March 2004
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Environmental Technology Verification Report

Treatment of Wastewater Generated During Decontamination Activities

UltraStrip Systems, Inc. Mobile Emergency Filtration System

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**Decontamination Wastewater Treatment**		
APPLICATION:	**Homeland Security**		
TECHNOLOGY NAME:	**UltraStrip Systems, Inc. Mobile Emergency Filtration System**		
TEST LOCATION:	**EPA Test & Evaluation Facility, Cincinnati, Ohio**		
COMPANY:	**UltraStrip Systems, Inc.**		
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NSF International (NSF) manages the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. NSF evaluated the performance of the UltraStrip™ Systems, Inc. (USS) Mobile Emergency Filtration System (MEFS), a portable modular wastewater treatment device designed to remove solids, chlorine, organics, pesticides, and metals from wastewater. Testing was completed at the EPA's Test & Evaluation Facility in Cincinnati, Ohio, which is operated by Shaw Environmental, Inc. Testing was conducted from November 19, 2003 through January 5, 2004.

EPA created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups consisting of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated, and that the results are defensible.

TECHNOLOGY DESCRIPTION

The following technology description is provided by the vendor and was not represent verified information.

UltraStrip Systems, Inc., an ISO 9001-registered company, manufactures the patent-pending MEFS. The MEFS is an easily portable, self-contained wastewater treatment system designed for treating wastewater generated from decontamination of sites contaminated by biological or chemical agents. The MEFS utilizes multiple treatment processes to neutralize or remove contaminants in the wastewater and has the capacity to treat approximately 26 gallons per minute (100 Lpm) on a batch or continuous flow basis.

The MEFS includes the following unit processes:

- Chlorine removal system (CRS) for chemical neutralization (dechlorination);
- Centrifuge for solids removal;
- Media filtration, including sand and activated carbon to remove small particles and dissolved organic compounds, and Bayoxide E33, a granular filter media formulated to remove metals;
- Ultrafiltration (UF) to remove fine particulates; and
- Reverse osmosis (RO) to remove very fine particulates, large microorganisms, and dissolved salts.

The MEFS is equipped with valves and piping to provide flexibility in operation so that individual unit processes can be bypassed. The system is also equipped with meters to monitor various performance parameters, such as flow rates, reject rates, pressures, and water temperatures. USS claims that the system will treat wastewater from decontamination operations involving highly chlorinated water or chemical agent contamination, to meet surface water discharge or reuse criteria.

VERIFICATION TESTING DESCRIPTION

Methods and Procedures

The testing methods and procedures used during the testing are detailed in the *Verification Test Plan for Treatment of Wastewater Generated During Decontamination Activities, UltraStrip Systems, Inc. (October, 2003)*. Three separate 10-day test phases were completed, during which the MEFS was challenged with a wastewater mixture including partially-treated sewage, used motor oil, surfactants, sediments, and a primary constituent of concern, depending on the testing phase:

- Trivalent arsenic, to simulate decontamination wastewater from an inorganic chemical agent (Lewisite) event;
- Methyl parathion, to simulate decontamination wastewater from an organic chemical nerve agent event; and
- Sodium hypochlorite (bleach), to simulate decontamination wastewater from a biological agent event, where chlorine dioxide and bleach were used to disinfect the affected area.

During each test day, influent and effluent samples were collected and analyzed for the primary constituents, secondary fouling parameters, and water quality indicator parameters. Primary analytical parameters included total arsenic, organo-phosphorous pesticides, and free and total chlorine. Secondary analytical parameters consisted of alkalinity, surfactants (MBAS), oil and grease (O&G), total suspended solids (TSS), 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia, total Kjeldahl nitrogen (TKN), and total phosphorus. Indicator parameters included pH, turbidity, and temperature. The system was evaluated to determine maximum flow rate, bypass flow rates from the UF and RO systems, ease of setup and installation, and operation and maintenance requirements.

Complete descriptions of the verification testing results and quality assurance/quality control procedures are included in the verification report.

PERFORMANCE VERIFICATION SUMMARY

System Installation, Operation, and Maintenance

The system was delivered to the site on a flatbed trailer and was inspected by USS personnel to ensure that system components were not damaged during shipping. The system underwent a wet test with clean water to check that it was watertight and operating properly. After USS personnel performed a few minor piping adjustments to accommodate the testing facility, the system was ready for operation.

Maintenance during testing consisted primarily of filling treatment chemical containers, replacing filter pads or activated carbon, and daily backwashing of the media filters. Backwashing took approximately 30 minutes and consisted of running clean water through the treatment processes and the clean-in-place loop, then running the rinseate water back through the treatment processes.

USS provided three equipment operators to operate the system during testing. Two operators were required to run the system, while the third provided backup or general assistance.

When used, the CRS system restricted the pumping ability of the primary influent pump, and an auxiliary pump was required to maintain rated flow rates. No other operational issues with the MEFS were noted.

Flow Capacity

The wastewater was mixed each morning in a tank supplied by the testing organization with a nominal volume of 10,000 gallons, and an operating volume of approximately 9,100 gallons. Due to the configuration of the piping hookups on the influent supply tank, the MEFS was unable to pump the last five inches (approximately 500 gallons) out of the bottom of the tank. Therefore, during each test day the MEFS treated approximately 8,600 gallons of wastewater.

The influent and bypass volumes and operating duration times were recorded for each test day, and were used to calculate the treated effluent volume and the average daily flow rate. During most test days, the MEFS achieved a flow rate ranging from approximately 21 to 24 gallons per minute (gpm), just below the system's rated capacity of 26 gpm (100 Lpm). There were two situations where decreased flow rates were noted. During the first four days of the inorganic chemical event test, when the centrifuge was bypassed, flow rates decreased to a range of 15 to 18 gpm. After the media filters were backwashed and the centrifuge brought on-line, the flow rate recovered. Also, the flow rate decreased steadily during the organic chemical event test, from an initial flow rate of 23 to 24 gpm to a final flow rate of 21 to 23 gpm.

Treatment Capability

Inorganic chemical event—The centrifuge (during the first four test days), CRS, and RO processes were bypassed for this test event. Decreased flow rates prompted USS to utilize the centrifuge in the final six days of the test event.

The target influent arsenic concentration was 5 mg/L, and the actual arsenic concentration ranged from 4.0 to 5.7 mg/L, with a mean of 5.0 mg/L. The effluent arsenic concentration was below detection limits (<0.010 mg/L) for the first four days of test event, and incrementally increased from 0.02 to 0.06 mg/L during the fifth through tenth days. This resulted in a mean treatment efficiency greater than 99.6 percent.

Organic chemical event—The CRS, Bayoxide E33 media filter, and RO processes were bypassed during this test event. The target influent concentration for methyl parathion was 1 mg/L.

The influent methyl parathion concentration ranged from 0.55 to 0.93 mg/L and averaged 0.72 mg/L. The effluent concentration increased incrementally from 0.00028 to 0.013 mg/L over the course of the test event, resulting in treatment efficiencies that ranged from 98.4 to greater than 99.9 percent, and averaged greater than 99.4 percent.

Biological agent event—Only the Bayoxide E33 media filter process was bypassed for this test event.

Effluent samples collected from the water treated by the RO process were analyzed for free chlorine, while samples for the rest of the analytical parameters were collected from the RO bypass. On one test day, effluent samples were collected from both the RO effluent and RO bypass. The target influent concentration for free and total chlorine was 5,000 mg/L as Cl_2.

The influent free chlorine and total chlorine concentration ranged from 3,700 to 6,700 mg/L (averaging 5,500 mg/L), with the free and total chlorine concentrations being essentially equal. The effluent free chlorine concentrations were below detection limits (<0.02 mg/L) for 13 of 20 samples, with the remaining seven samples ranging from 0.02 to 0.14 mg/L. The total chlorine detection limit (0.10 mg/L) was five times higher than the free chlorine detection limit. Since the effluent free chlorine concentration exceeded the total chlorine detection limit on only one sample (0.14 mg/L), the TO did not analyze the effluent for total chlorine.

Secondary and indicator parameters—The secondary and indicator parameters did not vary significantly between the three test events. Table 1 summarizes the secondary analytical parameters. The MEFS raised the water temperature by approximately 2°C, pH remained neutral, and turbidity dropped by approximately 74 to 87 percent.

Table 1. Secondary Analytical Parameter Summary

Parameter	Mean Influent Concentration (mg/L)	Treatment Efficiency (Percent) [1] Inorganic	Organic	Biological
Alkalinity	1,700	46	35	95 [3]
BOD_5	46	89	77	69 [2]
COD	48	81	71	-2,800 [2]
MBAS	0.86	62	21	-33
Ammonia (as N)	13	16	-2.4	33
Oil & Grease	7.0	48	58	72
TKN (as N)	11	7.8	-2.1	-110
Total phosphorus (as P)	1.1	98	78	61
TSS	23	92	77	52

[1] One-half the method detection limit was used when concentrations were below detection limits.
[2] The chlorinated and dechlorinated BOD_5 and COD samples were flagged as unreliable.
[3] Sodium hypochlorite is dissolved in an alkaline solution which is neutralized during dechlorination.

UF and RO Reject Flow Rates

The reject flows generated by the UF and RO processes were monitored and discharged to the test site's sewer, in compliance with facility-specific permit requirements. In the field, reject water likely would be pumped back to the influent storage tank for retreatment. During the inorganic chemical event test, the UF reject flow ranged from 6 to 16 percent of the influent volume, with no distinct trend or pattern. During the organic chemical event test, the UF reject flow started at approximately 9 percent, and increased to 12 to 14 percent by the end of testing. During the biological event test, when both the UF and RO processes were used, the reject flow ranged from 53 to 74 percent.

Consumables and Waste Generation

Over the course of the three test events, the MEFS consumed an average of approximately 180 kilowatt hours (kWh) of electricity per test day, and ranged from 113 to 221 kWh, and the system was run an average of 6.5 hours. The lowest readings were recorded during the first four days of the inorganic chemical event test, when the centrifuge was not run.

During the biological event test phase, CRS (calcium thiosulfate) was used for dechlorination. The MEFS used between 88 and 160 gallons and averaged 120 gallons of CRS per test day, and 34 to 90 liters of sodium hydroxide to maintain a caustic pH. During all three test phases, the MEFS used muriatic (hydrochloric) acid (50 to 1,000 mL/day), 50 percent alum flocculent (4 to 5 L/day), and a UF/RO membrane cleaner (6 L total) in the treatment process.

Over the course of the three test events, the MEFS generated 52 pounds (dry weight) of used oil-sorbent pads, which were located before the centrifuge to prolong the functionality of the activated carbon. The centrifuge generated 163 pounds of sludge. The activated carbon was replaced after both the inorganic chemical event and the organic chemical events. The spent carbon filled two 55-gallon drums per change out. These waste materials were classified non-hazardous, as determined by TCLP testing.

RO Membrane Integrity Test

The RO membrane and housing were evaluated using a pressure decay test to determine the physical integrity of the process. The test procedures are outlined in the American Society for Testing and Materials (ASTM) Designation D 6908-03, "Standard Practice for Integrity Testing of Water Filtration Membrane Systems, Practice A—Pressure Decay and Vacuum Decay Tests." The test estimates the ability of an RO system to reject particles in the one to two micron range. Tests were run before and after the biological event test phase and the results were used to assess whether processing the dechlorinated wastewater through the RO system impaired its treatment capabilities. The test results showed that the system could achieve a 3.7 log reduction for 1.4 micron particles, and that the wastewater did not impair the RO system.

Quality Assurance/Quality Control

NSF personnel completed a technical systems audit during testing to ensure that the testing was in compliance with the test plan. NSF also completed a data quality audit of at least 10 percent of the test data to ensure that the reported data represented the data generated during testing. In addition to QA/QC audits performed by NSF, EPA personnel conducted an audit of NSF's QA Management Program.

Original Signed By
E. Timothy Oppelt *April 28, 2004*

E. Timothy Oppelt Date
Director
National Homeland Security Research Center
Office of Research and Development
United States Environmental Protection Agency

Original Signed By
Gordon E. Bellen *May 4, 2004*

Gordon E. Bellen Date
Vice President
Research
NSF International

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report is not an NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of the *Verification Test Plan for Treatment of Wastewater Generated During Decontamination Activities, UltraStrip Systems, Inc., October 2003,* the verification statement, and the verification report (NSF Report #04/14/WQPC-HS) are available from:

ETV Water Quality Protection Center Program Manager (hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140

NSF web site: http://www.nsf.org/etv (electronic copy)
EPA web site: http://www.epa.gov/etv (electronic copy)

Appendices are not included in the verification report, but are available from NSF upon request.

