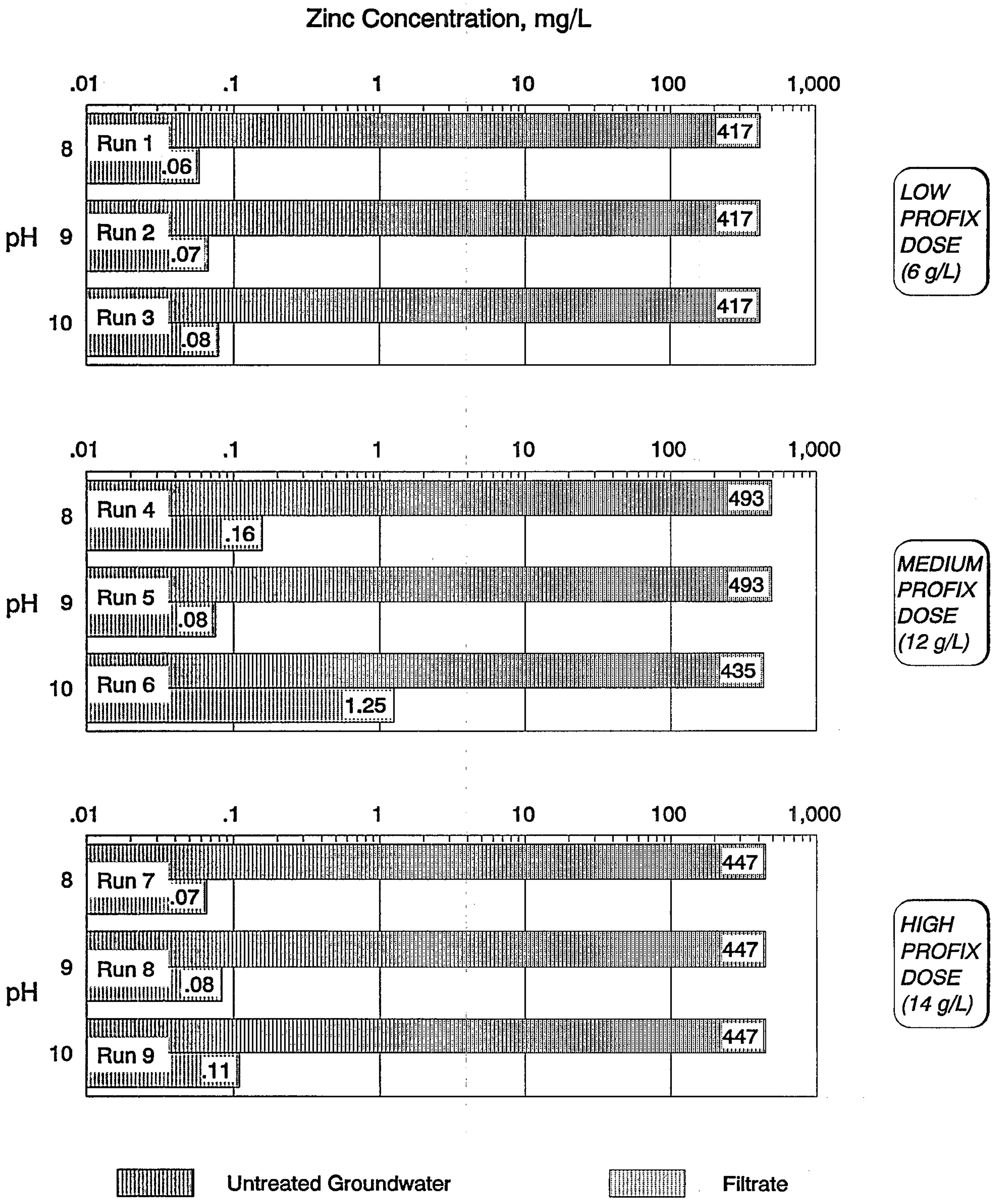
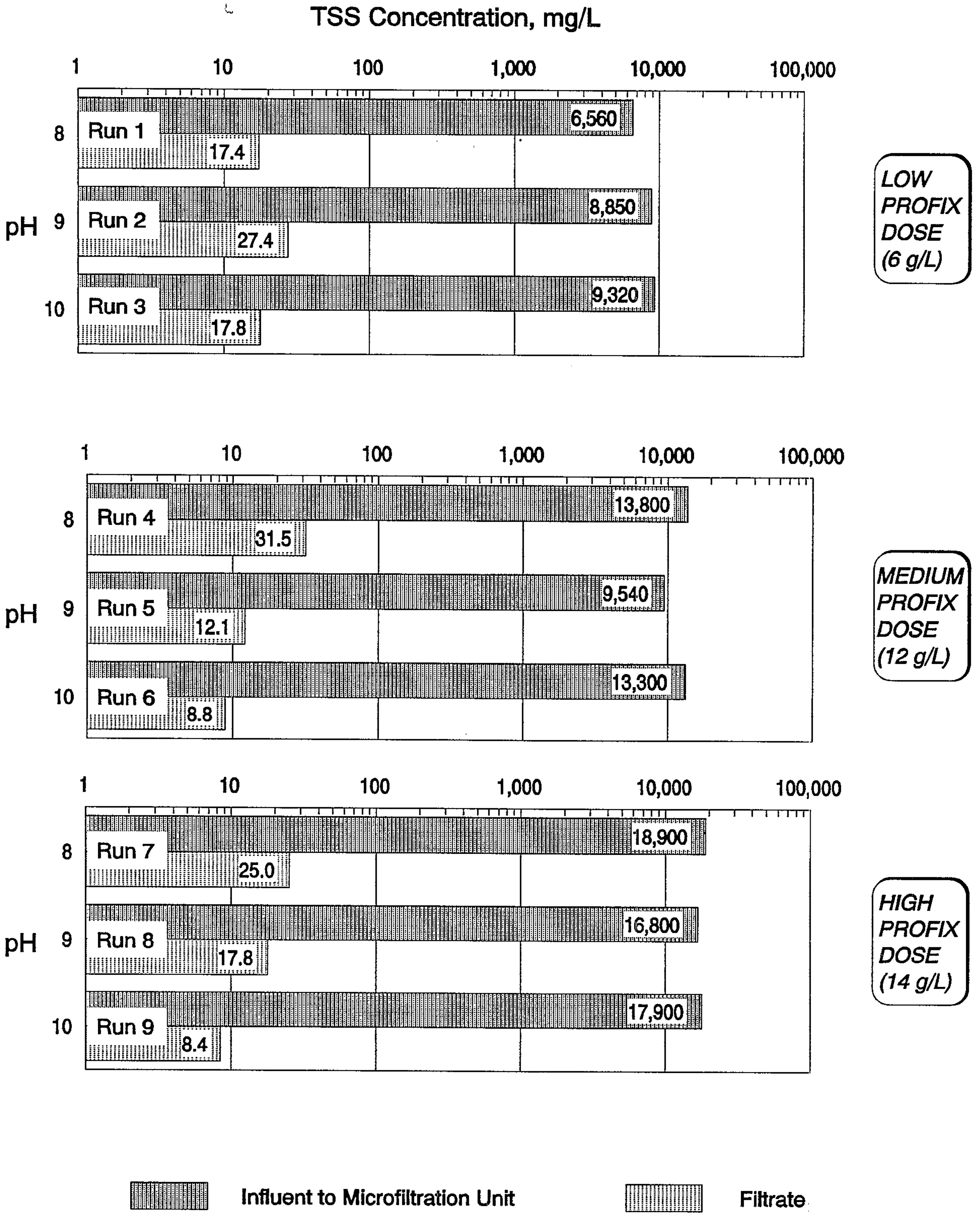


Figure B-3. Zinc Concentration Profiles for Phase 1 Runs.



