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Environmental Technology Verification Report

Removal of Chemical Contaminants in Drinking Water

Kinetico Incorporated
Pall/Kinetico Purefecta™ Drinking Water Treatment 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:	**POINT-OF-USE DRINKING WATER TREATMENT SYSTEM**	
APPLICATION:	**REMOVAL OF CHEMICAL CONTAMINANTS IN DRINKING WATER**	
PRODUCT NAME:	**PALL/KINETICO PUREFECTA™**	
COMPANY:	**KINETICO INCORPORATED**	
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NSF International (NSF) manages the Drinking Water Systems (DWS) Center under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The DWS Center recently evaluated the performance of the Pall/Kinetico Purefecta™ point-of-use (POU) drinking water treatment system. NSF performed all of the testing activities, and also authored the verification report and this verification statement. The verification report contains a comprehensive description of the test.

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.

ABSTRACT

The Pall/Kinetico Purefecta™ POU drinking water treatment system was tested for removal of aldicarb, benzene, cadmium, carbofuran, cesium, chloroform, dichlorvos, dicrotophos, fenamiphos, mercury, mevinphos, oxamyl, strontium, and strychnine. The Purefecta™ employs several components: a reverse osmosis (RO) membrane, carbon filters, and a bacteria/virus removal filter to treat drinking water. Treated water is stored in a three-gallon storage tank. The system was first tested with only the RO membrane component in place. The target challenge concentration of each chemical for each RO membrane test was 1 mg/L. Following the RO membrane challenges, the post-membrane carbon filter component was challenged alone with each chemical that the RO membrane did not remove to below 10 μg/L, except for cesium, which is not well removed by carbon. The target feed concentration of each chemical to a carbon filter component was the maximum effluent level measured during the RO membrane tests.

A total of 20 RO membrane components were tested, divided into ten pairs. Each pair of membranes was tested with only one of the ten organic chemicals because of concern that a chemical could compromise the integrity of the membrane material or membrane seals. One pair of RO membrane components was also challenged with the inorganic chemicals. Each RO membrane chemical challenge was conducted over a one-day period. Influent and effluent samples were collected during the operation period, and also the next morning. Post-membrane carbon filter challenges were conducted over a 15-hour duration. Two filters were tested for each chemical challenge, and each pair was only used for one challenge. Influent and effluent samples were collected at the beginning, middle, and end of the challenge period.

The Purefecta™ system as a whole, considering both the RO membrane challenge and post-membrane carbon filter challenge results combined, reduced all of the challenge chemicals by 99% or more, except for cesium.

TECHNOLOGY DESCRIPTION

The following technology description was provided by the manufacturer, and has not been verified.

The Purefecta™ is a five-stage POU drinking water treatment system. It employs activated carbon filters and an RO membrane to remove chemical contaminants from drinking water, and a mechanical filtration "biofilter" to remove microorganisms. The system includes a three-gallon maximum capacity pressurized bladder tank for storing the treated water, and a faucet to mount on the kitchen sink. The biofilter is manufactured by the Pall Corporation and supplied to Kinetico, who manufactures the system.

The influent water first passes through a pre-membrane sediment or carbon filter, and then through the RO membrane. The permeate water travels through the first stage of the Pall biofilter for virus removal, and then into the storage tank. When the flow of water into the system is started, treated water will be continually produced until the storage tank is nearly full. At that time, the water pressure in the tank activates an automatic shut-off device, stopping the flow of water through the system. After a portion of the water is dispensed from the storage tank, the shut-off device deactivates, allowing water to again flow into the system until the storage tank is nearly full. When the user opens the faucet, the partially treated water exits the storage tank, passes through the post-membrane carbon filter, and finally through the bacteria removal portion of the Pall biofilter. The Purefecta™ is designed to produce approximately four gallons of reject water for every gallon of treated water.

VERIFICATION TESTING DESCRIPTION

Test Site

The testing site was the Drinking Water Treatment Systems Laboratory at NSF in Ann Arbor, Michigan. A description of the test apparatus can be found in the test/QA plan and verification report. The testing was conducted August through November of 2004.

Methods and Procedures

Verification testing followed the procedures and methods detailed in the *Test/QA Plan for Verification Testing of the Pall/Kinetico Purefecta™ Point-of-Use Drinking Water Treatment System for Removal of Chemical Contamination Agents.* Because any contamination event would likely be short-lived, the challenge period for each chemical lasted only one day. Long-term performance over the life of the membrane was not investigated.