Verification Report
For
UltraStrip Systems, Inc. Mobile Emergency Filtration System

Prepared for

NSF International
Ann Arbor, Michigan
and
The Environmental Technology Verification Program
of the
U.S. Environmental Protection Agency
Edison, New Jersey

By

NSF International
Ann Arbor, Michigan

and

Scherger Associates
Ann Arbor, Michigan

March 2004

Notice

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development, has financially supported and collaborated with NSF International (NSF) on this verification under a Cooperative Agreement. This effort was supported by the ETV Water Quality Protection Center of the EPA Environmental Technology Verification (ETV) Program. This document has been peer reviewed, reviewed by NSF and EPA, and recommended for public release. Mention of trade names or commercial products does not constitute endorsement or recommendation by the EPA for use.

Foreword

The following is the final report on an Environmental Technology Verification (ETV) test performed for NSF International (NSF) and the United States Environmental Protection Agency (EPA). The verification test for the UltraStrip Systems, Inc. (USS) Mobile Emergency Filtration System (MEFS) was conducted from November 19, 2003 through January 5, 2004, at the EPA's Test and Evaluation (T&E) Facility, in Cincinnati, Ohio, operated by Shaw Environmental, Inc.

The EPA is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Contents

Figures

Tables

Acronyms and Abbreviations

BOD_5	5-day biochemical oxygen demand
°C	Celsius degrees
COD	Chemical oxygen demand
CRS	Chlorine removal system
DQI	Data quality indicators
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
ft^2	Square foot (feet)
gal	Gallon
gpm	Gallon per minute
ISO	International Organization for Standardization
Kg	Kilogram
kWh	Kilowatt hour
L	Liter
lb	Pound
Lpm	Liter per minute
MBAS	Methylene blue active substances
MEFS	Mobile Emergency Filtration System
MSD	Metropolitan Sewer District of Greater Cincinnati
NRMRL	National Risk Management Research Laboratory
mg/L	Milligram per liter
mL	Milliliter
µg/L	Microgram per liter
ND	Not detected
NSF	NSF International
O&M	Operation and maintenance
ORP	Oxidization/reduction potential
PLC	Programmable logic controller
QA	Quality assurance
QC	Quality control
USS	UltraStrip Systems, Inc.
RCRA	Resource Conservation and Recovery Act
RO	Reverse osmosis
RPD	Relative percent deviation
SOP	Standard operating procedure
T&E	EPA’s Test and Evaluation Facility
TKN	Total Kjeldahl nitrogen
TO	Testing Organization (Shaw Environmental)
TP	Total phosphorus
TOC	Total organic carbon
TSS	Total suspended solids
UF	Ultrafiltration
VO	Verification Organization (NSF)
VTP	Verification test plan

Acknowledgements

NSF International, Shaw Environmental, and Scherger Associates were responsible for all elements in the testing sequence, including test setup, calibration and verification of instruments, data collection and analysis, data management, data interpretation, and the preparation of this report.

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Contact Person: E. Radha Krishnan, P.E., or Rajib Sinha, P.E.

Scherger Associates
3017 Rumsey Drive
Ann Arbor, Michigan 48105
Contact Person: Dale Scherger

The vendor of the equipment is:

UltraStrip Systems, Inc.
3515 S.E. Lionel Terrace
Stuart, Florida 34997
Contact Person: Mickey Donn, Sr.

Chapter 1
Introduction

1.1 ETV Purpose and Program Operation

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The ETV Program's goal is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations (TOs); stakeholder groups that consist of buyers, vendor organizations, and permitters; and the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance/quality control (QA/QC) protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF) operates the ETV Water Quality Protection Center (WQPC) in cooperation with EPA. The WQPC evaluated the performance of the UltraStrip Systems, Inc. (USS) Mobile Emergency Filtration System (MEFS), which is a portable wastewater treatment system, incorporating chemical pretreatment, centrifuge, media filtration, ultrafiltration, and reverse osmosis in the treatment system. This document provides the verification test results for the MEFS.

It is important to note that verification of the equipment does not mean that the equipment is “certified” by NSF or “accepted” by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the TO.

1.2 Testing Participants and Responsibilities

The ETV testing of the MEFS was a cooperative effort between the following participants:

- EPA
- NSF International
- Shaw Environmental, Inc.
- Scherger Associates
- Severn Trent Laboratories, Inc.
- UltraStrip Systems, Inc.

1.2.1 U.S. Environmental Protection Agency

The EPA Office of Research and Development, through the Urban Watershed Branch, Water Supply and Water Resources Division, NRMRL, provides administrative, technical, and QA guidance and oversight on all ETV WQPC activities. This peer-reviewed document has been reviewed by NSF and EPA and recommended for public release.

The key EPA contact for this program is:

Mr. Ray Frederick, Project Officer, ETV Water Quality Protection Center
(732) 321-6627 e-mail: Frederick.Ray@epamail.epa.gov

U.S. EPA, NRMRL
Urban Watershed Management Research Laboratory
2890 Woodbridge Ave. (MS-104)
Edison, NJ 08837

1.2.2 NSF International—Verification Organization (VO)

NSF is EPA's verification partner organization for administering the WQPC. NSF is a not-for-profit testing and certification organization that has been instrumental in the development of consensus standards for the protection of public health and the environment.

NSF personnel provided technical oversight of the verification process, and audited the analytical laboratory, data gathering, and recording procedures. NSF also prepared the verification test plan (VTP) and this verification report.

NSF's responsibilities as the VO included:

- Preparation of the VTP;
- Qualify the TO and review the quality systems of all parties involved with the TO;
- Oversee the TO activities related to the technology evaluation and associated laboratory testing;
- Complete on-site audits of test procedures and the analytical laboratory;
- Develop the verification report and verification statement;
- Coordinate with EPA to approve the verification report and verification statement; and,
- Provide QA/QC review and support for the TO.

The key contacts at NSF for the VTP and program are:

Mr. Thomas Stevens, Program Manager
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Mr. Patrick Davison, Project Coordinator
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NSF International
789 N. Dixboro Road
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(734) 769-8010

1.2.3 Shaw Environmental—Testing Organization (TO)

The TO for this verification process was Shaw Environmental, Inc. (Shaw) of Cincinnati, Ohio, with support from Scherger Associates of Ann Arbor, Michigan. Shaw operates the T&E Facility under contract to the EPA and provides personnel necessary to perform experiments at this facility.

The responsibilities of the TO included:

- Provide all needed logistical support, establish a communications network, and schedule and coordinate activities of all participants;
- Ensure that the test conditions meet the stated objectives of the verification testing.
- Assist in preparation of the VTP;
- Oversee testing, including taking measurements and recording data;
- Manage, evaluate, interpret, and report the data generated by the testing; and
- Report on the performance of the technology.

Severn Trent Laboratories, Inc., in Amherst, New York, and North Canton, Ohio, provided the analytical laboratory services for the testing program.

The key personnel and contacts for the TO are:

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1.2.4 Vendor

UltraStrip Systems, Inc. is the vendor of the MEFS. The vendor was responsible for supplying and providing technical information during development of the VTP. USS personnel operated the MEFS during the testing.

The vendor contact is:

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(772) 287-4846 e-mail: mdonn@ultrastrip.com

UltraStrip Systems, Inc.
3515 S.E. Lionel Terrace
Stuart, Florida 34997

1.3 Verification Testing Site

This verification test was performed at the EPA National Risk Management Research Laboratory's (NRMRL) Test and Evaluation (T&E) Facility located on the grounds of the Cincinnati Municipal Sewer District's Mill Creek Sewage Treatment Plant. Completed in 1979, the T&E Facility has a 24,000 square foot high bay area for both bench and pilot scale research, supported by 14,000 square feet of laboratories, office space, and chemical storage.

The T&E Facility conducts hazardous waste treatment studies and is permitted by the State of Ohio as a Resource Conservation and Recovery Act (RCRA) Treatment, Storage and Disposal Facility (TSDF). The T&E Facility also holds a state Treatability Exclusion that permits the conduct of treatability studies in diverse matrices using any technology for small quantities of all categories of hazardous wastes.

The testing site was responsible for:

- Providing space and utilities for the verification test;
- Providing piping, pumps, valves, flowmeters, tanks, etc. needed to set up the test; and,
- Providing wastewater discharge location for effluent.

The EPA contact for the T&E Facility is:

Mr. John Ireland, Manager
Phone: (513) 569-7051 e-mail: ireland.john@epa.gov

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26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

EPA T&E Facility
1600 Gest Street
Cincinnati, Ohio 45204

Chapter 2
MEFS Description and Operating Processes

The information contained in this chapter is provided by the vendor and does not represent verified information. It is intended to provide the reader with a description of the UltraStrip Systems, Inc. Mobile Emergency Filtration System and to explain how the technology operates. The verified performance characteristics of the UltraStrip™ system are described in Chapter 4.

2.1 Equipment Description

UltraStrip Systems, Inc. (ISO 9001-2000) manufactures the patent-pending MEFS. The unit is a portable, self-contained wastewater treatment system designed for flexibility with an ability to treat contaminants from biological or chemical terrorist attacks. Multiple treatment processes are utilized to neutralize or remove contaminants in the wastewater generated during cleanup or decontamination activities. The MEFS has the capacity to treat approximately 26 gallons per minute (100 Lpm) on a batch or continuous flow basis. Figure 2-1 shows an exterior view of the steel container used to house the main treatment components.

Figure 2-1. Exterior view of the UltraStrip Mobile Emergency Filtration System.

2.2 Test Unit Specifications

The MEFS contains a number of different unit processes. The processes used for treating wastewater are dependent on the nature of the contaminants in the wastewater. The system includes the following unit processes:

- Chlorine removal system (CRS) for chemical neutralization/dechlorination;
- Centrifuge for solids removal;
- Media filters to remove dissolved organic and inorganic compounds and particulates;

- Ultrafiltration (UF) to remove fine particulates;
- Reverse osmosis (RO) to remove very fine particulates, large microorganisms, and dissolved salts; and,
- Optional ultraviolet disinfection (not utilized in this study).

The MEFS is equipped with valves and piping that provide flexibility in operation in that individual processes can be bypassed, if required. The system is also equipped with meters to monitor various performance parameters, such as flow rates, pressures, and water temperature. The schematic diagram of the treatment processes is shown in Figure 2-2. A summary of the system specifications was included in the VTP (Appendix A).

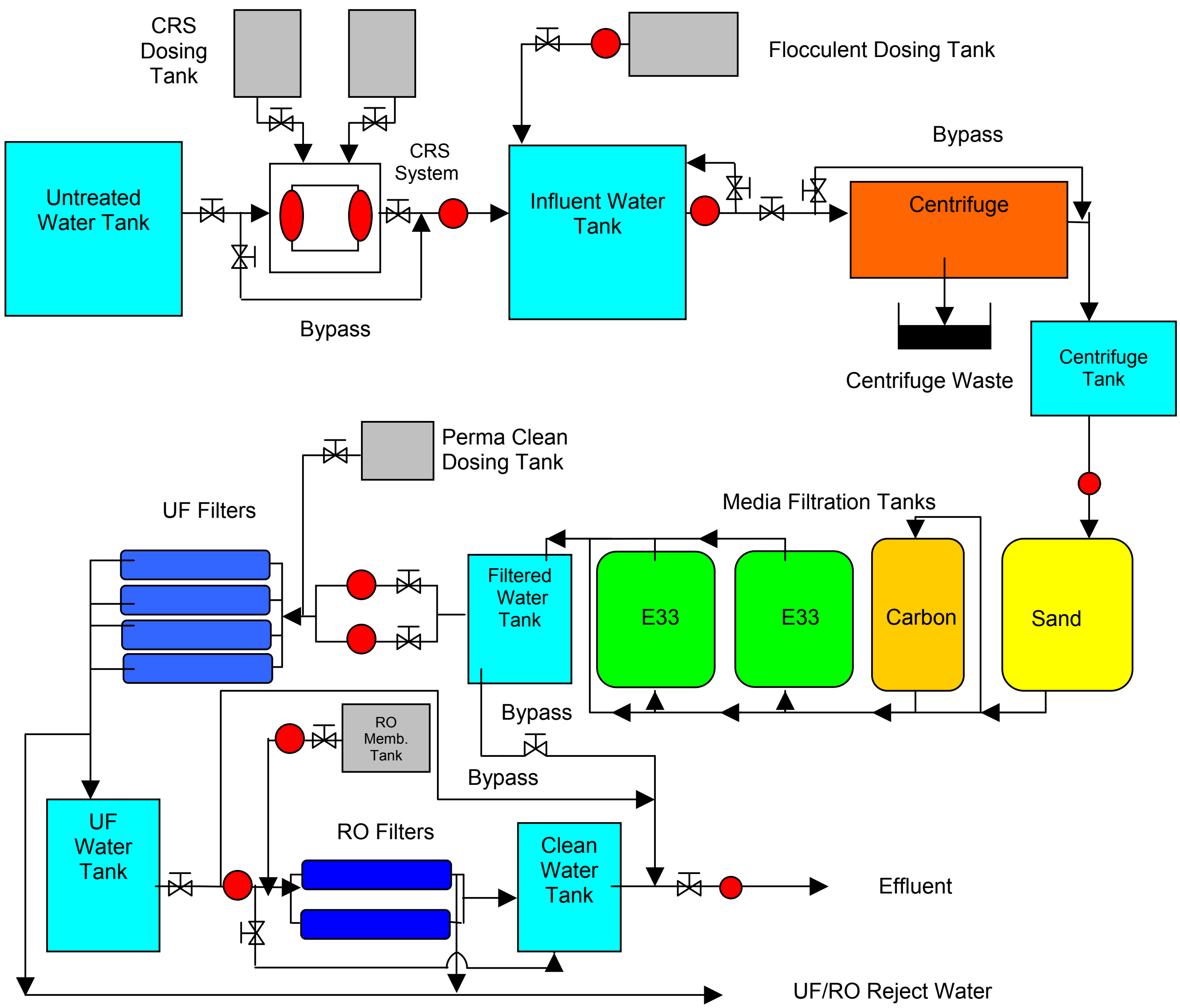


Figure 2-2. Schematic diagram of the USS treatment processes.