FigureB-4. TSS Concentration Profiles for Phase 1 Runs.

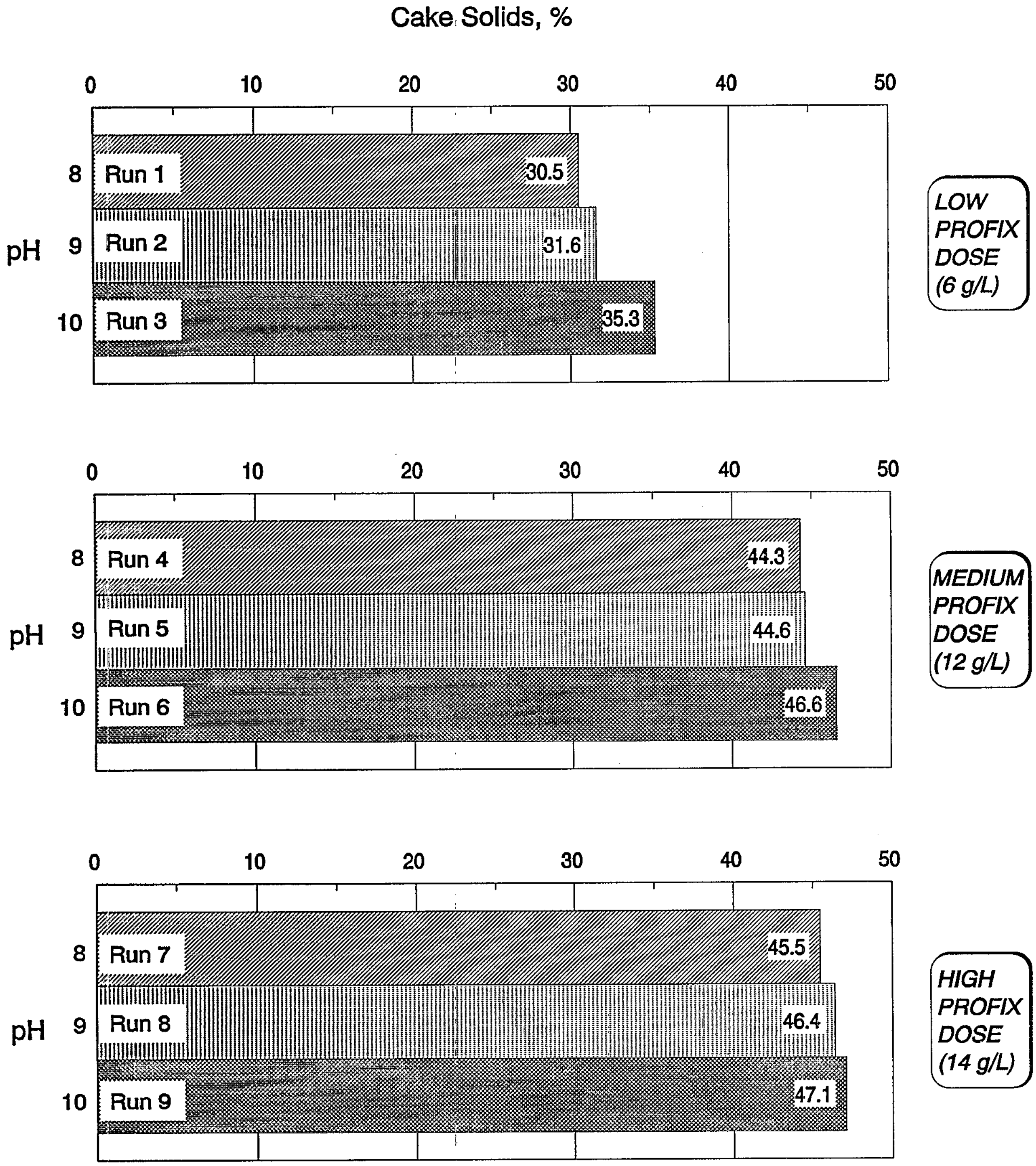


Figure B-5. Filter Cake Solids for Phase 1 Runs.