The system was first tested with only the RO membrane component in place. The complete Purefecta™ system, including the storage tank, was used for these tests, but empty cartridges were used in place of the carbon and bacteria/virus filters. A total of 20 RO membranes were challenged with the chemicals in Table 1. The target challenge concentration for each chemical was 1 mg/L. The 20 RO membrane components were divided into ten pairs. Each pair was tested with only one of the ten organic chemicals because of concern that a chemical, especially benzene or chloroform, could compromise the integrity of the membrane material or membrane seals. One pair of the RO membrane components was also challenged with the inorganic chemicals. The inorganic chemical challenges were conducted prior to the organic challenges to eliminate the possibility of damage to the membranes that could bias the inorganic chemical challenge results. Reduction of total dissolved solids (TDS) was also measured to evaluate whether any organic chemicals damaged the membrane material or membrane seals during the challenges.

Table 1. Challenge Chemicals

Organic Chemicals	Inorganic Chemicals
Aldicarb	Cadmium Chloride
Benzene	Cesium Chloride (nonradioactive isotope)
Carbofuran	Mercuric Chloride
Chloroform	Strontium Chloride (nonradioactive isotope)
Dicrotophos	
Dichlorvos	
Fenamiphos	
Mevinphos	
Oxamyl	
Strychnine	

Prior to chemical challenge testing, the RO membrane components were service-conditioned for seven days by feeding the systems test water without any chemical spikes. After completion of the conditioning period, the membranes were subjected to a TDS reduction test using sodium chloride to verify that they were operating properly. Each RO membrane chemical challenge was conducted over a one-day period.

The systems were operated for six tank-fill periods, and then were allowed to rest overnight. Influent and effluent samples were collected at start-up, after the 3rd tank fill, after the 5th tank fill, and the next morning after the membranes rested under pressure overnight.

Following the RO membrane challenges, post-membrane carbon filters were challenged with the chemicals that the RO membrane did not remove to below 10 μg/L, except for cesium, which is not well removed by carbon. The carbon filters were attached to a separate manifold that was of the same design as the manifold in the full system. The pre-membrane carbon filter was not tested because it is only designed to remove chlorine to protect the RO membrane. Two carbon filter components were tested for each chemical challenge, and each filter was only used for one challenge. The target challenge concentrations were the maximum effluent levels measured during the RO membrane tests.

Prior to testing, each carbon filter was service-conditioned by feeding water containing chloroform to simulate the potential chemical loading on the carbon halfway through the filter's effective lifespan. The target chloroform concentration was 300 ± 90 μg/L, which is the influent challenge concentration for the VOC reduction test in NSF/ANSI Standard 53 (chloroform is the surrogate challenge chemical for the test). The filters were operated at a flow rate of 0.5 gallons per minute (gpm) for 250 gallons (Kinetico's design capacity for the filter is 500 gallons).

The post-membrane carbon filter challenges were 15 hours in duration. Influent and effluent samples were collected at the beginning, middle, and end of the challenge period. The carbon filters were operated on an "on/off" operation cycle where the "on" portion was the time required to empty the system storage tank when full, and the "off" portion was the time required to fill the storage tank.

VERIFICATION OF PERFORMANCE

The results of the RO membrane challenges are presented in Table 2. The RO membrane treatment process removed 96% or more of all challenge chemicals except mercury and chloroform. The TDS reduction by each membrane component for all challenge tests was 94% or higher, and the TDS levels in the treated water samples did not increase through any of the challenge periods. This indicates that none of the chemicals compromised the performance of the membrane components to a degree that could be detected.

Table 2. RO Membrane Challenge Data

Chemical	Mean Influent (μg/L)	Mean Effluent (μg/L)	Percent Reduction (%)
Cadmium	1000	1.9	>99
Cesium	1000	40	96
Mercury	1100	680	38
Strontium	850	2	99
Aldicarb	950	7	>99
Benzene	1100	48	96
Carbofuran	950	6	>99
Chloroform	1100	170	85
Dichlorvos	1100	23	98
Dicrotophos	790	ND (10)	99
Fenamiphos	740	2	>99
Mevinphos	1400	19	99
Oxamyl	980	5	>99
Strychnine	1100	18	98

The post-membrane carbon filter components were challenged with mercury, benzene, chloroform, dichlorvos, mevinphos, and strychnine, based on the criteria that the RO membrane challenge effluents were above 10 µg/L. The target challenge levels were the maximum effluent levels measured during the RO membrane challenges. The carbon filters were operated at 0.8 gpm on an operation cycle where the "on" portion was four minutes and thirty seconds, and the "off" portion was one hour and ten minutes.

The carbon challenge results are shown below in Table 3. The carbon filters reduced all substances to non-detectible levels, except for mercury. However, the mean effluent value for mercury was only 2.7 µg/L, which still gives a percent reduction greater than 99%. Note that the percent reduction of strychnine was limited by the detection limit for the chemical.

The RO membrane and carbon challenge data combined shows that the two treatment technologies working in concert within the Purefecta™ system removed 99% or more of all of the challenge chemicals, except for cesium.

Complete descriptions of the verification testing results are included in the verification report.