The system is equipped with a generator, so no electrical hookup is necessary. However, since testing took place indoors, it was not practical to operate the generator during the verification testing, so the generator was removed from the tested unit. The entire system is housed in a 40-foot long inter-modal modular steel container unit that can be brought to a site ready for use.

2.2.1 Chemical Neutralization

The CRS was used to dechlorinate the wastewater during the biological (high chlorine wastewater) challenge, described further in Chapter 3. Dechlorination was achieved by mixing a neutralizing agent containing calcium thiosulfate into the wastewater in a mixing chamber filled with packing to provide adequate mixing and reaction time. According to the vendor, the CRS has a contact time of approximately two minutes at the MEFS's rated flow capacity of 100 Lpm (26 gpm); this process does not generate waste materials that require special handling or disposal. Figure 2-3 provides a photograph of the calcium thiosulfate dosing pumps and contact tanks of the CRS.

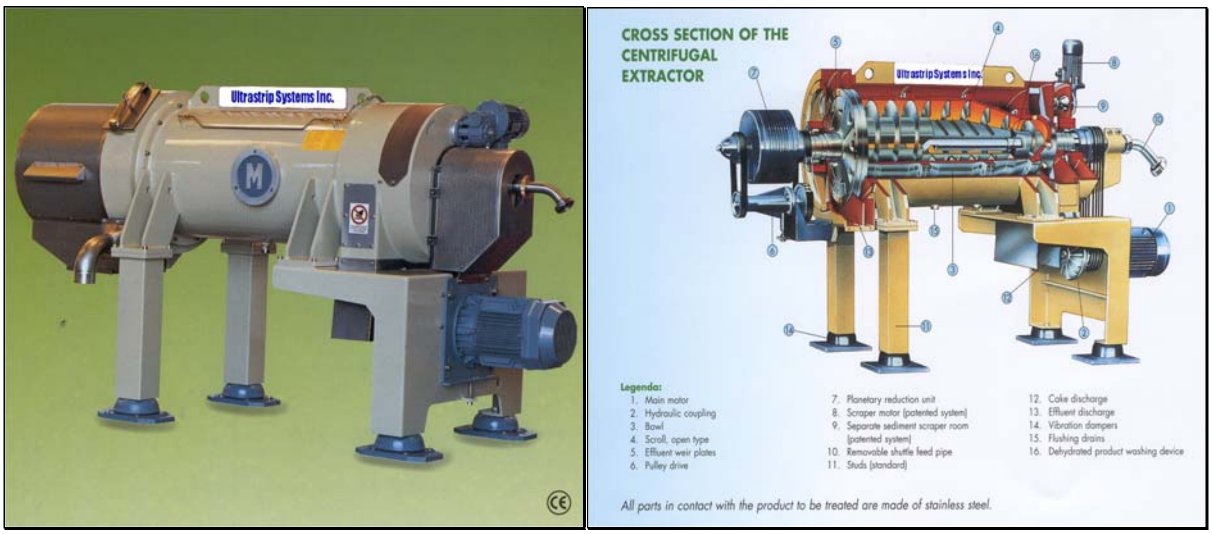
Figure 2-3. View of UltraStrip's CRS dechlorination system.

2.2.2 Internal Water Storage Tanks

The MEFS is equipped with intermediate water storage tanks positioned ahead of the various treatment processes. The tanks are designed to buffer water flow between treatment processes and to allow for the addition and mixing of chemical additives, such as pH adjustment or flocculants, when necessary. The storage tanks are constructed of 2 to 3 mm thick Grade 304 stainless steel, were sized to fit a system with a maximum flow capacity of 26 gpm (100 Lpm).

2.2.3 Centrifuge System

The centrifuge system is designed to remove suspended solids and contaminants associated with these solids from the wastewater. Separation is accomplished by the inertial forces imparted by spinning the centrifuge, which propels heavier particles to the periphery of the unit where they are removed from the system with a rotation internal auger. The separation takes place within a cylindrical truncated cone-shaped rotating drum, as shown in Figure 2-4. The solids removed by the centrifuge are collected in an open-top 55-gallon drum. The centrifuge was for a portion of the inorganic challenge test and used continuously for the organic and biological challenge tests.



(a) **(b)**

Figure 2-4. Centrifuge (a) photograph and (b) cross-section.

2.2.4 Media Filtration

Effluent from the centrifuge is pumped to the media filtration system. This system consists of four 30-inch diameter, 60-inch tall stainless steel filter tanks that operate in series, as shown in Figure 2-5. One canister, filled with a graded sand and garnet, is designed to remove solids down to approximately 5 microns (µm). A second tank, filled with granular activated carbon, is used to remove dissolved organics from the wastewater. Two tanks were filled with Bayoxide E 33 filter media, which is formulated to treat arsenic and other metals; they were used only during the inorganic chemical agent test, described in Chapter 3. The filters have a design capacity of 26 gpm.

Figure 2-5. Media filtration devices.

The media filters have an automatic backwash system that is activated at periodic time intervals. The backwash water is returned to the centrifuge inlet. Water used for backwash is piped from the reservoir tank positioned after the media and carbon filters, and is injected with a flocculent to assist in the backwash process. Valves in the system allow the filters to operate simultaneously, in parallel or individually, so that wastewater can continue to be processed through one filter unit while the other unit is in backwash mode.

2.2.5 Ultrafiltration System

Ultrafiltration (UF) is a technique of cross-flow filtration that minimizes filtration surface fouling. UF uses membranes to remove particles ranging in size from 0.003 to 0.02 µm. The membranes are made of cellulose acetate and operate under a pressure of 65 pounds per square inch (psi) at the filtration surface. This degree of filtration will remove virtually all particulate material that would be classified as suspended solids.

A high-pressure pump feeds the UF system from a reservoir tank containing the carbon adsorption effluent. The design flow is 26 gpm, and the reject flow rate is approximately 2.1 gpm (8 Lpm). The UF system was continuously utilized during all three challenge tests. Figure 2-6 shows a view of the UF system.

2.2.6 Reverse Osmosis System

The USS is configured with a reverse osmosis (RO) system following the UF system. The UF wastewater can be passed through the RO unit when required, or it can bypass the RO unit. RO is a technique of cross-flow filtration that uses a composite polyamide membrane to remove molecules ranging in size from 0.01 to 0.002 µm. The RO unit can provide removal of dissolved salts and dissolved metals such as arsenic and lead. In addition, the RO membranes may also reject certain dissolved organics.

Figure 2-6. View of the ultrafiltration system.

The RO unit has a design flow of 26 gpm to match the overall system design flow, with a reject rate of approximately 5.3 gpm (20 Lpm). The RO system operates at a pressure of approximately 130 psi. Figure 2-7 shows the RO system used in the MEFS.

According to the vendor, the combined reject flow rate from the RO and UF systems ranges from 20 to 30 percent, depending on the wastewater's characteristics. The rejected RO wastewater is discharged from the MEFS through a separate discharge point. During testing, the RO/UF reject wastewater was discharged to the sanitary sewer at the T&E Facility. In a field setting, RO and UF reject water could be piped back to the influent storage tank and get retreated, or it could be discharged to a location separate from the treated effluent discharge point.

2.2.7 Controls, Flowmeters and PLC Alarm Equipment

A programmable logic controller (PLC), which retains equipment setting and operating processes, operates the MEFS. The PLC is equipped with a serial port so data can be downloaded to a laptop computer. The PLC panel is shown in Figure 2-8.

The MEFS is equipped with two analog totalizing flowmeters that report flow rate (gpm) and total processed volume (gallons). The influent flowmeter is located ahead of the RO and ultrafiltration units, while the effluent flowmeter is located in-line with the treated effluent discharge pipe.

Figure 2-7. View of the reverse osmosis system.

2.3 USS Claims and Criteria

The MEFS is designed to be user-friendly and easily maintained. The system can be operated by one or two operators, depending on the application. The MEFS will treat wastewater from decontamination operations involving highly chlorinated water or chemical agent decontamination to meet surface water discharge or reuse criteria. Effluent quality achievable by the system for different water quality parameters is outlined in Table 2-1.

Figure 2-8. View of the PLC panel.

Table 2-1. USS Wastewater Treatment Claims

Parameter	Influent	Treated Effluent
BOD_5	100 mg/L	< 10 mg/L
TSS	100 mg/L	< 5 mg/L
Total coliform	10^6 to 10^8/100 mL	<2.2/100 mL
Total chlorine	100,000 mg/L (10%)	<1.0 mg/L

Chapter 3
Methods and Test Procedures

A VTP was prepared and approved for the verification of the UltraStrip system and is attached in Appendix A. This VTP details the procedures and analytical methods used to perform the verification test. The VTP includes tasks designed to verify the treatment capability of the UltraStrip System and to obtain information on the setup, operation, and maintenance requirements of the system.

The testing elements performed during the technology verification, including equipment operation, sample collection procedures, and analytical methods, are described in this section. Quality assurance and quality control procedures and data management methods are discussed in detail in the VTP.

3.1 Test Phases

The verification test was divided into three distinct testing phases. The basis for all three test phases was a standard synthetic wastewater consisting of effluent from the secondary clarifiers of a sewage treatment plant, hydrocarbons typically found on road surfaces and paved parking areas (used motor oil), surfactants (commercial cleaning and degreasing products), and sediments (sand and solids). These materials are used to simulate typical contributors to a wastewater stream from sites such as buildings, parking lots, roadways, subways, etc. The test phases were differentiated by the primary challenge constituent added to the synthetic wastewater to simulate wastewater generated from three different decontamination scenarios:

1. Chemical events with an inorganic chemical agent. In this case, remediation of a Lewisite (a chemical warfare agent) release was assumed where trivalent arsenic remains as a decontamination byproduct. A soluble arsenic salt (arsenic trioxide or sodium meta arsenite) was added to the synthetic wastewater to simulate this condition.

2. Chemical events with an organic chemical nerve agent, where remediation utilizes water-based cleaning solutions and neutralizing chemical(s). For this test, an organo-phosphorus pesticide (methyl parathion) was used as the surrogate and was added to the synthetic wastewater.

3. Biological events, where remediation utilizes chlorine-based materials, including chlorine dioxide, followed by washing with a bleach solution. For this test, sodium hypochlorite (bleach) was added to the synthetic wastewater. An active biological surrogate was not used for this test.

Each test phase followed the same testing approach. The primary challenge constituent was added to the synthetic wastewater and the MEFS was challenged over the course of a 10-day operating period. Influent and effluent samples were collected from the system and analyzed for various contaminants (including the primary challenge constituent) or contaminant indicators. The results were used to calculate removal efficiencies and system capacities, and to determine the system's treatment effectiveness. Data was also collected on the residues or waste products generated by the treatment processes, consumables, power consumption, and operation and maintenance requirements.

3.2 MEFS Setup and Startup

The MEFS is a self-contained modular system that arrived at the test site ready to be set up and operated. Timers and pump cycles on the various unit processes were checked and adjusted as needed. A clean water test of the system piping, connections, valves, etc. was completed to assure that the system was ready to begin testing.

3.3 Test Apparatus

The MEFS was set up inside the T&E Facility. Figure 3-1 shows the process flow diagram and equipment configuration for the test setup. A stock tank with a nominal volume of 10,000 gallons (operating volume of approximately 9,200 gallons) was used to contain the synthetic wastewater challenge mixture. The tank was circulated to keep the contents mixed, and was calibrated so that the volume of water in the tank could be measured with a dipstick. Sample ports were installed so that influent, treated effluent, and RO/UF reject liquid samples could be collected easily. A kilowatt-hour (kWh) meter was installed on the main electrical feed line to monitor power requirements.