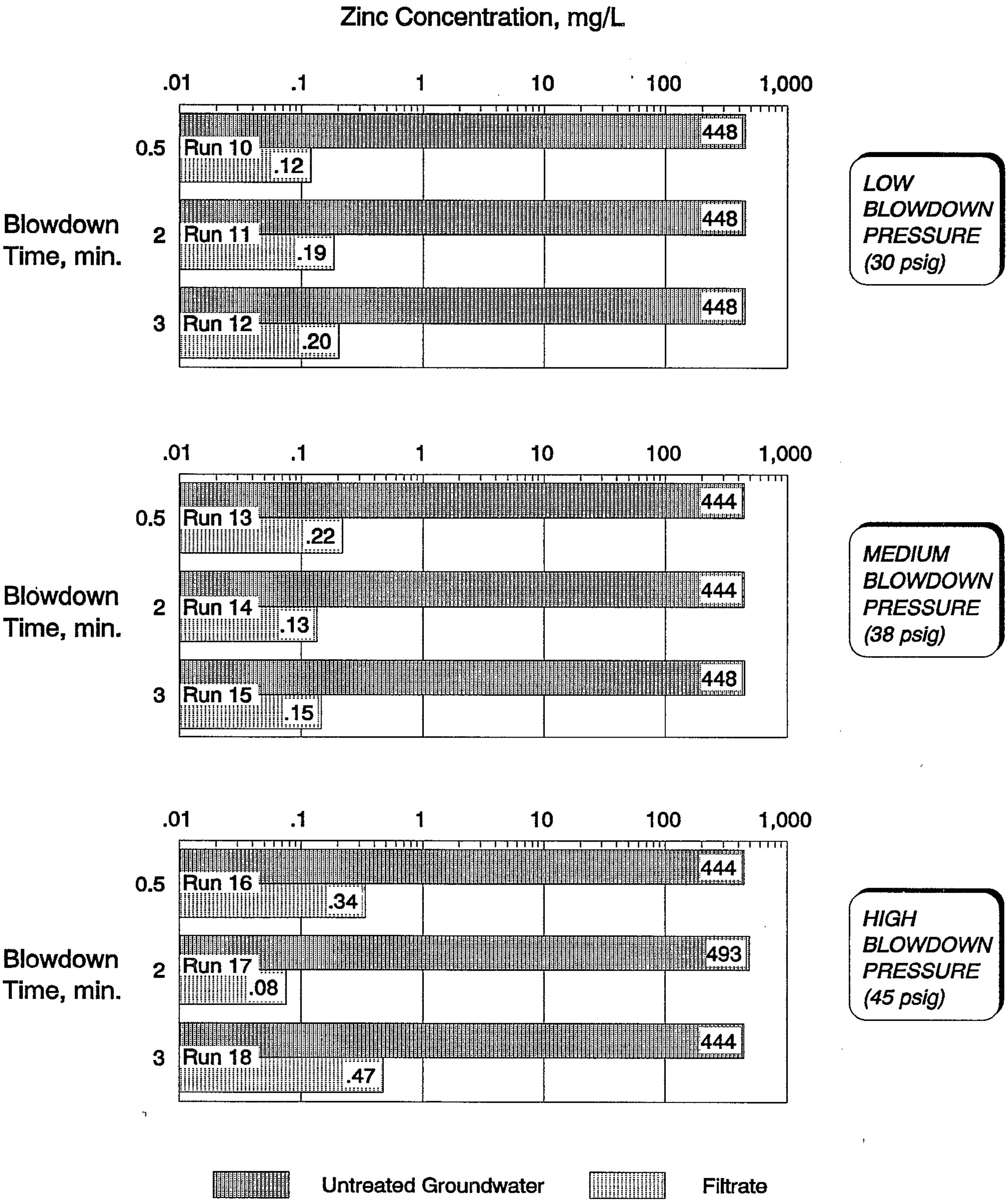


Figure B-6. Zinc Concentration Pofiles for Phase 2 Runs.

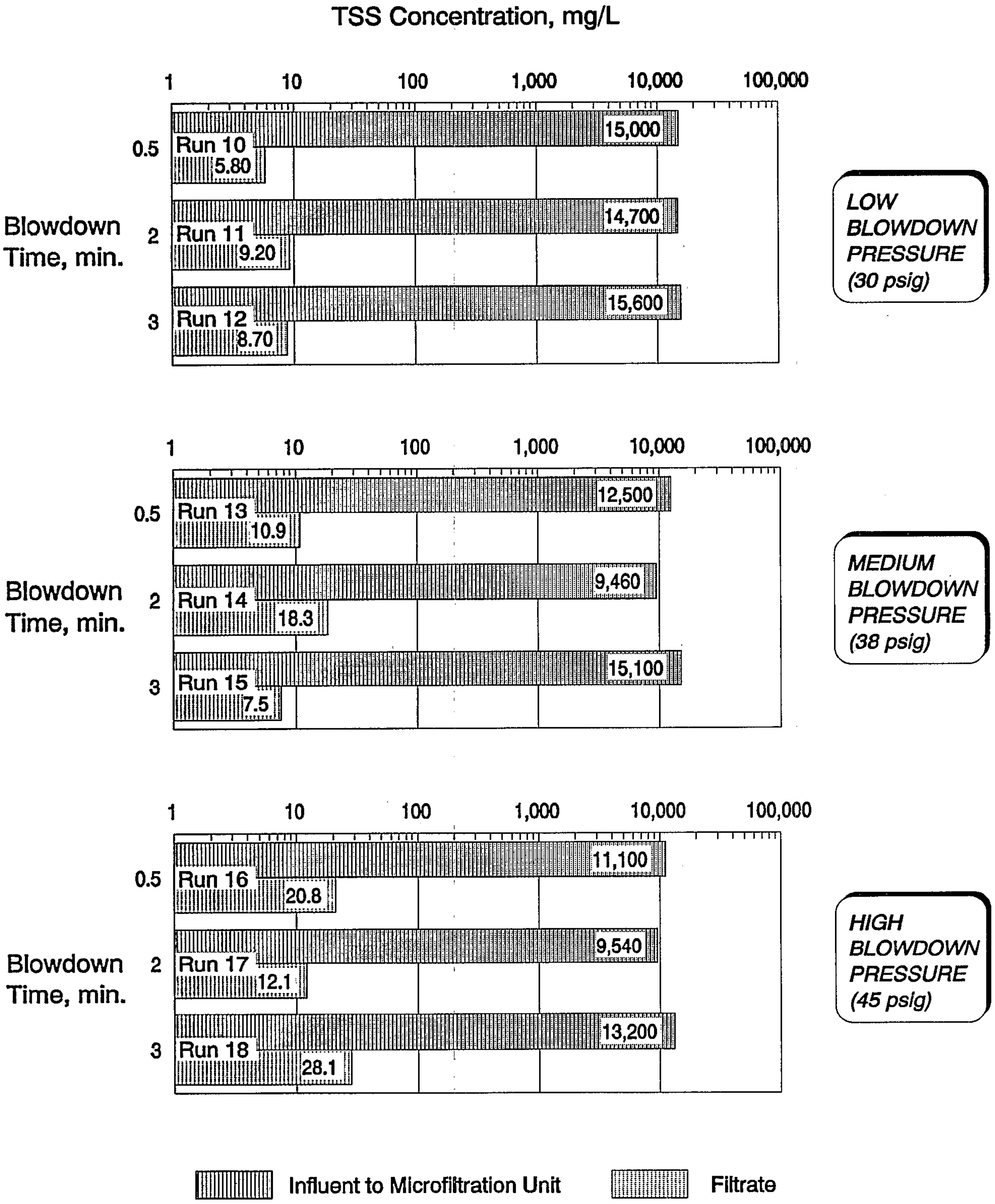


Figure B-7. TSS Concentration Profiles for Phase 2 Runs.