Table 3. Post-Membrane Carbon Filter Challenge Data

Chemical	Mean Influent (µg/L)	Mean Effluent (µg/L)	Percent Reduction (%)
Mercury	960	2.7	> 99
Benzene	83	ND (0.5)	> 99
Chloroform	320	ND (0.5)	> 99
Dichlorvos	29	ND (0.2)	> 99
Mevinphos	20	ND (0.2)	99
Strychnine	31	ND (5)	84

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

NSF ETV and QA staff monitored the testing activities to ensure that the testing was in compliance with the test plan. NSF also conducted a data quality audit of 100% of the data. Please see the verification report referenced below for more QA/QC information.

Original signed by Andrew Avel, 9/26/05
Andrew P. Avel Date
Acting Director
National Homeland Security Research Center
United States Environmental Protection Agency

Original signed by Robert Ferguson, 10/5/05
Robert Ferguson Date
Vice President
Water Systems
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 test protocol, the verification statement, and the verification report (NSF report # NSF 04/13b/EPADWCTR) are available from the following sources:
(NOTE: Not all of the appendices are included in the verification report. The appendices are available from NSF upon request.)

1. ETV Drinking Water Systems Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv/dws/dws_reports.html, and from
   http://www.nsf.org/etv/dws/dws_project_documents.html (electronic copy)
   EPA web site: http://www.epa.gov/etv (electronic copy)

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Kinetico Incorporated
Pall/Kinetico Purefecta^{TM} Drinking Water Treatment System

Prepared by:

NSF International
Ann Arbor, Michigan 48105

Under a cooperative agreement with the U.S. Environmental Protection Agency

Jeffrey Q. Adams, Project Officer
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

The U.S. Environmental Protection Agency (USEPA) through its Office of Research and Development has financially supported and collaborated with NSF International (NSF) under Cooperative Assistance Agreement No. R-82833301. This verification effort was supported by the Drinking Water Systems (DWS) Center, operating under the Environmental Technology Verification (ETV) Program. This document has been peer-reviewed, reviewed by NSF and USEPA, and recommended for public release.

Foreword

The U.S. Environmental Protection Agency (USEPA) 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, USEPA'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 USEPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

Table of Contents

Appendix

List of Tables

List of Figures

Abbreviations and Acronyms

ANSI	American National Standards Institute
°C	Degrees Celsius
DWS	Drinking Water Systems
ETV	Environmental Technology Verification
°F	Degrees Fahrenheit
GC/MS	Gas Chromatography/Mass Spectrometry
gpd	Gallons Per Day
gpm	Gallons Per Minute
HCl	Hydrochloric Acid
HPLC	High Pressure Liquid Chromatography
ICP/MS	Inductively Coupled Plasma – Mass Spectrometry
L	Liter
mg	Milligram
mL	Milliliter
NaOH	Sodium Hydroxide
ND	Non-detect
NRMRL	National Risk Management Research Laboratory
NSF	NSF International (formerly known as National Sanitation Foundation)
NTU	Nephelometric Turbidity Unit
POE	Point-of-Entry
POU	Point-of-Use
psi	Pounds per Square Inch
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance/Quality Control
RO	Reverse Osmosis
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SOP	Standard Operating Procedure
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
μg	Microgram
USEPA	U. S. Environmental Protection Agency

Acknowledgments

NSF was responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, data management, data interpretation and the preparation of this report.

The manufacturer of the equipment was:

Kinetico Incorporated
10845 Kinsman Road
Newbury, OH 44065

NSF wishes to thank the members of the expert technical panel for their assistance with development of the test plan.

Chapter 1
Introduction

1.1 Environmental Technology Verification (ETV) Program Purpose and Operation

The U.S. Environmental Protection Agency (USEPA) has 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; with 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, by conducting field or laboratory testing, collecting and analyzing data, and by 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.

The USEPA has partnered with NSF International (NSF) under the ETV Drinking Water Systems (DWS) Center to verify performance of drinking water treatment systems that benefit the public and small communities. It is important to note that verification of the equipment does not mean the equipment is "certified" by NSF or "accepted" by USEPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations under conditions specified in ETV protocols and test plans.

1.2 Purpose of Verification

The purpose of this verification was to evaluate treatment system performance under a simulated intentional or non-intentional chemical contamination event. Because any contamination event would likely be short-lived, the challenge period for each chemical lasted only one day. Long-term performance over the life of the membrane was not investigated.

1.3 Development of Test/Quality Assurance (QA) Plan

USEPA's "Water Security Research and Technical Support Action Plan" (USEPA, 2004) identifies the need to evaluate point-of-use (POU) and point-of-entry (POE) treatment system capabilities for removing likely contaminants from drinking water. As part of the ETV program, NSF developed a test/QA plan for evaluating POU reverse osmosis (RO) drinking water treatment systems for removal of chemical contaminants. To assist in this endeavor, NSF assembled an expert technical panel, which gave suggestions on a protocol design prior to development of the test/QA plan.