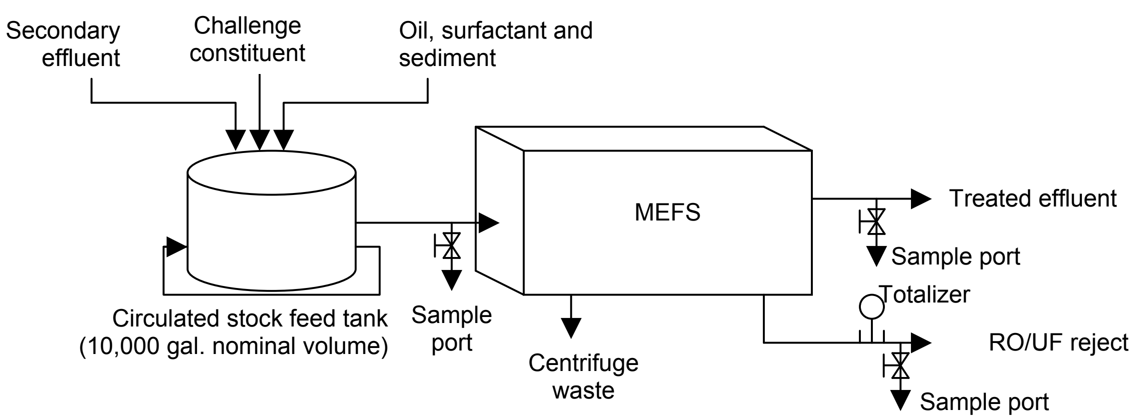


Figure 3-1. Testing rig schematic.

3.4 General Test Procedures

The procedures described in this section were conducted for each of the three test phases.

3.4.1 MEFS Preparation

The test rig and MEFS components were inspected by USS personnel prior to each test day. Readings from the power meter, totalizer, and other related devices were recorded in the project logbook. Once the stock feed tank was adequately prepared and its volume measured, the TO informed USS personnel that the test was ready to begin.

3.4.2 Synthetic Wastewater Preparation

The synthetic wastewater was prepared in the mixed stock feed tank, shown in Figure 3-2. As outlined in Section 3.5, the tank was filled with secondary effluent, sediment, used oil, surfactant, and the primary challenge agent. When a stock solution was prepared, the mass of chemicals and volume of secondary effluent was recorded by the TO. The contents of the tank were kept mixed throughout the run by a submersible pump that drew the wastewater from one end of the tank and discharged the pumped water through a perforated PVC pipe at the other end.

(a) Side view.

(b) Front view.

(c) Inside view.

Figure 3-2. Views of the influent tank.

3.4.3 Initiate System Operation

Prior to the start of operations each day, the TO recorded the totalized flow readings from flowmeters on each pumped line and within the MEFS, and the totalized kWh meter. USS personnel established the unit operating processes necessary to treat the particular challenge wastewater being processed on that day and the MEFS was started. For the organic and inorganic event tests, a feed pump in the MEFS pumped the challenge wastewater from the stock feed tank to the system. For the biological event test, a submersible pump in the stock feed tank pumped the water to the MEFS.

3.4.4 Sample Collection

Influent and effluent water samples were collected as outlined in the VTP. Sample collection procedures and analytical parameters are summarized in Section 3.6 of this report. The same influent and effluent sample locations were utilized throughout the tests with samples collected from additional locations as necessary. In test runs with the RO systems operating, a sample of the reject water was collected. Relevant sampling information was recorded in the testing logs.

3.4.5 Conclude Operation

At the conclusion of operations on each test day, the MEFS feed pump was shut off and USS personnel performed routine maintenance as specified in the MEFS O&M manual (such as filter backwashing). These activities followed the same routine that would be followed in actual field conditions. The time that the tests were concluded, the final volume of water in the stock tank, the kilowatt-hour meter reading, and other relevant information were recorded in the testing logs.

3.4.6 System Component Operation and Maintenance

The overall system performance was measured both quantitatively and qualitatively throughout the testing program. Qualitative measures were assessed by observations of, and experience with, the unit during the setup and testing phases. Records were maintained on the ease and time of installation, maintenance, and other operating observations. Throughout the course of the testing day, the MEFS was regularly inspected to ensure that equipment was functioning properly. Operating parameters, such as dosing tank feed rates, residue or bypass generation rates, operating pressures, and process flow rates were routinely monitored and recorded by USS operators. Maintenance actions, if necessary, were completed and recorded in the logbook. These observations, experiences and records provide the basis for evaluating the system performance in terms of operation and maintenance.

3.5 Synthetic Wastewater Composition

The synthetic wastewater reflected general constituents that would be expected in a wastewater stream generated by the decontamination of sites such as buildings, parking lots, roadways, or subway or bus stations. The base water for the test challenge wastewater was obtained from the effluent of the secondary clarifiers of the Mill Creek Sewage Treatment Plant of the Greater Cincinnati Metropolitan Sewer District (MSD). This secondary effluent wastewater was piped directly to the T&E Facility. The base characteristics of the secondary effluent were determined from analytical data from approximately 70 sampling events that occurred between November 2000 and February 2001; these are shown in Table 3-1.

Table 3-1. Secondary Effluent—Base Characteristics

Parameter	Mean Concentration (mg/L)	Concentration Range (mg/L)
Total suspended solids (TSS)	36	31-44
5-day Biological Oxygen Demand (BOD_5)	26	19-31
Chemical Oxygen Demand (COD)	124	120-130
Carbonaceous BOD (CBOD)	21	14-25
Alkalinity	219	210-230
Total phosphorus (as P)	1	ND-5
Total Kjeldahl nitrogen (TKN, as N)	18	1-36
Ammonia (NH_3-N) (as N)	14	ND-31
Nitrates and nitrites (NO_2/NO_3, as N)	1	ND-20

ND – Not detected.

The secondary effluent was augmented with used motor oil, sediment (diatomaceous earth), and surfactants to better mimic likely real-world conditions. Before being added to the tank, the specific quantities of used oil and surfactant were measured in laboratory beakers and the sediment was weighed using a calibrated scale. Table 3-2 shows the target characteristics for the synthesized wastewater.

Table 3-2. Synthetic Wastewater—Target Characteristics

Parameter	Concentration (mg/L)
TSS	50-100
BOD_5	40-100
COD	100-200
Oil & grease (O&G)	10-20
Total phosphorus (as P)	0.5-5
TKN (as N)	0.4-40
NH_3-N (as N)	0.4-40
Surfactants (MBAS)	10
pH	6.0-8.0

The verification challenge consisted of three different test phases in which a primary challenge constituent was added to synthetic wastewater.

3.5.1 Inorganic Chemical Event – Arsenic Compound

The verification of wastewater treatment from a hypothetical chemical attack involving Lewisite was based on the assumption that the cleanup process will use inactivation solutions to clean and deactivate the Lewisite, resulting in a wastewater with elevated arsenic concentrations. Concentrations of arsenic for testing purposes were targeted at approximately 5 mg/L. An arsenic salt (arsenic trioxide or sodium meta arsenite) was added to the synthetic wastewater challenge to serve as the primary challenge agent.

3.5.2 Organic Chemical Event – Organo-Phosphorus Compound

The verification of treatment of the wastewater from the cleanup of a hypothetical organic chemical attack was based on the assumption that the cleanup process would entail oxidizing the chemical, followed by a thorough cleaning of all surfaces. Testing assumed that there was less than complete reaction between the oxidant and the active chemical, resulting in the need to remove the chemical from the waste stream. It is common to use a surrogate to simulate the presence of a nerve agent or similar chemicals. Organo-phosphorus pesticides, such as methyl parathion, have been used for this purpose. The verification of this event included the addition of methyl parathion to the challenge wastewater to achieve a target contaminant concentration of one (1) mg/L to serve as the primary challenge agent.

3.5.3 Biological Event – Chlorine Compound

The verification of wastewater treatment from a hypothetical biological attack was based on the assumption that a chlorine-based chemical (chlorine dioxide or bleach) would be the main chemical used to deactivate a biological agent. The use of household bleach (5.25 percent sodium hypochlorite solution) at a ratio of one part bleach per ten parts water is typically recommended as a wiping agent to disinfect solid surfaces. A 1:10 solution of bleach and water would have a total chlorine concentration of approximately 2,500 mg/L (as Cl). For this test phase, bleach was measured by volume, based on a volumetric calibration on the container (500-gallon tote), and poured into the stock feed tank to raise the chlorine concentration of the wastewater to approximately 2,500 mg/L (as Cl), as specified in the VTP, or 5,000 mg/L as Cl_2. The common reporting practice for free and total chlorine concentrations are as Cl_2, so the testing results will be expressed with chlorine results as Cl_2.

3.6 Laboratory Analytical Constituents

The primary locations used to assess the treatment capabilities of the MEFS were the untreated wastewater influent and the treated effluent. During a portion of the biological agent testing in which the RO/UF reject rates were very high, effluent samples were collected from the RO/UF reject water in place of or in addition to treated effluent. This is explained in detail in Chapter 4.

3.6.1 Analytical Parameters – All Tests

The sampling and analytical program consisted of collecting and analyzing samples for a number of indicator and secondary parameters for all three test phases, with special analytical parameters added based on the specific testing event being performed. Table 3-3 summarizes the sample collection and analysis program for each of the three tests.

Table 3-3. Summary of Base Sample Collection and Analysis for All Verification Tests for All Three Challenge Wastewater Types – Influent and Effluent

Parameter	Sample Type	Frequency	Number of Days	Number of Samples [1]
Indicator Parameters				
pH	Grab	Daily	30	60
Temperature	Grab	Daily	30	60
Turbidity	Grab	Daily	30	60
Secondary Parameters				
Alkalinity	Grab	Daily	30	60
O&G	Grab	Daily	30	60
TSS	Composite[2]	Daily	30	60
COD	Composite[2]	Daily	30	60
BOD_5	Composite[2]	3 per week	18	36
MBAS (surfactants)	Composite[2]	3 per week	18	36
TKN	Composite[2]	3 per week	18	36
Ammonia	Composite[2]	3 per week	18	36
Total phosphorus	Composite[2]	3 per week	18	36

[1] Number of samples was based on two primary sampling locations: untreated influent and treated effluent.
[2] All composite samples were flow proportional, using grab samples of equal volume at predetermined treated water volumes.

3.6.2 Test Phase-Specific Analytical Parameters

The sampling and analysis plan included specific parameters based on the primary challenge constituent for each test phase.

- Sampling and analysis for total arsenic was added to the sampling schedule for the ten days of the inorganic chemical event challenge verification testing.
- Sampling and analysis for organo-phosphorus pesticide (methyl parathion) was added to the sampling schedule for the ten days of the organic chemical event challenge verification testing.

- Sampling and analysis for total residual chlorine and free chlorine was added to the sampling schedule for the ten days of the biological event challenge verification testing.

These additional parameters are summarized in Table 3-4.

Table 3-4. Summary of Special Sample Collection and Analysis for Verification Tests

Parameter	Sample Type	Frequency	Number of Days	Estimated Number of Samples
Chemical – Arsenic Compound				
Total arsenic	Composite[1]	Daily	10	20
Chemical – Organo Phosphorus Compound				
Organo-phosphorus pesticide	Composite[1]	Daily	10	20
Biological – Chlorine Compound				
Total residual chlorine	Grab	Twice daily	10	40
Free chlorine	Grab	Twice daily	10	40

[1] Composite samples were flow proportional, using grab samples of equal volume at predetermined treated water volumes.

3.7 Flow Monitoring

The MEFS was equipped with totalizing flowmeters to measure the influent, treated effluent, and RO/UF reject effluent. The TO verified the performance of these totalizers by using recorded influent and RO/UF reject water volumes to complete a mass balance. The volume of influent entering the MEFS was determined by measuring the water level inside the stock tank before and after each day of testing. A calibrated totalizing flowmeter was installed on the RO/UF reject water discharge line to determine the volume of water rejected by the RO and UF systems. The treated water volume was determined by subtracting the RO/UF reject volume from the influent volume. The volume of water in the centrifuge waste was sufficiently low to be neglected. The average daily flow rate was determined by dividing the treated water volume by the run time. The flow rates were recorded in the operating log.

3.8 Residuals

Solids were removed from the centrifuge on a continuous basis and deposited into a 55-gallon waste drum. The solids concentration and total volume of solids from the centrifuge were monitored during testing. Residuals generated during testing were accumulated and disposed of appropriately at the end of the testing program.

3.9 Operation and Maintenance

The MEFS was started and operated in accordance with the O&M manual provided by USS. A copy of the manual is included as Appendix B. USS personnel operated, maintained, and monitored the system during the test period, with oversight from the TO. The TO maintained records showing operating conditions and maintenance performed.

USS operators used the USS preventative maintenance checklist to record checks on the system. Unit processes were visually inspected for any signs of incorrect performance or abnormal conditions. Maintenance performed was logged in the on-site maintenance log.

In addition to the operating records kept at the site, the PLC monitored several critical parameters for the operation of the USS unit processes. The PLC monitored pump cycles, flow, electrical components, and the operation of floats and sensors related to MEFS operation. These conditions could be adjusted if needed. Flow rates, volume of water processed, amount of chemical solutions pumped from the feed tanks, power consumption, backwash flow rates, and related operational data were recorded by the TO and USS operators in separate logbooks.

Power consumption was monitored on a daily basis with a standard electrical power meter (kilowatt-hour meter). Meter readings were taken at least daily throughout the test and recorded in the logbook.

The quantities of consumable supplies and the need for related equipment expenses were recorded in the operating log. Personnel time to complete O&M activities was also recorded in the logbook by the TO.