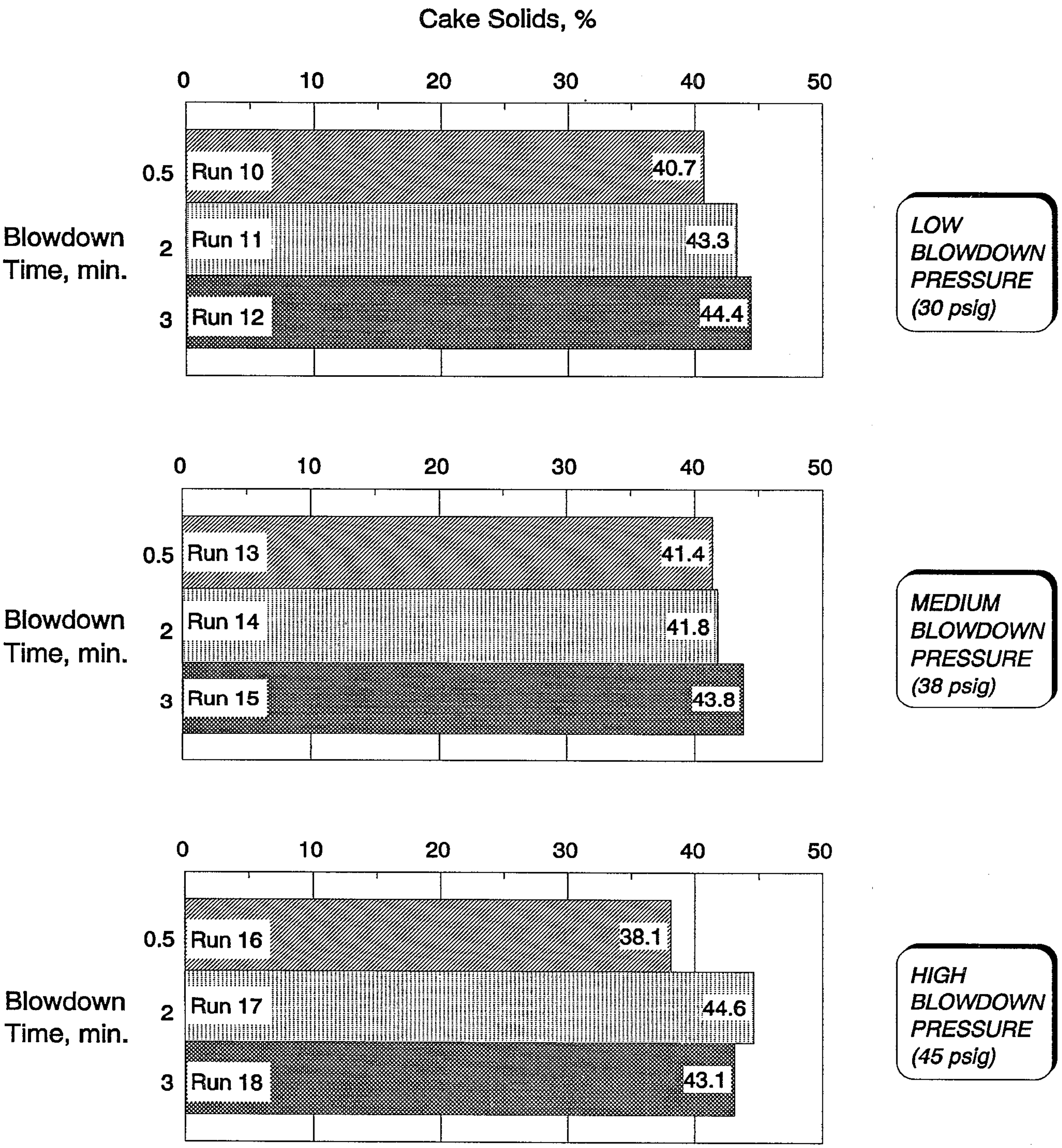


Figure B-8. Fliilter Cake Solids for Phase 2 Runs.

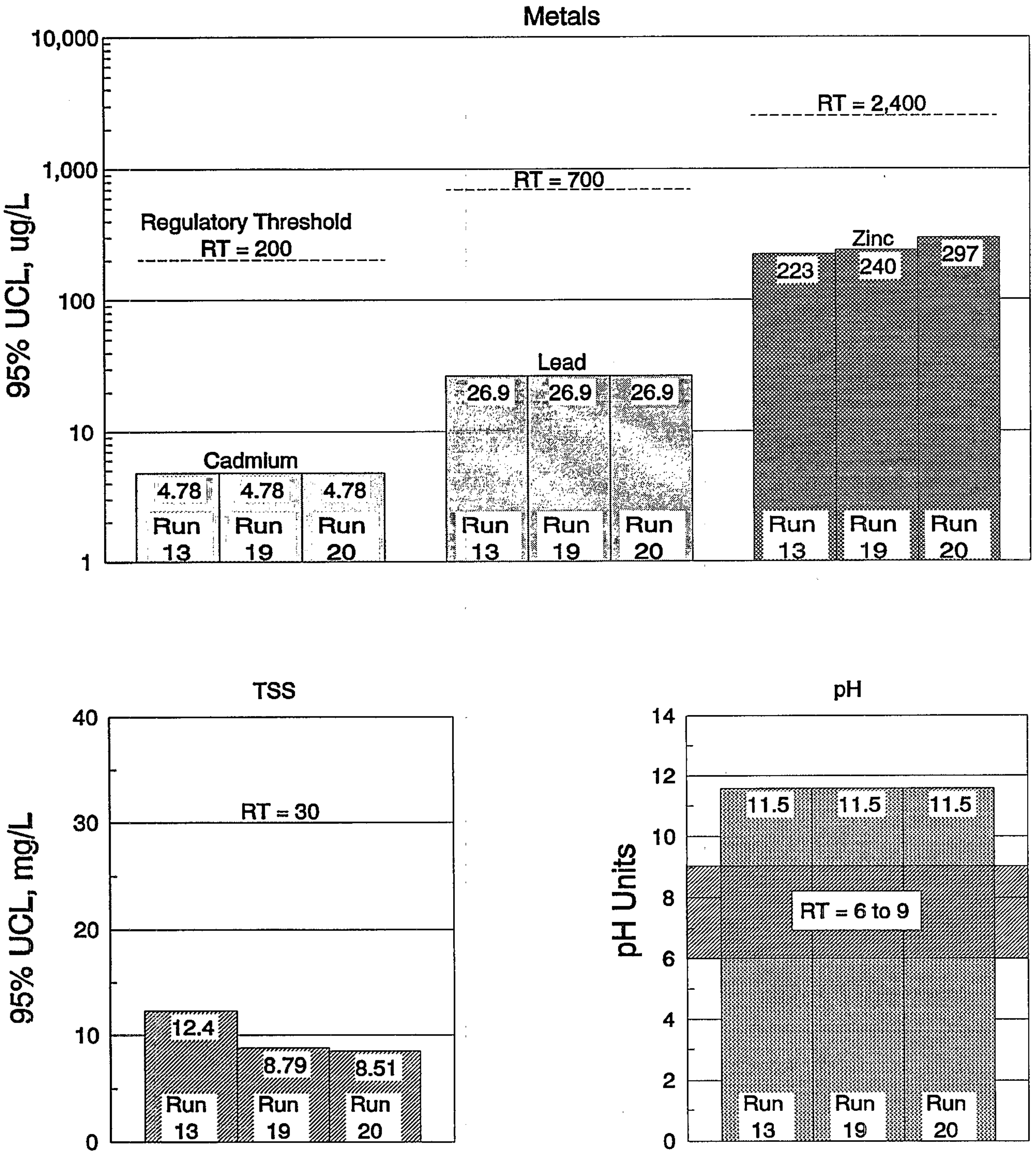


Figure B-9. Comparison of Filtrate Quality for Reproducibility Runs with Regulatory Thresholds.