The product-specific test/QA plan for evaluating the Pall/Kinetico Purefecta™ was entitled *Test/QA Plan for Verification Testing of the Pall/Kinetico Purefecta™ Point-of-Use Drinking Water Treatment System for Removal of Chemical Contamination Agents.*

By participating in this ETV evaluation, the vendor obtains USEPA and NSF verified independent test data indicating potential user protection against intentional or non-intentional chemical contamination of drinking water. Verifications following an approved test/QA plan serve to notify the public of the possible level of protection against chemical contamination agents afforded to them by the use of a verified system.

1.4 Challenge Chemicals

The challenge chemicals for this verification are listed in Table 1-1.

Table 1-1. Challenge Chemicals

Organic Chemicals	Inorganic Chemicals
Aldicarb	Cadmium Chloride
Benzene	Cesium Chloride (nonradioactive isotope)
Carbofuran	Mercuric Chloride
Chloroform	Strontium Chloride (nonradioactive isotope)
Dicrotophos	
Dichlorvos	
Fenamiphos	
Mevinphos	
Oxamyl	
Strychnine	

1.5 Testing Participants and Responsibilities

The ETV testing of the Pall/Kinetico Purefecta™ was a cooperative effort between the following participants:

NSF
Kinetico, Inc.
USEPA

The following is a brief description of each of the ETV participants and their roles and responsibilities.

1.5.1 NSF International

NSF is a not-for-profit organization dedicated to public health and safety, and to protection of the environment. Founded in 1946 and located in Ann Arbor, Michigan, NSF has been instrumental in the development of consensus standards for the protection of public health and the environment. The USEPA partnered with NSF to verify the performance of drinking water treatment systems through the USEPA's ETV Program.

NSF performed all verification testing activities at its Ann Arbor location. NSF prepared the test/QA plan, performed all testing, managed, evaluated, interpreted, and reported on the data generated by the testing, and reported on the performance of the technology.

Contact Information:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
Phone: 734-769-8010
Fax: 734-769-0109
Contact: Bruce Bartley, ETV Program Manager
Email: bartley@nsf.org

1.5.2 Kinetico Inc.

The verified system is manufactured by Kinetico Inc., a manufacturer of water treatment products for home and business.

The manufacturer was responsible for supplying the RO systems in accordance with section 3.1.1, and for providing logistical and technical support as needed.

Contact Information:

Kinetico Inc.
10845 Kinsman Road
Newbury, OH 44065
Phone: 1-800-944-9283
Contact Person: Mr. Rod Yoder
Email: ryoder@kinetico.com

1.5.3 Pall Corporation

The Pall Corporation is a manufacturer of products for fluid filtration, separation, and purification. Pall manufactures and supplies to Kinetico the bacteria and virus removal filter component for the Purefecta™.

1.5.4 U.S. Environmental Protection Agency

The USEPA, through its Office of Research and Development, has financially supported and collaborated with NSF under Cooperative Agreement No. R-82833301. This verification effort was supported by the DWS Center operating under the ETV Program. This document has been peer-reviewed, reviewed by the USEPA, and recommended for public release.

Chapter 2
Equipment Description

2.1 Principal of Operation

2.1.1 RO Membrane

Membrane technologies are among the most versatile water treatment processes because of their ability to effectively remove a wide variety of contaminants. RO membranes operate by the principal of cross-flow filtration. In this process, the influent water flows over and parallel to the filter medium and exits the system as reject water. Under pressure, a portion of the water diffuses through the membrane becoming "permeate". The membrane allows water molecules to pass through its pores, but not most dissolved inorganic chemical molecules and larger molecular weight organic chemical molecules. These molecules are concentrated in and washed away with the reject water stream.

2.1.2 Activated Carbon Filtration

Activated carbon removes organic chemicals from water through the process of adsorption. The chemicals are attracted to and attach to the surface of the carbon through electrostatic interactions. The adsorbent properties of activated carbon are a function of the raw material used and the activation process. Once the carbon is saturated with adsorbed molecules, it must be replaced.