Any other observations relating to the operating condition of unit processes, or the test system as a whole, were recorded by the TO in the logbook. Observations of changes in effluent quality based on visual observations, such as color change, oil sheen, obvious sediment load, etc., were also recorded by the TO in the logbook.

3.10 Additional Test Not Specified in the VTP

After the VTP had been approved, an integrity test for the ultrafiltration and reverse osmosis processes was added to the verification test procedures to verify the soundness of membranes and housings. The integrity test procedures followed the American Society of Testing and Materials (ASTM) Test Designation D 6908-03, *Standard Practice for Integrity Testing of Water Filtration Membrane Systems.* The test determined the integrity of the RO device (membranes, seals, connections, etc.) using an air-based pressure decay test. The test was conducted before the first day and after the last day of the biological contaminant test phase. The first test determined whether the UF and RO systems' membranes and housings were sound. The test at the end of the ten-day time period provided an indication of whether the exposure to the high chlorine content wastewater impacted the membranes or seals, reducing the effectiveness of the systems. The simplicity and ease of the test allowed it to be completed at any time during actual operation of the system to assure the integrity of the systems.

Chapter 4
Verification Testing Results and Discussion

This chapter summarizes the data collected during each of the three test phases, as well as information regarding the synthetic wastewater composition, setup, installation, and operation. The data from the three test phases are presented in the following manner:

- Treatment process: this indicates which treatment processes were utilized or bypassed during each test.

- Analytical data: these are separated into three classifications:

    - Primary data, where the analytical data for the primary constituents (arsenic, methyl parathion, or chlorine) are summarized. The influent and effluent concentrations and treatment efficiency for each test day are reported.

    - Secondary data, where wastewater indicator parameters (such as BOD_5 and alkalinity) or the parameters detecting the presence of the fouling compounds (such as O&G and TSS) are summarized. The influent and effluent concentrations are summarized into mean and range and the efficiency based on the mean is reported.

    - Indicator data, where screening parameters monitored with field monitoring devices as the MEFS is being operated and samples are being collected, including pH, temperature, and turbidity are summarized. The data points are summarized into mean or median and range.

- Flow data: this includes the total water volume processed, the reject water from the UF or RO systems, and the flow rate.

- Consumables/waste generation: this includes items such as power consumption, treatment process chemicals, and waste materials generated from spent filter media, centrifuge sludge, etc.

4.1 Synthetic Wastewater Composition

The VTP established target concentrations for the analytical parameters, as presented in Table 3-2. The TO strived to maintain consistent constituent concentrations in the synthetic wastewater during the course of testing so that the system would be properly challenged. The weights of constituents added to the challenge water were used to calculate the constituent loadings and are presented in the field notes (Appendix D). The constituent analytical concentrations are summarized in Table 4-1.

Table 4-1. Synthetic Wastewater Secondary Parameter Concentration Ranges

Parameter	Target Range (mg/L)	Influent Ranges by Test Phase Inorganic	Organic	Biological
Alkalinity	N/A	140 - 1,200	160 - 280	2,900 – 5,200
BOD_5	40 - 100	7.3 - 22	3.7 - 17	<2.0 - 380[1]
COD	100 - 200	42 - 81	21 - 96	100 - 970[1]
MBAS	10	<0.2 - 7.2	<0.2 - 2.3	<0.2 - 1.7
Ammonia (as N)	0.4 - 40	5.4 - 28	19 - 39	<0.04 - 0.35
Oil & Grease	10 - 20	<5.0 - 10	<5.0 -16	<5.0 - 5.2
TKN (as N)	0.4 - 40	6.3 - 15	14 - 33	1.2 - 2.4
Total Phosphorus (as P)	0.5 - 5.0	1.8 - 2.5	<0.1 - 0.81	<0.10 - 0.40
TSS	50 - 100	14 - 39	<4.0 - 41	<5.0 - 23

[1] Apparent matrix interferences were noted with the BOD_5 and COD data during the biological event test.

With the exception of ammonia, TKN, and phosphorous, the secondary parameter concentrations were lower than the target range. The sodium hypochlorite added to the synthetic wastewater during the biological event test phase significantly increased alkalinity, and decreased ammonia and TKN concentrations. The laboratory reported difficulties during the biological event test phase in performing the analyses for BOD_5 and COD data; consequently this data is flagged to be used with caution.

4.2 Inorganic Chemical Event—Arsenic

As described in Section 3.5.1, arsenic trioxide or sodium meta arsenite was added to the synthetic wastewater during this test so that the resulting arsenic concentration in the wastewater was approximately 5 mg/L.

4.2.1 Treatment Process

Prior to mobilization of the unit, the MEFS's media filtration devices were filled with new filter media (sand, Bayoxide E33, and carbon). Once the system was on-site, a series of short shakedown tests were performed using potable water and secondary effluent wastewater. These shakedown tests were to confirm that the system was operating properly mechanically.

UltraStrip designated the treatment process for the inorganic treatment test (arsenic removal) to include the centrifuge, media filtration (sand, activated carbon, and Bayoxide E33), and ultrafiltration. The CRS and RO systems were bypassed during the test.

After observing the synthetic wastewater characteristics, UltraStrip decided to use oil sorbent pillows in the influent water tank to remove hydrocarbons and reduce usage and potential fouling of the activated carbon. On the first four days of test, UltraStrip also decided to bypass the centrifuge. After four days of testing, the solids loading in the wastewater caused a significant decrease in the flow rate through the system, so the centrifuge was returned to the treatment process for the duration of the test. Thus, the final system configuration included oil absorbent pillows on the surface of the first tank to control oil, followed by the centrifuge, sand filtrations, activated carbon, Bayoxide E33 media, and ultrafiltration.

4.2.2 Analytical Data

The arsenic analytical data are summarized in Table 4-2.

Table 4-2. Arsenic Analytical Data Summary

Run Number	Influent (mg/L)	Effluent (mg/L)	Efficiency[1] (percent)
1	5.4	<0.010	>99.9
2	5.0	<0.010	99.9
3	4.0	<0.010	99.9
4	5.3	<0.010	>99.9
5	5.5	0.022	99.6
6	4.9	0.021	99.6
7	5.7	0.025	99.6
8	5.0	0.030	99.5
9	5.0	0.044	99.1
10	4.9	0.061	98.8
Mean	**5.0**	**0.024**	**>99.6**

[1] One-half of the method detection limit was used to calculate mean efficiency for analytical results below detection limits.

The MEFS was able to treat arsenic to concentrations below detectable limits for the first four days (approximately 36,000 gallons) of testing. From the fifth to tenth day of testing, arsenic concentrations increased from 0.022 mg/L to 0.061 mg/L, indicating that some breakthrough was occurring, but high removal efficiencies were still being achieved.

The secondary inorganic chemical test phase analytical data are summarized in Table 4-3. A summary of the analytical data and the completed analytical data packages are enclosed in Appendix C. The effluent data for O&G, TSS, and total phosphorus were all below detection limits, resulting in high treatment efficiencies. The MEFS was able to reduce BOD_5 and COD to near or below the quantification limits, yielding calculated treatment efficiencies in the 80 to 89 percent range. Low reductions of TKN and ammonia concentrations were recorded.

Table 4-3. Inorganic Chemical Test Phase Secondary Analytical Data Summary

Parameter	Influent (mg/L) Mean	Influent (mg/L) Range	Effluent (mg/L) Mean	Effluent (mg/L) Range	Mean Efficiency[1] (percent)
Alkalinity	330	140 - 1,200	180	110 - 380	46
BOD_5	14	7.3 - 22	1.6	<2.0 - 3.2	89
COD	60	42 - 81	11	<10 - 21	81
MBAS	0.98	<0.2 - 7.2	0.37	<0.2 - 2.2	62
Ammonia (as N)	13	5.4 - 28	11	4.5 - 19	16
O&G	5.1	<5.0 - 10	<5.0	<5.0 - <5.0	51
TKN (as N)	11	6.3 - 15	9.8	5.5 - 16	7.8
Total Phosphorus (as P)	2.3	1.8 - 2.5	<0.1	<0.1 - <0.1	98
TSS	25	14 - 39	<4.0	<4.0 - <4.0	92

[1] One-half of the method detection limit was used to calculate mean efficiency for analytical results below detection limits.

The indicator parameter inorganic chemical test phase data are summarized in Table 4-4. The average water turbidity level dropped approximately 87 percent as a result of treatment processes. The temperature increased to some extent and had no significant impact on pH.

Table 4-4. Inorganic Chemical Test Phase Indicator Parameter Data Summary

Parameter (units)	Influent Median	Influent Range	Effluent Median	Effluent Range
pH (S.U.)	6.9	6.2 - 7.6	6.9	6.0 - 7.4
Temperature (^{o}C)	18.0	17.3 - 20.7	19.7	18.8 - 22.0
Turbidity (NTU)	15.2	6.1 - 34	1.3	0 - 11

4.2.3 Flow Data

The flow data are summarized in Table 4-5. USS personnel initially thought the solids concentration in the synthetic wastewater was low enough to bypass the centrifuge from the treatment process. This decision resulted in a noticeable decrease in the flow rate. The mean flow rate was much lower when the centrifuge was not used (16.6 gpm) as compared to when the centrifuge was used (23.0 gpm). The difference between the influent totalizer on the MEFS and the control reading (water drawn from the influent feed tank) varied between –5.0 percent and 6.3 percent, but averaged 1.4 percent variance over the course of the 10-day run. The effluent totalizer deviation had a wider range (-14.6 percent to 8.9 percent), but a lower average over the 10-day run (-0.4 percent). The UF reject rate varied between 6 percent and 16 percent. The 16 percent rejection rate was recorded when the centrifuge was not operating, and the high rate may be the result of the UF system rejecting solids that passed through the earlier treatment processes.

Table 4-5. Inorganic Chemical Test Phase Flow Data Summary

Day	Influent (gal) MEFS Reading	Influent (gal) Control Reading[1]	Influent (gal) Variance (percent)	Effluent (gal) MEFS Reading	Effluent (gal) Control Reading[2]	Effluent (gal) Variance (percent)	UF Reject (percent)	Mean Flow Rate[3] (gpm)
1	9,484	9,499	0.2	8,770	8,584	-2.2	10	17.9
2	7,662	7,969	3.9	7,661	7,164	-6.9	10	15.6
3	8,083	7,917	-2.1	7,634	6,662	-14.6	16	16.0
4	8,585	8,176	-5.0	7,264	7,683	5.5	6	16.9
5	8,347	8,550	2.4	7,396	7,564	2.2	12	22.5
6	8,797	8,655	-1.6	8,162	7,877	-3.6	9	22.4
7	7,713	8,234	6.3	7,238	7,365	1.7	11	21.1
8	8,189	8,444	3.0	7,238	7,405	2.3	12	23.8
9	8,453	8,655	2.3	7,528	7,755	2.9	10	23.9
10	7,925	8,339	5.0	6,789	7,449	8.9	11	24.2
Totals	**83,238**	**84,438**	**1.4**	**75,680**	**75,508**	**-0.4**	**11**	**20.4**

[1] Influent control reading taken from the challenge water tank volume.
[2] Effluent control reading determined by subtracting the metered UF/RO reject volume from the influent control reading.
[3] Mean flow rate calculated by dividing the USS influent reading by test run duration (see daily monitoring logs in Appendix D).

4.2.4 Consumables and Residual Generation

The power and treatment chemicals consumed during the inorganic chemical event test phase are summarized in Table 4-6. Muriatic (hydrochloric) acid was used for pH adjustment, and alum was used as a flocculent. Both chemicals were injected into the storage tank inside the MEFS located before the centrifuge. The power consumption was generally lower when the centrifuge was not operated (113 to 139 kWh) versus when it was operated (139 to 176 kWh).

The residuals generated during the inorganic chemical event test phase are summarized in Table 4-7. The spent carbon was classified as non-hazardous, as determined by Toxicity Characteristic Leachate Procedure (TCLP). The spent carbon was transported to a Type II landfill for disposal. The TCLP data are included in Appendix C. The centrifuge sludge and oil absorbent pads from this test were accumulated with the sludge and pads from the other tests and discarded as a single waste stream. The disposal arrangements for these materials are summarized in Section 4.3.4.

In addition to the centrifuge sludge, spent carbon, and oil absorbent pads, approximately 7,500 gallons of UF reject water was generated during the inorganic chemical event test phase. For the purposes of verification testing, this water was discharged to a sanitary sewer at the T&E Facility, in accordance with the facility-specific sanitary discharge permit. In a field setting, the UF reject water can be piped back to the influent storage tank and re-filtered, or discharged to a location separate from the treated effluent discharge location.

The residual material disposal arrangements were based on specific waste characteristics and applicable regulations, and may not be indicative of the disposal requirements in a field setting.