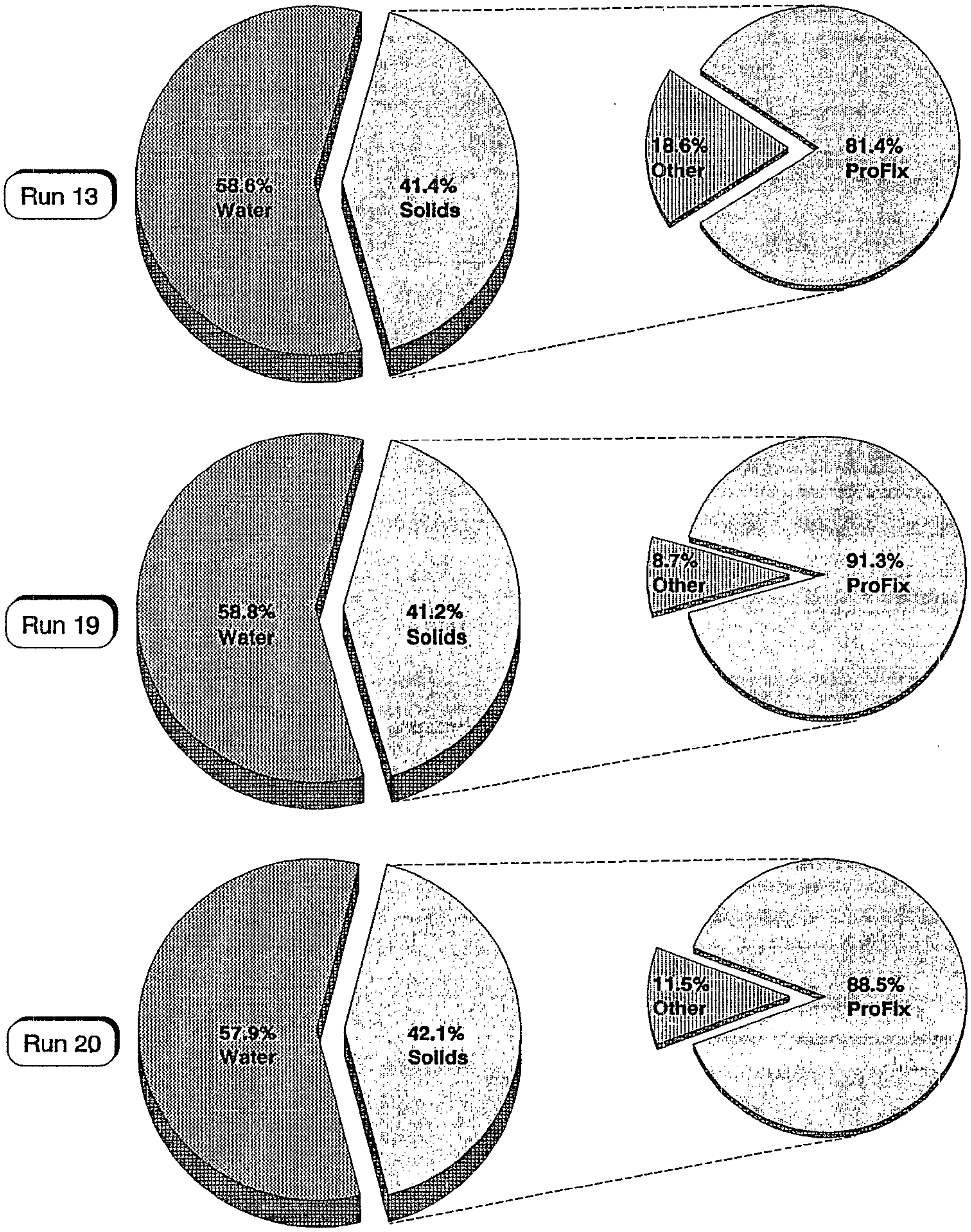


Figure B-10. Filter Cake Composition for Reproducibility Runs.

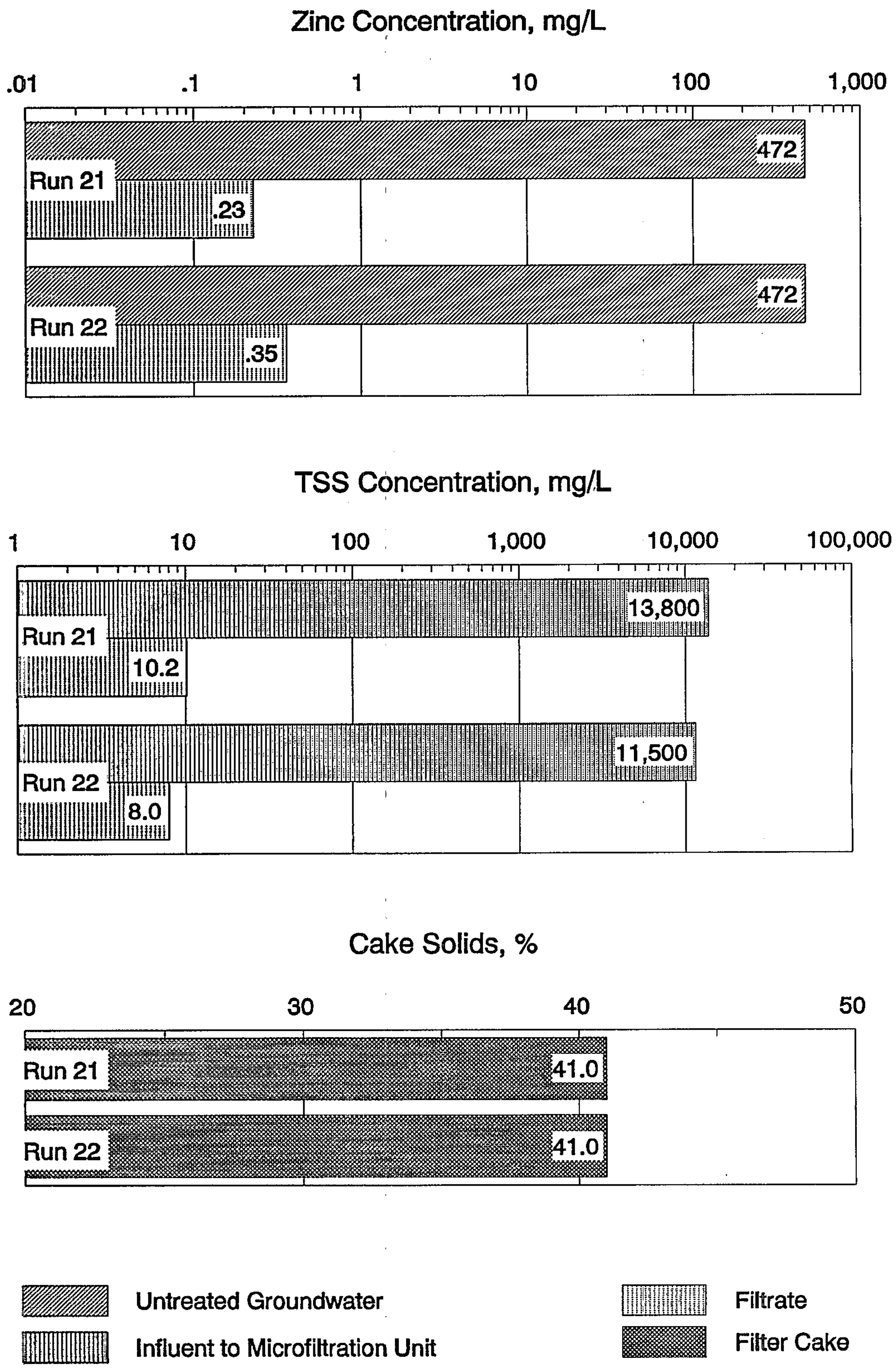


Figure B-11. Tyvek® Performance for Reusability Runs.