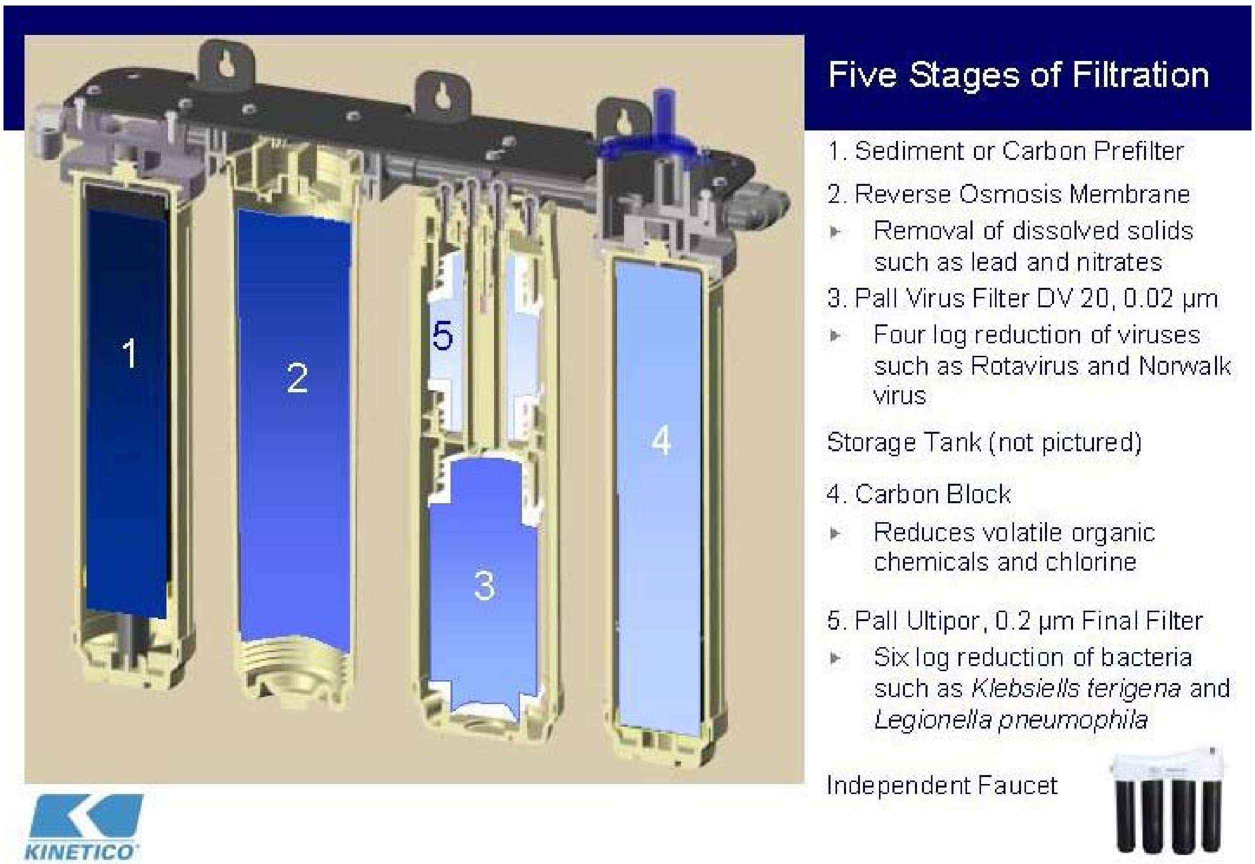
2.2 Equipment Capabilities

The Purefecta™ is certified by NSF to NSF/ANSI Standard 58 – *Reverse Osmosis Drinking Water Treatment Systems*. The system has a certified production rate of 19.8 gallons per day (gpd), and an efficiency rating of 25.9%. Efficiency rating as defined by Standard 58 is "a percentage measure of the amount of influent water that is delivered as permeate under a closed permeate discharge set of actual use conditions." These measurements are based on system operation at 50 pounds per square inch (psi) inlet pressure, a water temperature of 77 °F, and a total dissolved solids (TDS) level of 750 ± 40 mg/L. The amount and quality of treated water produced varies depending on the inlet pressure, water temperature, and level of TDS. These measurements were not subject to verification during this study.

2.3 System Components

The Purefecta™ is a five-stage POU treatment system. It uses activated carbon, an RO membrane, UF membranes, and optional sediment filtration to treat drinking water. The system also includes a three gallon maximum capacity storage tank, and a faucet to dispense the treated water. A cutaway diagram of the treatment components is shown in Figure 2-1, and a photograph of the full system is shown in Figure 2-2. The inlet water first passes through an activated carbon or sediment filter, and then through the RO membrane. The permeate water travels through the first stage of the Pall biofilter for virus removal. The partially treated water is then sent to the storage tank. When the user opens the faucet, the water exits the storage tank, passes through the post-membrane activated carbon filter, and then lastly through the bacteria removal portion of the Pall biofilter, before exiting the faucet. Please note that this description, and the system operation description in section 2.4 are given for informational purposes only. This information was not subject to verification.

Figure 2-1. Cutaway Schematic Diagram of Purefecta™ Treatment Elements



2.4 System Operation

When the flow of water into the system is started, treated water will be continually produced until the storage tank is nearly full. At that time, the water pressure in the tank causes an automatic shut-off device to activate, stopping the flow of water through the system. After approximately two-thirds of the water is dispensed from the storage tank, the shut-off device deactivates, allowing water to again flow into the system until the storage tank is nearly full. The operational storage tank capacity will vary slightly from unit to unit, and is also affected by the inlet water pressure, but is approximately two gallons under normal use conditions.