Table 4-6. Inorganic Chemical Test Phase Power and Chemical Consumption

Day	Test Duration (hr)	Power Consumption (kWh)	Muriatic Acid (mL)	50% Alum (L)
1	9.33	116[1]	50	5
2	8.50	135[1]	50	4
3	8.42	113[1]	50	4.5
4	8.23	139[1]	30	4
5	6.33	176	50	4
6	6.42	172	50	4.5
7	6.50	156	50	3
8	6.25	158	50	4
9	6.75	164	500	4
10	5.75	171	1,000	4

[1] The centrifuge was not run during the first four days.

Table 4-7. Inorganic Chemical Test Phase Residual Generation Summary

Residual	When Generated	Quantity
Centrifuge sludge	Continuously	57 lbs.
Oil absorbent pads	Daily	18 lbs.
Spent carbon	End of test	Two 55-gal drums

4.3 Organic Chemical Event—Methyl Parathion

As described in Section 3.5.2, methyl parathion was added to the synthetic wastewater during the organic chemical event test phase. The target methyl parathion concentration in the wastewater was 1 mg/L.

4.3.1 Treatment Process

USS designed the treatment process for the organic chemical test to include the centrifuge, media filtration (sand and activated carbon), and ultrafiltration. The CRS, Bayoxide E33, and RO systems were bypassed during this test. Oil sorbent pillows in the influent water tank in the MEFS helped to remove hydrocarbons and prolong the effectiveness of the activated carbon.

USS replaced the activated carbon in the activated carbon media filter canister after the inorganic chemical event test, and prior to the organic chemical test.

4.3.2 Analytical Data

The methyl parathion analytical data are summarized in Table 4-8.

Table 4-8. Methyl Parathion Analytical Data Summary

Day	Influent (mg/L)	Effluent (mg/L)	Efficiency (Percent)
1	0.64	0.00028 [J]	>99.9
2	0.84	0.00033 [J]	>99.9
3	0.93	0.00066 [J]	>99.9
4	0.63	0.00099 [J]	99.8
5	0.80	0.0013	99.8
6	0.80	0.0021	99.7
7	0.55	0.0056	98.9
8	0.73	0.0058	99.2
9	0.56	0.0089	98.4
10	0.71	0.013	98.2
Mean	**0.72**	**0.0039**	**>99.4**

[J] Estimated value, concentration was below the laboratory reporting limit, but above the method detection limit.

Similar to the arsenic test, the methyl parathion test showed greater than 99.9 percent removal efficiency during the first three days of testing, followed by an incremental increase in methyl parathion concentrations during the fifth through tenth days of testing.

The secondary organic chemical test phase analytical data are summarized in Table 4-9. The MEFS reduced BOD_5 and COD to near or below the quantification limits, yielding calculated treatment efficiencies in the 71 to 77 percent range. The lower percentile efficiency reflects the low influent BOD_5 and COD concentrations. Low reductions of TKN and ammonia concentrations were recorded. Effluent data for O&G samples were below detection limits, while many of the TSS and total phosphorus effluent concentrations were also below detection limits.

The indicator parameter inorganic chemical test phase data are summarized in Table 4-10. The median water turbidity level dropped approximately 71 percent. The treatment processes had a negligible impact on pH and temperature.

Table 4-9. Organic Chemical Test Phase Secondary Analytical Data Summary

Parameter	Influent (mg/L) Mean	Influent (mg/L) Range	Effluent (mg/L) Mean	Effluent (mg/L) Range	Mean Efficiency[1] (percent)
Alkalinity	240	159 - 284	157	112 - 238	35
BOD_5	10	3.7 – 17	2.4	1 - 4.1	77
COD	61	21 - 96	18	5.0 - 28	71
MBAS	1.0	<0.2 - 2.3	0.80	<0.2 – 2.2	21
Ammonia (as N)	28	19 - 39	28	24 - 38	-2.4
O&G	5.9	<5.0 - 16	<5.0	<5.0 - <5.0	58
TKN (as N)	22	14 - 33	23	14 - 34	-2.1
Total Phosphorus (as P)	0.35	<0.1 - 0.81	<0.1	<0.1 – 0.19	78
TSS	18	4.0 - 41	4.1	<4.0 - 23	77

[1] One-half of the method detection limit was used to calculate mean efficiency for analytical results below detection limits.

Table 4-10. Organic Chemical Test Phase Indicator Parameter Data Summary

Parameter	Influent Mean	Influent Range	Effluent Mean	Effluent Range
pH (S.U.)	7.1	6.8 - 7.4	7.2	6.8 - 7.4
Temperature (^{o}C)	18.0	16.1 - 19.8	20.0	18.6 - 21.8
Turbidity (NTU)	13.1	6.4 - 24.4	3.8	0 - 8.6

4.3.3 Flow Data

The flow data for the organic chemical test phase is summarized in Table 4-11. The flow rate decreased sequentially from approximately 24 gpm on the first day to 21.5 gpm on the tenth day, and was as low as 20.7 gpm (a 15 to 16 percent decrease). The UF reject water volume and percentage increased from approximately 780 gal (9 percent) on the first day to approximately 1,150 gal (13 percent) on the tenth day.

Table 4-11. Organic Chemical Test Phase Flow Data Summary

Day	Influent (gal) MEFS Reading	Influent (gal) Control Reading[1]	Influent (gal) Variance (Percent)	Effluent (gal) MEFS Reading	Effluent (gal) Control Volume[2]	Effluent (gal) Variance (Percent)	UF Reject (Percent)	Mean Flow Rate[3] (gpm)
1	8,375	8,445	0.8	8,030	7,659	-4.8	9	24.2
2	8,453	8,972	5.8	8,057	8,192	1.6	9	23.3
3	8,506	8,550	0.5	8,136	7,816	-4.1	9	23.5
4	8,268	8,445	2.1	7,898	7,703	-2.5	9	23.8
5	8,585	8,603	0.2	7,925	7,758	-2.2	10	22.9
6	8,189	8,444	3.0	7,476	7,596	1.6	10	22.8
7	8,321	8,444	1.5	7,317	7,401	1.1	12	20.7
8	8,612	8,550	-0.7	7,370	7,390	0.3	14	21.4
9	8,374	8,497	1.4	7,476	7,379	-1.3	13	23.6
10	8,585	8,550	-0.4	7,951	7,402	-7.4	13	21.5
Totals	**84,268**	**85,500**	**1.4**	**77,636**	**76,296**	**-1.8**	**11**	**22.8**

[1] Influent control reading taken from the challenge water tank volume.
[2] Effluent control reading determined by subtracting the metered UF/RO reject volume from the influent control reading.
[3] Mean flow rate calculated by dividing the USS influent reading by test run duration (see daily monitoring logs in Appendix D).

4.3.4 Consumables and Residual Generation

Power and chemical consumption information for the organic chemical event test phase is summarized in Table 4-12. The power, muriatic acid, and 50 percent alum consumption rate remained fairly steady and constant throughout the ten-day testing period.

Residual generation for the organic chemical event test phase is summarized in Table 4-13. The residuals associated with this test phase were classified as hazardous, due to the use of methyl parathion, and carried the P071 (methyl parathion) hazardous waste code. The centrifuge solids and oil absorbent pads from this test were combined with the sludge and pads from the other tests and discarded. These residual materials were transported to a hazardous waste incinerator for destruction.

In addition to the centrifuge sludge, spent carbon, and oil absorbent pads, approximately 6,600 gallons of UF reject water were generated during the organic chemical event test phase. For the purposes of verification testing, this water was discharged to a sanitary sewer at the T&E Facility, in accordance with the facility-specific sanitary discharge permit. In a field setting, the UF reject water can be piped back to the influent storage tank and re-filtered, or discharged to a location separate from the treated effluent discharge location.

The residual material disposal arrangements were based on specific waste characteristics and applicable regulations, and may not be indicative of the disposal requirements in a field setting.

Table 4-12. Organic Chemical Event Phase Power and Chemical Consumption Summary

Day	Length of Run (hr)	Power Consumption (kWh)	Muriatic Acid (L)	50% Alum (L)
1	5.88	175	1.5	3
2	6.30	158	1.5	4
3	6.25	171	1.5	4
4	6.05	165	2	4
5	6.33	190	2	4
6	6.17	180	2	4
7	6.90	194	2	4
8	6.35	185	2	4
9	6.00	187	2	4
10	6.58	210	2	4

Table 4-13. Organic Chemical Test Phase Residual Generation Summary

Residual	When Generated	Quantity
Centrifuge sludge	Continuously	36 lb.
Oil absorbent pads	Daily	18 lb.
Spent carbon	End of test	2 55-gal drums

4.4 Biological Event—Chlorine Compound

As described in Section 3.5.3, sodium hypochlorite (bleach) was added to the synthetic wastewater during this test to produce wastewater having free and total chlorine concentrations of approximately 5,000 mg/L (Cl_2). These concentrations were achieved by adding between 300 and 473 gallons of commercial bleach containing 10 percent sodium hypochlorite. The active chlorine species is the hypochlorite ion (OCl^{--}), which was formed when chlorine bleach was dissolved in water. The concentration of active hypochlorite was approximately 2,500 mg/L as Cl, as stated in the VTP.

4.4.1 Treatment Processes

The treatment processes used for the biological event test phase targeted chlorine removal, and included the CRS (dechlorination), centrifuge, media filtration (sand and activated carbon), ultrafiltration, and reverse osmosis. Oil sorbent pillows were inserted in the influent water tank to remove hydrocarbons to prolong the effectiveness of the activated carbon. The vendor replaced the activated carbon in the media filter with fresh carbon prior to the biological event test. The Bayoxide E33 media filters were bypassed during this test.

The CRS was positioned before the USS influent pump. The suction head loss through the CRS reduced the influent feed pump capacity, resulting in a reduction of the flow rate. An auxiliary submersible pump in the stock feed tank was utilized to overcome the head loss in the CRS.

The biological event test phase began on December 20, 2003. The first day of testing was a startup/shakedown to resolve difficulties with the test equipment, pumps, etc. The CRS was optimized to ensure chemical feeds were operating properly. There were no samples collected or analyzed on December 20, but operational and flow data was recorded and are presented in this section. The first day of complete testing was December 21, 2003, and the last test day was January 6, 2004. Testing did not occur during the Christmas and New Year holidays. The result is ten days of analytical data and eleven days of operational and flow data. The MEFS did not require special shutdown or restart procedures during the holidays.

4.4.2 Analytical Data

During the biological event test phase, the TO collected effluent samples to be analyzed for free chlorine from the RO effluent, while the secondary and indicator parameters were collected from the UF and RO reject water. On one of the ten test days, a sample was also collected from the treated effluent and analyzed for most of the secondary parameters. Free and total chlorine samples were collected and analyzed twice daily, as specified in the VTP.

The free and total residual chlorine analytical data are summarized in Table 4-14. Free and total chlorine concentrations in the influent wastewater were virtually identical, which indicates there were no chloramines in the influent. The high concentration of chlorine added to the wastewater reacted with the low concentrations of ammonia and drove the chloramines past the breakpoint (breakpoint chlorination), resulting in only free chlorine in the wastewater.

Since there were no chloramines in the influent, chloramines were not expected in the effluent; the effluent samples were analyzed only for free chlorine. Free chlorine concentrations were below detection limits for 13 of the 20 samples, with the remaining seven samples ranging from 0.02 mg/L to 0.14 mg/L.

Table 4-14. Free and Total Chlorine Data Summary

Day	Influent Chlorine (mg/L as Cl_2) Total	Free	Effluent Chlorine (mg/L as Cl_2) Free	Free Chlorine Treatment Efficiency[1] (percent)
1	6,800	6,600	0.05	>99.999
	6,300	6,500	<0.02	>99.999
2	6,300	5,800	0.14	>99.999
	6,300	6,400	<0.02	>99.999
3	5,900	5,900	0.04	>99.999
	6,000	5,700	<0.02	>99.999
4	6,500	6,500	<0.02	>99.999
	6,700	6,700	<0.02	>99.999
5	5,700	6,000	0.04	>99.999
	6,200	6,000	<0.02	>99.999
6	6,700	6,600	0.02	>99.999
	6,000	6,000	<0.02	>99.999
7	5,600	5,700	<0.02	>99.999
	4,900	5,200	<0.02	>99.999
8	4,100	4,100	<0.02	>99.999
	4,400	4,000	<0.02	>99.999
9	4,000	4,100	0.03	>99.999
	3,700	3,600	0.02	>99.999
10	4,000	4,000	<0.02	>99.999
	3,900	3,900	<0.02	>99.999
Mean	**5,500**	**5,500**	**0.02**	**>99.999**

[1] One-half of the method detection limit was used to calculate mean efficiency for analytical results below detection limits.

The secondary parameters (sampled from the RO/UF reject water) are summarized in Table 4-15. The analytical laboratory reported difficulty with analyzing the BOD_5 and COD in the sterile (influent) and oxidized (effluent) samples. The BOD_5 and COD data were flagged due to these analytical problems and are not considered to be a reliable performance indicator. Alkalinity concentrations in the influent were higher than observed during the other two test phases, due to the sodium hydroxide in the bleach, and treatment by the MEFS significantly reduced alkalinity concentrations. MBAS and TKN concentrations showed an increase, though the influent and effluent concentrations for both parameters were low.