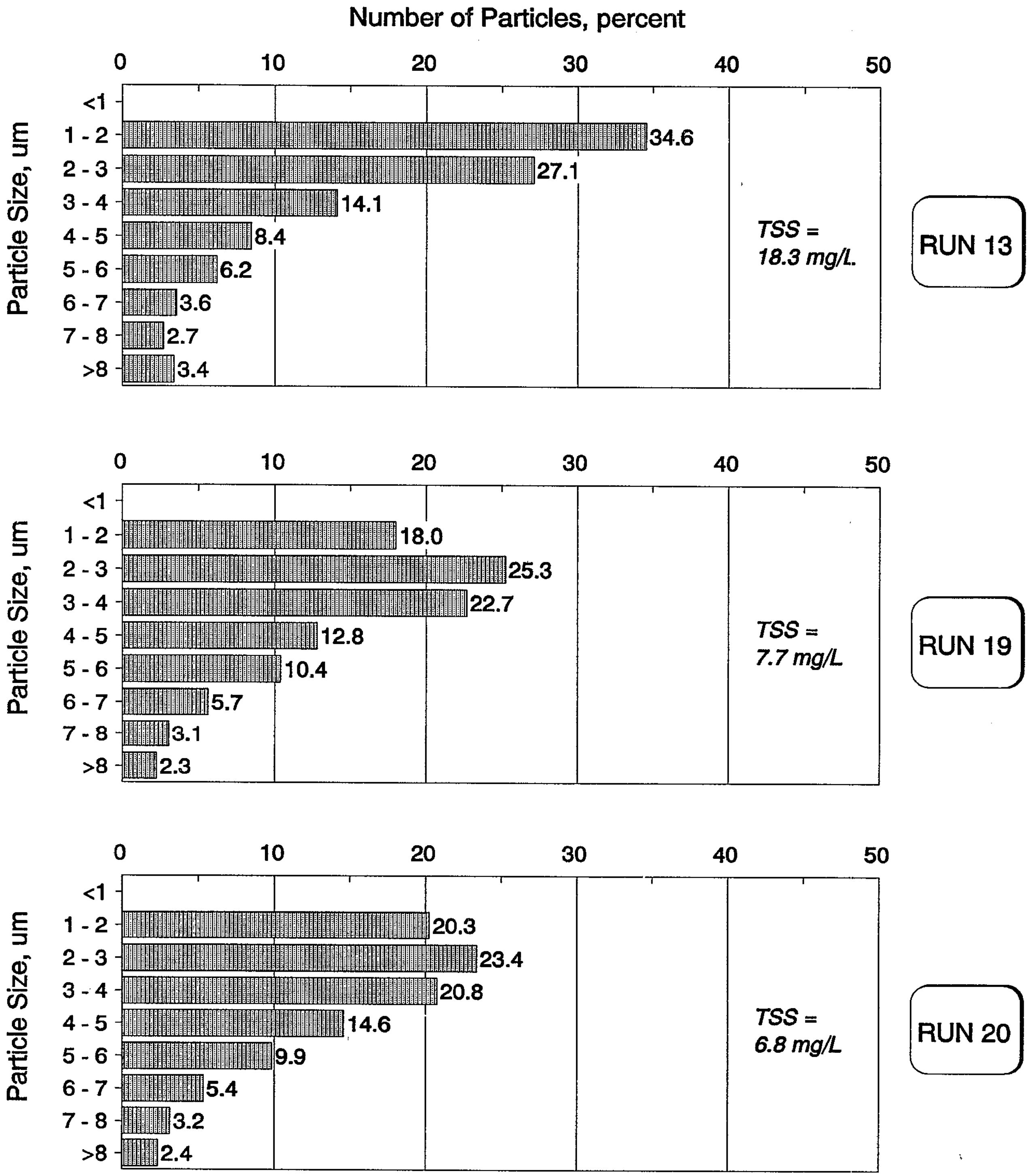


Figure B-12. Filtrate Particle Size Distribution for Reproducibility Runs.

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Appendix C
Case Studies

Introduction

This appendix summarizes case studies on the use of the DuPont/Oberlin microfiltration technology. These case studies describe the performance of full-scale DuPont/Oberlin microfiltration units treating industrial wastewaters. The information available for these case studies varies from detailed analytical and cost data to relatively little information on system performance and cost. The following case studies are summarized in this appendix:

Case Study	Facility and Location
C-1	Westinghouse Savannah River Site, Aiken, South Carolina
C-2	DuPont Electronics Materials, Inc., Manati, Puerto Rico
C-3	DuPont Electronics, Sun Valley, California

Case Study C-1
Westinghouse Savannah River Site
Aiken, South Carolina

This case study presents the results of full-scale testing and use of a DuPont/Oberlin microfiltration system at the Westinghouse Savannah River site (SRS) in Aiken, South Carolina. The microfiltration system uses Tyvek® T-980 filter media to remove submicron particles from wastewater. SRS began using this system in July 1985 to treat wastewater from its metal finishing and aluminum forming operations and from an autoclave process.

A series of tests were conducted to evaluate the effectiveness of the DuPont/Oberlin microfiltration system at the SRS. The performance of the filtration unit was studied as a function of several variables including filter media, filter aid, and polymer additive. The results of these tests are presented below. The information presented in this case study is based on a paper presented by Mr. Hollis Martin of Westinghouse at the American Electroplaters and Surface Finishers/Environmental Protection Agency (EPA) Conference on Pollution Control for the Metal Finishing Industry in January 1989, as well as current data on system operations provided by Mr. Martin.