The Purefecta™ uses Kinetico's "PureMometer™" filter life indicator to tell the user how much capacity remains on the carbon or sediment prefilter, the biofilter, and the post-membrane carbon filter. The PureMometer™ is located on the top of the system manifold, easily visible to the user (see Figure 2.2). The PureMometer™ indicator stick decreases in height as treated water is produced. After approximately 500 gallons are produced, the system shuts off. The meter is reset when the user replaces the post-membrane carbon filter.

Figure 2-2. Photograph of the Purefecta™

2.5 Rate of Waste Production

As discussed in section 2.2, the efficiency rating of the Purefecta™ is 25.9%, which means the system produces approximately three gallons of reject water for each gallon of product water produced. The efficiency rating was not verified as part of this evaluation.

2.6 Equipment Operation Limitations

Kinetico gives the following limitations for the drinking water to be treated by the system:

- temperature of 35 – 100 °F;
- inlet pressure of 40 – 100 psi;
- pH of 3 – 11;
- maximum TDS level of 3000 mg/L;
- hardness less than 10 grains per gallon; and
- iron less than 0.1 mg/L.

2.7 Operation and Maintenance Requirements

Kinetico recommends that all maintenance be done by qualified Kinetico professionals. The following are the operation and maintenance requirements:

- Replacement of the pre-membrane carbon or sediment filter, the biofilter, and the post-membrane carbon filter annually, or when the meter described in section 2.4 stops the production of treated water;
- Sanitization of the system when the carbon filters and biofilter are replaced; and
- Measurement of the TDS level of the product water when the other filters are changed. RO membrane replacement is recommended when the TDS reduction performance falls below 90%.

Chapter 3
Methods and Procedures

3.1 Introduction

The challenge tests followed the procedures described in the *Test/QA Plan for Verification Testing of the Pall/Kinetico Purefecta™ Point-of-Use Drinking Water Treatment System for Removal of Chemical Contamination Agents*.

As described in section 2.3, the Purefecta™ employs an RO membrane, activated carbon filters, and a bacteria/virus removal filter to treat drinking water. The system was first tested with only the RO membrane component in place. After the RO membrane challenges were complete, the post-membrane carbon filter was challenged alone. This approach allowed an evaluation of the individual performance of each component, and also served to simulate a worst-case scenario where the carbon filters are at or past the end of their useful life. This approach also allowed each treatment component to be challenged using a test water that presented more of a worse-case scenario for that component. The pre-membrane carbon filter was not tested, because it is not a standard component, and it is only designed to remove chlorine to protect the RO membrane. The pre-membrane sediment filter also was not tested, because it also is not a standard component, and it is only designed to remove suspended sediment particles to protect the RO membrane from clogging.

3.1.1 RO Membrane Challenges

The RO membranes were challenged with each chemical in Table 3-1. The target challenge concentration for each chemical was 1 mg/L, which is much higher than most challenge levels in the NSF/ANSI Standards for POU devices. Only two membranes were challenged with each chemical. The organic chemical challenges were conducted one chemical at a time, but the inorganic chemicals were combined into one challenge. Each membrane was only tested with one of the ten organic chemicals, because of concern that some of them, especially benzene and chloroform, could damage the membranes or membrane seals at the high challenge levels. This approach eliminated the possibility that membrane performance against subsequent chemicals was negatively biased. TDS reduction was also measured during the challenges, to serve as a membrane performance benchmark, and also to evaluate whether any organic chemicals damaged the membrane or integrity of the membrane seals.

A total of twenty RO membrane units were tested, divided into ten pairs. The inorganic chemicals challenge was conducted first. The two systems used for the inorganic chemicals challenge were used again for an organic chemical challenge.

As discussed in section 1.2, each challenge period was only one day. The systems were operated for six tank-fill periods, and then were allowed to rest overnight. Influent and effluent samples were collected during the operation period, and also the next morning after the rest period. In addition to influent and effluent samples, reject water samples were also collected and analyzed in an attempt to determine whether any of the chemicals adsorbed onto or absorbed into the membrane material in significant amounts. See section 3.2.5.2 for RO membrane challenge protocol details.

Table 3-1. Challenge Chemicals

Organic Chemicals	Inorganic Chemicals
Aldicarb	Cadmium Chloride
Benzene	Cesium Chloride (nonradioactive isotope)
Carbofuran	Mercuric Chloride
Chloroform	Strontium Chloride (nonradioactive isotope)
Dicrotophos	
Dichlorvos	
Fenamiphos	
Mevinphos	
Oxamyl	
Strychnine	

3.1.2 Post-Membrane Carbon Filter Challenges

The post-membrane carbon filter was tested alone with the organic chemicals the RO membrane did not remove to below 10 μg/L. The inorganic chemicals were considered on a case-by-case basis, since USEPA does not consider carbon to be the best available technology for removing cadmium, cesium, or strontium. As with the membranes, the carbon filters were challenged in pairs, and each pair was only tested once. Each challenge was 15 hours. The target challenge concentrations for the carbon filter tests were the maximum effluent levels measured during the RO tests. See section 3.2.5.3 for the post-membrane carbon filter test protocol details.