Table 4-15. Biological Test Phase Secondary Parameter Analytical Data Summary

Parameter	Units	Influent Mean	Influent Range	Effluent Mean	Effluent Range	Mean Efficiency[1] (percent)
Alkalinity	mg/L	4,200	2,900 - 5,200	220	130 - 290	95
BOD_5[2]	mg/L	120	<2.0 - 380	36	<2.0 - 200	69
COD[2]	mg/L	24	5 - 140	680	100 - 970	-2,800
MBAS	mg/L	0.58	<0.20 - 1.8	0.77	<0.2 - 1.7	-33
Ammonia	mg/L as N	0.19	0.061 - 0.56	0.13	<0.04 - 0.35	33
O&G	mg/L	10	<5.0 - 33	<5.0	<5.0 - 5.2	72
TKN	mg/L as N	0.79	0.49 - 1.3	1.7	1.2 - 2.4	-110
Phosphorus	mg/L as P	0.52	0.18 - 0.86	0.21	<0.10 - 0.4	61
TSS	mg/L	23	<4.0 - 55	11	5.0 - 23	52

[1] One-half of the method detection limit is used to calculate values below detection limits.
[2] BOD_5 and COD samples during the biological event test phase appear to be greatly influenced by matrix interferences and are not considered a reliable indication of performance of the MEFS.

On December 23, 2003, one effluent sample of water treated by the RO unit was analyzed for secondary parameters except MBAS and BOD_5. Samples for MBAS and BOD_5 were not collected because the analytical laboratory would not have been able to analyze the samples within the hold time due to the Christmas holiday. The results are summarized in Table 4-16.

Table 4-16. Effluent Analytical Results—December 23, 2003

Parameter	Units	RO/UF Reject	Treated Effluent
Alkalinity	mg/L	290	26.2
COD	mg/L	101	<10
Ammonia	mg/L as N	0.072	<0.04
O&G	mg/L	<5.0	<5.0
TKN	mg/L as N	1.6	0.32
Phosphorus	mg/L as P	<0.1	<0.1
TSS	mg/L	5.0	6.0

Based on this sample, the RO membrane further reduced the alkalinity, COD, ammonia, and TKN concentrations in the wastewater. Oil & grease and phosphorous concentrations were below detection limits for both the RO/UF reject and treated effluent, while TSS showed a slight increase, though both concentrations were close to the method detection limit (4.0 mg/L).

The indicator parameters are summarized in Table 4-17.

Table 4-17. Biological Test Phase Indicator Parameter Data Summary

	Influent		Effluent	
Parameter	**Median**	**Range**	**Median**	**Range**
pH (S.U.)	9.3	8.8 - 9.7	7.8	5.4 - 8.4
Temperature (^{o}C)	17.5	15.0 - 19.7	23.3	20.8 - 27.3
Turbidity (NTU)	43.1	0 - 68.8	6.8	0 - 23.6

There was some increased variability in the turbidity data, but for all tests the data shows that the MEFS reduced the mean turbidity by approximately 84 percent. The influent pH, effluent temperature, and turbidity values were slightly higher during the chlorine test as compared to the arsenic and methyl parathion tests. This is because bleach has a relatively high pH, the dechlorination chemical reaction is exothermic, and the chlorine wastewater was more turbid.

4.4.3 Flow Data

The flow data for the biological event test phase are summarized in Table 4-18. The UF/RO reject water rate varied between 53 and 73 percent, due in part to the RO system rejecting salts generated from the CRS process. The difference between the USS totalizer and the influent drawn from the tank ranged from –0.7 to 1.5 percent. At the end of the last day, there was a 0.1 percent deviation between the two values. The effluent totalizer showed a wide variance with the control volume from day to day (-24.1 to 4.0 percent), but a relatively small deviation over the course of the 11-day period (-2.7 percent). The average daily flow rate remained steady throughout the test period, ranging from 23.1 gpm to 24.6 gpm.

4.4.4 Consumables and Residual Generation

Power and chemical consumption information for the biological event test phase is summarized in Table 4-19.

The power consumption increased slightly, as compared to the other two test phases, due likely to the additional pumps utilized to operate the Captor and RO systems. As stated in Section 4.1.1, the influent feed pump was not used during this test phase. The submersible pump used to pump water to the MEFS was not connected to the power consumption meter.

Captor (calcium thiosulfate) was used to dechlorinate the wastewater, while sodium hydroxide was used to keep the pH high (around 10) so that calcium thiosulfate would react efficiently. Perma Clean 77 was used to clean the membranes in the UF and RO units. Three liters of muriatic acid were used on the eighth day of testing to descale the MEFS.

Table 4-18. Biological Event Test Phase Flow Data Summary

	Influent (gal)			Effluent (gal)			UF/RO	Mean
Day	MEFS Totalizer	Control Volume[1]	Variance (percent)	MEFS Totalizer	Control Volume[2]	Variance (percent)	Reject (percent)	Flow Rate[3] (gpm)
1	8,215	8,339	1.5	3,804	3,946	3.6	53	23.4
2	8,295	8,367	0.9	3,329	3,252	-2.4	61	23.4
3	8,269	8,367	1.2	2,800	2,918	4.0	65	24.2
4	8,321	8,339	0.2	2,668	2,150	-24.1	74	24.1
5	8,400	8,444	0.5	3,170	3,234	2.0	62	24.1
6	8,480	8,444	-0.4	2,827	2,763	-2.3	67	23.1
7	8,506	8,444	-0.7	2,351	2,291	-2.6	73	24.3
8	8,374	8,367	-0.1	2,694	2,668	-1.0	68	24.6
9	8,321	8,339	0.2	3,275	3,318	1.3	60	24.4
10	8,400	8,339	-0.7	3,090	3,052	-1.2	63	24.5
11	8,427	8,339	-1.1	3,275	3,055	-7.2	63	24.3
Totals	**92,007**	**92,128**	**0.1**	**33,283**	**32,647**	**-2.7**	**65**	**24.1**

[1] Influent control reading taken from the challenge water tank volume.
[2] Effluent control reading determined by subtracting the metered UF/RO reject volume from the influent control reading.
[3] Mean flow rate calculated by dividing the USS influent reading by test run duration (see daily monitoring logs in Appendix D).

Table 4-19. Biological Event Phase Power and Chemical Consumption Summary

Day	Length of Run (hr)	Power Consumption (kWh)[1]	CRS Agent (gal)	Sodium Hydroxide (L)	Perma Clean 77 (L)	Muriatic Acid (L)
1	6.30	182	119	90	0	0
2	5.82	171	137	70	0	0
3	5.77	203	120	65	0	0
4	5.77	218	120	60	2	0
5	5.83	210	160	60	0	0
6	6.10	218	120	60	0	0
7	5.78	221	130	60	4	0
8	5.67	194	125	50	0	3
9	5.67	195	100	37	0	0
10	6.37	214	98	34	0	0
11	5.72	197	88	34	0	0

[1] The power consumption from the submersible pump was not measured.

Residual generation information for the biological event test phase is summarized in Table 4-20.

Table 4-20. Biological Event Phase Power and Chemical Consumption Summary

Waste Item	When Generated	Quantity
Centrifuge sludge	Continuously	70 lbs.
Oil absorbent pads	Daily	16 lbs.
Spent carbon	End of test	Two 55-gal drums

In addition to the centrifuge sludge, spent carbon, and oil absorbent pads, approximately 58,700 gallons of UF and RO reject water was generated during the biological event test phase. For the purposes of verification testing, this water was discharged to a sanitary sewer at the T&E Facility, in accordance with the facility-specific sanitary discharge permit. In a field setting, the UF/RO reject water can be piped back to the influent storage tank and re-filtered, or discharged to a location separate from the treated effluent discharge location.

The residual material disposal arrangements were based on specific waste characteristics and applicable regulations, and may not be indicative of the disposal requirements in a field setting.

4.5 Additional Test Not Specified in the VTP

As noted in Section 3.10, a pressure decay integrity test was conducted on the RO unit before and after the biological event challenge. The objectives of the pressure decay test for the ETV testing were twofold:

1. To determine the integrity of the RO system by calculating the log reduction value for a particle size that a typical RO unit should reject.

2. To determine the impact, if any, the chlorinated wastewater from the biological event test phase has on the RO system.

The test followed the procedures outlined in the American Society for Testing and Materials (ASTM) Designation D 6908-03, *Standard Practice for Integrity Testing of Water Filtration Membrane Systems, Practice A—Pressure Decay and Vacuum Decay Tests.* This test provides a determination of the minimum equivalent diameter of a potential defect in the membrane or a seal that could allow water and particulates to pass through the system untreated. According to the ASTM procedure, this pressure decay test should detect defects larger than 1 to 2 µm. The test procedure also calculates the log reduction value for a particle the size of the smallest equivalent diameter.

The tests were conducted before the first day and after the last day of the biological event test. The testing procedure utilized for the MEFS followed the ASTM test procedure. The RO system was temporarily operated with clean water at its normal operating pressure. It was drained of liquid on the upstream or influent side of the membrane, and the downstream or effluent side of the RO system was opened so that the downstream pressure was equal to the atmospheric pressure. The upstream side was then pressurized with compressed air to pre-determined test pressures, and the pressure decay on the upstream side was monitored over time. A variety of recordings, including test pressures, time, test water and ambient air temperature, and atmospheric pressure were recorded and used in calculations to identify potential defects in the RO system greater than or equal to the minimum equivalent diameter.

Working with USS personnel, the TO conducted the tests using four different test pressures in the following order: 10, 15, 20, and 30 pounds per square inch (psi). The lower pressure tests were conducted first to ensure that the test did not damage the RO system. The higher test pressure produces a lower equivalent defect diameter, so the higher test pressure was used as the basis for calculating the smallest possible defects.

The data were calculated using the test conducted at the highest pressure (30 psi). The results from the first test day would provide an estimate of the equivalent defect diameter and log reduction value. Comparing the log reduction value results from the first and second test days identifies a defect caused by operating the RO system during the biological event test phase. The testing results are summarized in Table 4-21.

Table 4-21. RO System Pressure Decay Test Summary

Test Date	Minimum Defect Diameter (µm)	Log Reduction Value
12/19/03	1.4	3.7
1/6/04	1.4	3.7

The test pressure data set on the first test day indicates that the RO system was capable of creating a $10^{-3.7}$ reduction in particles with a diameter conservatively estimated at 1.4 µm during both tests. This would indicate that the RO system was not adversely affected by the wastewater treated during the biological event test phase.

4.5.1 Installation and Operation & Maintenance Findings

The MEFS required little set up once it was brought to the test site, and there were no performance issues noted with the system during any point of testing. The equipment, piping, and wiring inside the MEFS were well organized. The wastewater treatment equipment, auxiliary tanks, and PLC components were indelibly labeled, as were the pipes, valves, and fittings. The treatment components could be visually monitored by operating personnel, although there was not a great deal of free space within the MEFS.

The MEFS's flow rate did not achieve its rated capacity of 26 gpm (100 Lpm); the average daily flow rates for the three test phases ranged from 21 to 24 gpm. There were two situations encountered that resulted in moderate flow rate reductions. The first was at the beginning of the inorganic chemical test phase, when the centrifuge was bypassed, flow rates dropped to 16 to 18 gpm. The second was toward the end of the organic chemical test phase, when flow rates dropped to 21 to 23 gpm. During both tests, the likely cause of the decrease in flow rate was an increase of sediment being treated by the media filters or UF system.

The ultrafiltration and reverse osmosis treatment systems generated reject water at varying volumes. The UF system was used during the inorganic and organic chemical event test phases, and with UF and RO were used during the biological event test phase. The UF system rejected water at a rate ranging from 6 to 16 percent of the influent flow during the inorganic and organic chemical event test phases. During the biological event test phase, the combined UF and RO reject rate increased to 53 to 74 percent of the influent flow.

Power use by the MEFS ranged from approximately 113 to 221 kWh of electricity during the three test phases, which lasted from approximately 5.67 to 9.3 hours. According to the vendor, the MEFS is typically equipped with a diesel-powered electric generator, but USS removed it for this test because it was not practical to run a generator inside the enclosed building where the testing was conducted. The system power requirement is non-standard for North American use and a frequency converter and transformer was necessary for this installation.

The CRS was used only for the biological event test phase. The MEFS used approximately 90 to 160 gallons of neutralizing agent to treat a volume of wastewater of approximately 8,400 gallons having free and total chlorine concentrations of approximately 5,500 mg/L (as Cl_2). Aside from the CRS neutralizing agent, the MEFS used sodium hydroxide, muriatic acid, flocculants, and defouling chemicals to treat wastewater.