Facility Operations

The Savannah River Plant produces nuclear materials for the U.S. Department of Energy (DOE). The facility is managed for DOE by Westinghouse as of April 1, 1989 (prior to that by DuPont). Fuel and target assemblies for the nuclear reactors of the Savannah River Plant are fabricated in the 300-M area of the facility. Metal finishing, aluminum forming, and various cleaning operations in the 300-M area produce effluents that discharge to a wastewater treatment plant. Principal metals in the wastewater include uranium, aluminum, nickel, lead, zinc, copper, and chromium. These metals are removed from the effluent by wastewater equalization, precipitation, flocculation, and microfiltration. A second waste stream, consisting of insoluble metal oxides from autoclave test effluent, is treated by a separate wastewater equalization and microfiltration system. The chemical compositions of wastewaters from 300-M area and autoclave operations are shown in Table C-1-1.

Prior to undergoing pressure filtration, 300-M area wastewater is acidified to pH 3, and aluminum sulfate is added to ensure phosphate removal. The pH is then raised to approximately 8 by addition of sodium hydroxide to precipitate the metals. This pretreated wastewater is filtered using the microfiltration system, which is the primary unit operation in treating 300-M area wastewater. The filtrate is analyzed and discharged to Tims Branch Creek in South Carolina. The average composition of the filtrate discharged in June 1990 and associated National Pollutant Discharge Elimination System (NPDES) limits are presented in Table C-1-1. The filter cake contains both hazardous (F006) and radioactive material; therefore, it is considered a mixed waste. Prior to disposal, the filter cake is stabilized and solidified with cement. The treated filter cake is subject to hazardous waste land disposal restrictions.

System Performance

The performance of the DuPont/Oberlin microfiltration systems was evaluated following changes in filter media, filter aid, and polymer additives. These investigations were motivated by a rising peak demand for the two filtration units and a consequent need for greater efficiency. The effects of these changes and a summary of the maintenance provided for the system over the last 5 years are presented below.

Filter Media

The Oberlin pressure filtration systems were installed at the 300-M area of the Savannah River Plant in July 1985. The filtration area of each unit is 24 square feet. Originally, Tyvek® 1042B was chosen because of its high filtration efficiency and good sheet tensile and tear strength compared to other filter media. When DuPont developed a new Tyvek® series specifically designed for filtration applications, DuPont conducted tests comparing the new Tyvek® T-980 media with the original Tyvek® 1042B. Wastewater from the 300-M and autoclave areas were used to test the two Tyvek® materials; the same batches of wastewater were used for the comparison.

Tyvek® T-980 increased the cycle time and average flow rate through the filter by 13 and 11 percent, respectively, for effluent from the 300-M area operations. The filtrate turbidity did not differ significantly between the two filter media. For the autoclave wastewater, the cycle time remained approximately the same; however, the average flow rate through the filter increased by 9 percent, and the filtrate turbidity decreased by 40 percent. The increased filtration flow rate observed for both systems using Tyvek® T-980 indicates that the new filter media increases the efficiency of the microfiltration system.

Tyvek® T-980 was also compared to other filter media, such as a wet cast microporous membrane, biaxial stretch polytetrafluoroethylene laminated membrane, and melt blown polypropylene media. The performance of these media compared to Tyvek® T-980 for filtering the 300-M area wastewater was investigated. Tyvek® T-980 outperformed other filter media by producing a clearer filtrate with the best cake release from the media. Furthermore, the filter cake from Tyvek® T-980 had the highest solids content. A high solids

Table C-1-1. Operating Data for the DuPont/Oberlin Microfiltration System

Contaminant	300-M Wastewater[a] mg/L	Filtrate mg/L	Autoclave Wastewater[a] mg/L	Filtrate mg/L	NPDES Permit Limits Daily Max. mg/L	NPDES Permit Limits Monthly Average mg/L
Uranium	2.59	0.03	16.3	< 0.1	1.0[b]	0.5[b]
Aluminum	180.0	1.97	0.25	< 0.1	6.43	3.2
Nickel	12.14	< 0.1	0.04	< 0.1	2.46	1.23
Lead	0.79	0.1	0.04	< 0.1	0.69	0.43
Zinc	0.54	< 0.1	< 0.1	< 0.1	0.64	0.32
Copper	0.18	< 0.1	0.04	< 0.1	0.42	0.21
Cadmium	< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.05
Chromium	0.1	< 0.1	< 0.1	< 0.1	1.24	0.62
Nitrate (as N)	685.0	634.0	0.03	< 0.1	1,355.0[b]	677.0[b]
Phosphate (as P)	4.46	3.00	0.11	< 0.1	16.7[b]	6.83[b]
pH	8.4	8.3	NA[c]	NA	6.0 - 10.0	NA
Total Suspended Solids	800	5	300	< 4	60	31

Notes:
a The values are monthly averages based on daily analyses.
b These values are only guidelines.
c Not available.

content generally indicates a lower volume of waste requiring disposal.

Filter Aid

Fine grades of diatomaceous earth were initially used as filter aids in 300-M area wastewater treatment with the Tyvek® 1042B media. When a significant concentration of 1 to 3 micron particles (nickel and iron) were present, Celite 577 was used; when wastewater contained particles greater than 3 microns, Standard Super-Cel was used. These filter aids were tested against PerFLO 30SP, a new high-grade filter aid. DuPont compared the performance of selected combinations of filter media and filter aid while filtering the same batch of wastewater.

Investigations using 300-M area wastewater focused on the traditional combination of Tyvek® 1042B and Celite 577 and the new combination of Tyvek® T-980 and PerFLO 30SP. Compared to Tyvek® 1042B and Celite 577, the combination of Tyvek® T-980 and PerFLO 30SP produced better results: the filtrate contained 45 percent less suspended solids and the average flow rate through the filter increased by a factor of 2.5. In addition, the filtration cycle time doubled. The increase in both the filtration cycle and the flow rate resulted in approximately 5 times as much wastewater filtered per cycle, and 80 percent less filter media was used. The amount of filter aid required decreased 20 percent with PerFLO 30SP compared to Celite 577.

A different set of filter media/filter aid combinations were used to test filtration of the autoclave wastewater. In this test series, Tyvek® T-980 was investigated using both Celite 577 and PerFLO 30SP and compared to Tyvek® 1042B and Standard Super-Cel. Although PerFLO 30SP greatly improved the performance of the 300-M area wastewater filtration system, it did not enhance the performance of the autoclave wastewater filtration system. The combination of Tyvek® T-980 and Celite 577 yielded the best results. Although the feed cycle remained constant for all combinations, flow rate increased 45 percent and the turbidity decreased 90 percent when Celite 577 was used. The microstructure of PerFLO 30SP, compared to diatomaceous earth filter aids, limited the ability to capture very fine metal oxide particles found in the autoclave effluent.

Polymers

During early operation of the microfiltration units, an anionic polymer was added to the wastewater to increase filtration efficiency. However, the polymer activation tank was too large, allowing the polymer to age and form an unfilterable slime. Therefore, use of polymer was temporarily discontinued.