3.1.3 System Operation Scenarios

The challenge protocol was designed to evaluate system performance under two different operation scenarios. The first is operation with the product water storage tank over half full, giving high back-pressure. This is how the system is likely to operate in the home, as the user will usually dispense small volumes of water until the shut-off valve deactivates, allowing the storage tank to fill again. RO membrane performance is affected by the net driving pressure on the membrane. The net driving pressure is the feed water pressure minus the osmotic pressure minus the back-pressure from the storage tank. As the storage tank fills up and the tank bladder expands, the back-pressure increases, reducing the net driving pressure. As the net driving pressure drops, the ion rejection performance of the membrane can also drop (Slovak, 2000).

This test protocol was designed so that the test units operate for multiple tank fills under conditions where the net driving pressure was as low as possible. After the first tank fill, the lab technician dispensed the product water to the drain until the shut-off valve deactivated, allowing the unit to again produce treated water. This cycle was repeated for a total of five storage tank fill periods.

The second operation scenario is continued contaminant rejection while the system is at rest. The NSF/ANSI Standard 58 testing protocols call for a two-day stagnation period to check whether the membrane can maintain rejection of the contaminants. NSF has observed that RO systems can give higher contaminant concentrations after the rest period than before. This phenomenon is due to the membrane's difficulty maintaining the osmotic differential across the membrane, and perhaps also imperfections in the membrane material. At the end of each challenge, the test units were allowed to rest under pressure overnight, and product water samples were collected for analysis the next morning.

3.2 Verification Test Procedure

3.2.1 Challenge Protocol Tasks

The following are the tasks in the challenge protocol, and the order in which they were conducted:

1. Installation of the RO test units on the test rig, and seven days of conditioning (section 3.2.4.1);
2. One-day TDS challenge test to evaluate system integrity (section 3.2.5.1);
3. Conditioning of the post-membrane carbon filters while the RO membrane tests are being conducted (section 3.2.4.2); and
4. Chemical challenge tests
   a. RO inorganic chemicals challenge (section 3.2.5.2)
   b. RO organic chemical challenges (section 3.2.5.2)
   c. Post-membrane carbon filter challenges (section 3.2.5.3).

3.2.2 Test Rig

All test units were plumbed to "injection rig" test stations in the NSF Drinking Water Treatment Systems Testing Laboratory. The injection rigs have a common 90-gallon tank to hold the test water without the challenge chemicals. Fresh water is periodically added to the tank as it is being used. Online monitors and a computer system automatically control the water level and water chemistry. Downstream of the feedwater tank a precisely controlled pump is used to inject the challenge chemical(s) at the proper concentrations. Immediately downstream of the pump lies a motionless in-line mixer to assure complete mixing of the challenge water. An influent sample port is downstream of the in-line mixer. No schematic diagram of the injection rig is available, due to the proprietary nature of the design.

3.2.3 Test Water

3.2.3.1 RO Membrane Conditioning and Challenge Test Water

The test water for the RO membrane conditioning and challenges was a synthetic water constructed from deionized municipal drinking water. The municipal water was first filtered through activated carbon to remove chlorine, then it was deionized and treated with reverse osmosis. Sodium chloride was added for TDS, and the pH was adjusted with hydrochloric acid

(HCl) or sodium hydroxide (NaOH), if necessary, to achieve the following characteristics prior to addition of the challenge chemical(s):

- pH – 7.5 ± 0.5 for the TDS reduction test, conditioning, and organic chemical challenges, 6.0-6.5 for the inorganic chemicals challenge;
- total chlorine – ≤ 0.05 mg/L;
- temperature – 25 ± 1 °C;
- TDS – 750 ± 75 mg/L; and
- turbidity – ≤ 1 Nephelometric Turbidity Unit (NTU).

TDS, pH, temperature, and turbidity were maintained within the appropriate range by a computer system with on-line monitors. In addition, grab samples were collected and analyzed for all parameters according to the sampling plans described in sections 3.2.4.1, 3.2.5.1, and 3.2.5.2. Note that the pH specification for the inorganic chemicals challenges was 6.0 to 6.5, to ensure that the inorganic chemicals were present as dissolved free ions in the challenge water. This ensured that the inorganic chemicals challenges were testing the ability of the RO membrane to reject the ions instead of physically removing suspended particles of the inorganic chemicals.

3.2.3.2 Post-Membrane Carbon Filter Conditioning and Challenge Test Water

The test water for post-membrane carbon filter conditioning and testing was the "general test water" specified in *NSF/ANSI Standard 53, Drinking water treatment units – health effects* (NSF International, 2002). This water is the Ann Arbor municipal drinking water that is adjusted, if necessary, to have the following characteristics prior to addition of the challenge chemical:

- pH – 7.5 ± 0.5;
- TDS – 200-500 mg/L
- temperature – 20 ± 2.5 °C;
- total organic carbon (TOC) – > 1.0 mg/L; and
- turbidity – ≤ 1 NTU.