The MEFS generated residuals consisting of centrifuge solids, used oil absorbent pads, spent activated carbon, and reject water from the RO and UF units. Disposal arrangements made for the residual materials were based on characterizations performed on the materials

USS supplied three operators to run the system during testing, though the system could, and often was, controlled by two operators. The MEFS required minimal maintenance during testing. Maintenance consisted primarily of filling treatment chemical containers, replacing filter pads or activated carbon, and daily backwashing of the media filters. Backwashing consisted of running clean water through the treatment processes in the opposite direction and through the clean-in-place loop, then running the rinseate water back through the treatment processes before discharging it through the effluent discharge pipe. This procedure took approximately 30 minutes, and was conducted after the end of each day of testing.

The CRS was positioned before the USS influent pump. The suction head loss through the CRS reduced the influent feed pump capacity, resulting in a reduction of the flow rate. An auxiliary submersible pump in the stock feed tank was used to overcome head loss in the CRS.

The treatment system did not have a pH and oxidization/reduction potential (ORP) meter in the CRS outlet to monitor completion of the chemical reaction in the CRS. The reaction of calcium thiosulfate and bleach could generate chlorine gas and hydrogen sulfide at very low pH levels. Therefore, it is important that the system include adequate means of monitoring pH and ORP to maintain the correct chemical feed rates for adequate hypochlorite reaction without generating toxic gases.

Chapter 5
Quality Assurance/Quality Control

The VTP established the quality assurance/quality control (QA/QC) program to be used during verification testing to ensure that data and procedures are of measurable quality and support the quality objectives for this verification test. This plan was tailored to this specific VTP and requirements for verification of the USS in this application. The plan was developed with guidance from the EPA's "Guidance for Quality Assurance Project Plans" and "Guidance for the Data Quality Objectives Process." Verification test procedures and data collection followed the QAPP, and a summary of the results are reported in this section. The full laboratory QA/QC results and supporting documentation are presented in Appendix C.

5.1 Audits

Prior to the commencement of testing, the VO conducted audits of the laboratories responsible for analysis of samples collected during the testing program. Severn Trent Laboratory (STL) in North Canton, Ohio, analyzed the methyl parathion samples. The STL laboratory in Buffalo, New York, analyzed all remaining analytical laboratory parameters. The TO analyzed samples for the indicator parameters, and conducted the free and total chlorine analyses. The VO also conducted two audits on the TO; first during equipment setup, and second during testing.

The audits found that the field and laboratory procedures were followed, and that the overall approaches being used were in accordance with the established QAPP. Recommendations for changes or improvements were made, and the responsible parties responded quickly to the recommendations.

5.2 Verification Test Data – Data Quality Indicators (DQI)

Several DQIs had been identified as key factors in assessing the quality of the data and in supporting the verification process. These indicators were:

- Precision
- Accuracy
- Representativeness
- Comparability
- Completeness

In the following sections, a description of each DQI is presented, along with a statistical verification of the performance measurement for each quantitative DQI for precision and accuracy.

5.2.1 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. Analytical precision is a measurement of how far an individual measurement may deviate from a mean of replicate measurements. Precision is determined from analysis of field and laboratory duplicates and spiked duplicates. The standard deviation, relative standard deviation and/or relative percent difference (RPD) recorded from sample analyses are methods used to quantify precision. Relative percent difference is calculated by the following formula:

$$\text{RPD} = \frac{|C_1 - C_2|}{\overline{C}} \times 100\% \tag{5-1}$$

Where:
C_1 = Concentration of the compound or element in the sample.
C_2 = Concentration of the compound or element in the duplicate.
$\overline{C}$ = Mean of samples.

Field duplicates of both influent and effluent samples were collected at a frequency of one duplicate for every ten influent and effluent samples collected. The laboratory ran duplicate samples as part of the laboratory QA program. Duplicates were analyzed on a frequency of one duplicate for every ten samples analyzed. The laboratory also performed matrix spike/matrix spike duplicates (MS/MSD) for certain analytical parameters. The data quality objective for precision is based on the type of analysis performed. The analytical precision based on MS/MSD is summarized in Table 5-1, while analytical precision based on laboratory duplicates is presented in Table 5-2.

Table 5-1. Analytical Precision Based on MS/MSD Recovery

Parameter	No. of Samples	Percent Recovery				Percent RPD			
		Mean	Max	Min	Std. Dev.	Mean	Max	Min	Std. Dev.
Arsenic	4	136	178	102	38.41	6.9	11.9	1.9	7.0
BOD_5	4	46	97	0	53.27	5.4	10.9	0	7.7
COD	2	140	148	131	12.02	12.2	12.2	12.2	0
MBAS	2	34	34	34	0.00	0	0	0	0
O&G	25	91	118	80	9.62	9.8	33.7	0	9.8
Alkalinity	2	98	98	98	0.00	0	0	0	0

Table 5-2. Analytical Precision Based on Field Duplicates

Parameter	No. of Samples	Percent RPD Mean	Max	Min	Std. Dev.
Ammonia	3	58.18	172.71	0.00	99.19
Arsenic	2	2.42	2.53	2.30	0.16
BOD_5	5	23.12	89.16	1.75	37.23
COD	6	145.97	529.00	15.40	192.15
MBAS	5	18.84	58.06	0.00	23.27
O&G	6	11.82	44.73	0.00	18.45
Alkalinity	6	1.38	5.48	0.00	2.13
TKN	3	9.71	14.29	5.76	4.30
Total phosphorous	3	32.49	88.89	3.17	48.86
TSS	6	30.93	115.79	0.00	43.35
Methyl parathion	2	12.65	17.89	7.41	7.41
Total chlorine[1]	1	1.68	NA	NA	NA
Free chlorine	2	33.33	66.67	0.00	47.14

[1] Precision for total chlorine was based on a single set of samples. The RPD value for total chlorine is expressed in the "Mean" column, and the other statistics are not applicable (NA).

As can be seen from this data, field duplicates showed a much higher degree of variability for all general water quality parameters, and much lower variability for the key parameters of arsenic, methyl parathion, and chlorine.

5.2.2 Accuracy

Accuracy is defined for water quality analyses as the difference between the measured or calculated sample value and the true value of the sample. Spiking a sample matrix with a known amount of constituent and measuring the recovery obtained in the analysis is a method of determining accuracy. Using laboratory performance samples with a known concentration in a specific matrix can also monitor the accuracy of an analytical method for measuring a constituent in a given matrix. Accuracy is usually expressed as the percent recovery of a compound from a sample. The following equation will be used to calculate percent recovery:

$$\text{Percent Recovery} = [(A_T - A_i) / A_s] \times 100\% \qquad (5\text{-}2)$$

Where:
A_T = Total amount measured in the spiked sample.
A_i = Amount measured in the un-spiked sample.
A_s = Spiked amount added to the sample.

During verification testing, the laboratory ran matrix spike samples at a frequency of one spiked sample for every ten samples analyzed. The laboratory also analyzed liquid and solid samples of known concentration as lab control samples. Laboratory control samples are summarized in Table 5-3.

Table 5-3. Accuracy Results – Laboratory Control Samples

Parameter	No. of Samples	Percent RPD Mean	Max	Min	Std. Dev.	QC Limit
Ammonia	9	101	106	90	5.50	90-110
BOD_5	24	99	120	83	9.77	85-115
COD	17	99	120	83	8.68	90-110
MBAS	12	105	132	96	9.35	90-110
n-hexane extractable material[1]	1	96	NA	NA	NA	78-114
Alkalinity	14	102	108	95	3.84	90-110
TKN	14	102	108	95	3.84	90-110
Total phosphorus	11	99	108	92	4.58	90-110
TSS	12	99	100	96	1.30	88-110
Arsenic	9	101	103	98	1.92	85-115

[1] Accuracy for n-hexane extractable material was based on a single set of samples. The RPD value for total chlorine is expressed in the "Mean" column, and the other statistics are not applicable (NA).

5.2.3 Completeness

Completeness is a measure of the number of valid samples and measurements that are obtained during a test period. Completeness will be measured by tracking the number of valid data results against the specified requirements of the test plan.

Completeness will be calculated by the following equation:

$$\text{Percent Completeness} = (V / T) \times 100\% \qquad (5\text{-}3)$$

Where:

V = Number of measurements that are valid.
T = Total number of measurements planned in the test.

The goal for this data quality objective was to achieve minimum 80 percent completeness for samples scheduled in the test plan. The primary indicator parameters evaluated in this test program were arsenic, methyl parathion, and chlorine. For each of these parameters, there were no rejected results, resulting in a completeness of 100 percent.

The BOD_5 and COD results for the biological event test, while acceptable for analytical accuracy, were not used in the evaluation of verification testing because of analytical problems associated with performing these tests on a sample that had been sterilized and oxidized by bleach.

No results were rejected for any of the other sampling parameters; however, detailed QA/QC examination of the data revealed the following issues:

BOD

- Sample USETV-E-120401 and USETV-E-12041 field duplicates were initially analyzed within the analytical holding time for BOD; however all of the QC failed low. The results could not be quantified accurately. The sample was reanalyzed outside of holding time and exhibited compliant results .

- Sample USETV-E-120201 was initially analyzed within the analytical holding time for BOD, however the oxygen was insufficiently depleted. The results could not be accurately quantified. The sample was reanalyzed outside of holding time and exhibited compliant results. One surrounding continuing calibration verification was low, but the batch QC was compliant.

- Sample USETV-E-120501 was initially analyzed within the holding time for BOD, however the oxygen was insufficiently depleted. The results could not be quantified accurately. The sample was reanalyzed outside of holding time and exhibited compliant results.

- USETV-I-010401, USETV-E-010401, USETV-I-010301, and USETV-E-010301 were analyzed outside their hold time.

COD

- The recovery of sample USETV-I-12030 matrix spike duplicate exhibited results above the quality control limits for COD. However, the laboratory control sample was acceptable.

- The recovery of sample USETV-E-112501 matrix spike exhibited results above the quality control limits for COD. The recovery of sample USETV-E-112501 matrix spike duplicate exhibited results above the quality control for COD. However, the laboratory control sample was acceptable.

TKN

- The recovery of sample USETV-I-120301 matrix spike exhibited results below the quality control limits for TKN. The recovery of sample USETV-I-120301 matrix spike duplicate exhibited results below the quality control limits for TKN. However, the laboratory control sample was acceptable.

TSS

- Initial TSS results for samples USETV-I-120801, USETV-I-120802, and USETV-E-120801 were incorrectly reported by the laboratory, due to a manual data entry error. The laboratory subsequently revised the data report, and the corrected results were used in the verification report.

MBAS

- The recovery of sample USETV-I-120303 matrix spike exhibited results below the quality control limits for MBAS. The recovery of sample USETV-I-120303 matrix spike duplicate exhibited results below the quality control limits for MBAS. However, the laboratory control sample was acceptable.

- Samples USETV-I-122001 and USETV-E-122001 were originally analyzed for MBAS within the required holding time, however, the QC failed high. Reanalysis was performed outside holding time and the values obtained confirmed that the high QC did not bias the results high.

- The recovery of sample USETV-E-11250 matrix spike exhibited results below the quality control limits for MBAS. The recovery of sample USETV-E-11250 matrix spike duplicate exhibited results below the quality control limits for MBAS. However, the laboratory control sample was acceptable.

- Samples USETV-I-010301 and USETV-E-010301 were analyzed outside their hold time.

These issues are appropriately flagged in the analytical reports and the data used in the final evaluation of the MEFS.

References

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5. United States Environmental Protection Agency: *Methods and Guidance for Analysis of Water*, EPA 821-C-99-008, 1999. Office of Water, Washington, DC.

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9. United States Environmental Protection Agency: *USEPA Guidance for Quality Assurance Project Plans, USEPA QA/G-5*, USEPA/600/R-98-018, 1998. Office of Research and Development, Washington, DC.

10. United States Environmental Protection Agency, *Guidance for the Data Quality Objectives Process, USEPA QA/G-4*, USEPA/600/R-96-055, 1996. Office of Research and Development, Washington.

Glossary of Terms

Accuracy - a measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction.

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a qualitative term that expresses confidence that all necessary data have been included.

Precision - a measure of the agreement between replicate measurements of the same property made under similar conditions.

Quality Assurance Project Plan – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project.

Residuals – the waste streams, excluding final effluent, which are retained by or discharged from the technology.

Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point, a process condition, or environmental condition.

Standard Operating Procedure – a written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained.

Technology Panel - a group of individuals with expertise and knowledge of wastewater treatment and homeland security issues.

Testing Organization – an organization qualified by the Verification Organization to conduct studies and testing of technologies in accordance with protocols and test plans.

Vendor – a business that assembles or sells wastewater treatment equipment.

Verification – to establish evidence on the performance of in drain treatment technologies under specific conditions, following a predetermined study protocol(s) and test plan(s).

Verification Organization – an organization qualified by EPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

Verification Report – a written document containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results. The Test Plan(s) shall be included as part of this document.

Verification Statement – a document that summarizes the Verification Report reviewed and approved by USEPA.

Verification Test Plan – A written document prepared to describe the procedures for conducting a test or study according to the verification protocol requirements for the application of treatment technology. At a minimum, the Test Plan shall include detailed instructions for sample and data collection, sample handling and preservation, precision, accuracy, goals, and quality assurance and quality control requirements relevant to the technology and application.

Appendices