Improvements in polymers and activation systems stimulated new interest in polymer addition. Laboratory tests indicated that 0.5 mg/L Praestol A3040L anionic polymer would triple the filtration rate of metal hydroxide wastewater containing 500 to 600 mg/L total suspended solids (TSS), and 8 mg/L Praestol K144L cationic polymer would double the filtration rate of metal phosphate wastewater containing 800 to 1,000 mg/L TSS when used with PerFLO 30SP filter aid and Tyvek® T-980 filter media. Unique anionic and cationic polymer addition systems were installed for full-scale evaluation.

The performance of the polymers met with laboratory expectations. Presently, 8 mg/L of Praestol K144L is used to enhance metal phosphate removal from the wastewater. Polymer addition further enhances the Tyvek® T-980/PerFLO 30SP combination by decreasing filter media and filter aid usage by 7 and 3.4 times, respectively.

Maintenance

Due to a hydraulic problem in the filter feed system (not part of the DuPont/Oberlin system), the filters have cycled at four times their normal rate. Despite this excessive cycling, maintenance during the 5 years of operation was minimal. The media support belt is replaced about every 3 months, and the diaphragm of the filter fed inlet valve is replaced annually. The high pressure air bags on the upper platform were replaced once in the past 5 years as a precaution. The belt chains were replaced one time after a mechanic improperly installed a replacement belt. The Wilden M2 filter aid feed pump diaphragms are replaced about every 6 months. The top platen seal was replaced once in the past 5 years.

Costs

Solids removal capacity of the 300-M area and autoclave wastewater treatment facilities has been greatly increased by the improved filter aid and media. The cost of PerFLO 30SP filter aid is half that of fine grades of diatomaceous earth; moreover, 20 percent less is needed. The new filter media (Tyvek® T-980) also costs less to manufacture, and 80 percent less is used. The operating and maintenance cost, including polymer, filter aid, and filter media, is about 5 dollars per 1,000 gallons of wastewater processed.

Conclusions

Performance of the DuPont/Oberlin microfiltration system for removing suspended metal hydroxides and metal phosphates from wastewater is maximized by using Tyvek® T-980 as the filter media, in conjunction with PerFLO 30SP filter aid and Praestol K144L cationic polymer. The volume of filter cake requiring disposal decreased by 15 percent. Results of extraction procedure toxicity and toxicity characteristic leaching procedure (TCLP) analyses of the listed F006 mixed waste produced by this configuration satisfy land disposal restrictions. EPA is reviewing the Westinghouse petition for delisting the spent filter rolls. The effluent from the microfiltration unit meets all NPDES requirements.

Case Study C-2
DuPont Electronics Materials, Inc.
Manati, Puerto Rico

This case study presents information provided by DuPont Electronics Materials, Inc. (DEMI) on the application of the DuPont/Oberlin microfiltration system at the company's facility in Manati, Puerto Rico. Little information is available for this case study regarding facility operations, system performance, and costs.

Facility Operations

Operations at the DEMI facility produce a wastewater slurry of 2,000 gallons per day. The slurry contains 1,000 to 5,000 parts per million (ppm) of suspended "frit" (calcinated or partly fused, high-lead content glass material) and 2,000 to 10,000 ppm of total suspended solids.

System Performance

The objective of the facility's microfiltration treatment unit is to remove suspended particulates from the wastewater slurry ranging from 0.5 to 30 microns in size. Before filtration, two additives are combined with the wastewater to assist in filtration: a filter aid and an organic polymer. The filter aid is an amorphous volcanic aluminum silicate. Approximately 12 pounds of filter aid is added per filtration cycle (440 gallons of process water). Approximately 10 milliliters of 0.1 percent quaternary acrylamide cationic polymer is added per cycle.

The microfiltration system uses Tyvek® T-980 filter media. According to DuPont, the microfiltration system replaced 0.45 micron cartridges, which were costing the plant $1,200 per day. Additional filter cartridges rated at 10 and 1 micron (Filterite U10AW20U and U1AW20U, respectively) are used following the microfiltration system to ensure that particles less than 1 micron in size have been removed. This additional filtering is conducted in case any operational problems have occurred with the microfiltration system. The microfiltration system, with filter cartridges, removes nearly all particles between 0.5 and 30 microns.

The filtration system is operated automatically and requires only plant air and electricity (110 volts). Each treatment cycle lasts approximately 20 to 30 minutes and processes about 440 gallons of frit-containing water. No data were available for blowdown times, operating pressures, or other operating parameters.

Costs

Maintenance and operating costs for this system are low. The system only requires attention for 5 minutes every half hour for the operator to add polymer and filter aid manually. Valves, diaphragms, and other minor parts require occasional replacement.

Case Study C-3
DuPont Electronics
Sun Valley, California

The Component Materials Division of DuPont Electronics manufactures ceramic dielectric powders used in the multilayer ceramic capacitor industry. This case study is based on data provided by the facility; more detailed information describing facility operations, system performance, and costs are not available.

Facility Operations

The ceramic powders manufacturing process produces two liquid waste streams containing a complex array of metal oxides and titanates. Elements with the highest concentrations are barium, titanium, neodymium, bismuth, and lead. The compositions of the two waste streams vary according to daily operations, but lead and total suspended solids levels are typically in the range of 0.5 to 5.0 percent. The treatment objective is to reduce the concentration of metals to meet applicable effluent limits. Most of the metals are in the form of suspended solids; there is no chemical or physical pretreatment before filtration.

System Performance

The facility uses two 7-square foot Oberlin pressure filters (model HB) to remove suspended solids from wastewater. These two units are in two different locations 1/4-mile apart. A single treatment unit processes 350 to 400 gallons per hour in a cycle time of 15 to 20 minutes. The two units operate at a blowdown time of less than 5 minutes with an airbag pressure of 120 psi.. Each filtration unit uses Tyvek® T-980 as the filter media.

Diatomaceous earth (Superaid) is used as a filter aid. Agglomeration is promoted with a polymer flocculent (Praestol K122L) at a dosage of 50 ppm in one unit and 300 ppm in the other, depending on the type of waste each unit treats. Both the filter aid and polymer flocculent are added automatically in-line to the filters.

The effluent streams from the pressure filtration treatment units satisfy Los Angeles sewer effluent limits of 5.0 ppm for soluble lead and 26.0 ppm total suspended solids. Typical effluent characteristics are 0.2 to 0.4 ppm soluble lead and 5 ppm total suspended solids. The effluent concentrations of other metals are unknown.

The moisture content of the filter cake is approximately 50 percent. The filter cake is classified as hazardous waste because it does not meet TCLP test requirements. Therefore, it is disposed of in a hazardous waste landfill. DuPont plans to use ProFix in lieu of diatomaceous earth to eliminate offsite stabilization and reduce operating costs.

Costs

Operating costs are related primarily to filtration supplies. The monthly costs of Superaid, K122L polymer, and Tyvek® T-980 are $150, $20, and $50, respectively. The systems require approximately 1 to 2 hours of operator time per day, including equipment cleaning.

Maintenance costs are very low. In 5 years of operation, the two systems experienced no major downtime or repair requirements.

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