Please note that the TOC parameter only has a minimum level specified, since it is the natural TOC in the municipal water supply. During testing, the TOC in the water supply ranged from 1.9 to 2.6 mg/L. However, the TOC levels in the organic chemical challenge waters were much higher due to the methanol used as the carrier solution for the chemicals.

TDS, pH, and temperature were maintained within the appropriate range by a computer system with on-line monitors. The pH of the Ann Arbor drinking water was above 7.5 during the test period, so the pH was adjusted with HCl. The TDS level was within the allowable range, so no adjustments were needed. The water was not dechlorinated prior to use.

Grab samples were collected and analyzed for all parameters according to the sampling plans described in sections 3.2.4.2 and 3.2.5.3. Total chlorine was also measured, although there is no specification given for it as there is in section 3.2.3.1 for the RO membrane test water.

3.2.3.3 Chemical Challenges

The appropriate chemical(s) were added to the base test waters given in sections 3.2.3.1 and 3.2.3.2 to make the challenge waters. The RO membrane challenge target concentration for each chemical was 1 ± 0.5 mg/L. The target challenge concentrations for the carbon filter tests were the maximum effluent levels measured during the RO tests. For each challenge, concentrated solution of the chemical(s) was made, and this mixture injected into the influent water stream at an appropriate rate. Due to analytical procedure lengths, the amount of chemical to add to the test water to achieve the proper challenge concentration was calculated based on the known concentration in the feed solution. The tests were conducted without waiting for confirmation of the influent level from the chemistry laboratory. All challenge chemical influent samples were within the allowable limits.

3.2.4 Test Unit Installation and Conditioning

3.2.4.1 RO Membrane Test Units

The RO membrane test units were delivered and installed on the test rigs by Kinetico representatives. Kinetico's recommended conditioning procedure of operation for two tank-fill periods was not conducted, instead the units underwent a seven day, seven tank-fills conditioning period. Previous POU RO system ETV tests for microbial agents indicated that perhaps membrane performance does not stabilize until after four or five days (four or five tank fills) of conditioning. A seven-day conditioning period ensured that the membranes were performing optimally prior to the chemical challenges.

For the first six days, the units were operated at 60 ± 3 psi inlet pressure for one storage tank fill period per day using the water described in section 3.2.3.1. Influent water samples were collected each day at the beginning of the operation period for analysis of pH, TDS, temperature, total chlorine, and turbidity. The units rested under pressure overnight, and the storage tanks were emptied the next morning prior to beginning that day's operation period.

On the seventh day, the units were instead operated at 80 ± 3 psi inlet pressure. Influent water samples were collected at the beginning of the operation period for analysis of pH, TDS, temperature, total chlorine, and turbidity. The times required to fill the storage tanks were measured and recorded for the three units whose tanks filled the fastest. On the morning of the eighth day, the times to dispense the first liter of water and to empty the storage tanks with the faucet fully open were measured and recorded for the three units whose operating times were recorded the previous day. The tank fill times, times to empty the storage tank, and first liter flow rate data were used to determine the operating parameters for the post-membrane carbon filters during the carbon filter challenge tests. The longest time to empty the storage tank was used for the "on" time portion of the operation cycle. The shortest tank fill time was used for the "off" portion of the cycle. The flow rates for the carbon filter challenges were set at the fastest first liter flow rate. Operation at 80 psi instead of 60 psi caused the tank fill time to be shorter, which gave a worse case testing scenario for the carbon filters. See section 3.2.5.3 for further discussion about the post-membrane carbon filter challenge tests.

3.2.4.2 Post-Membrane Carbon Filter Test Units

The carbon filters were plumbed to a test station and operated using the water described in section 3.2.3.2 amended with 300 ± 90 μg/L of chloroform until 250 gallons passed through each filter. This is the volume equal to one-half of Kinetico's stated capacity of 500 gallons for the filter. The filters were operated at an inlet water pressure of 60 ± 3 psi and a maximum flow rate of 0.5 gallons per minute (gpm), on a ten minutes on, ten minutes off cycle. Chloroform at 300 μg/L is the influent challenge concentration for the organic chemical reduction test in NSF/ANSI Standard 53 (chloroform is the surrogate chemical for the Standard 53 organic chemical reduction claim). The chloroform served to load the carbon filters to a degree that simulated contaminant loading in the middle of their effective lifespan. Influent samples were collected for analysis of chloroform, pH, temperature, TOC, and turbidity at start-up, approximately 25% of capacity, and approximately 50% of capacity. Effluent samples were collected at the same three points for chloroform analysis.

If the filters were not immediately used for a challenge test, they were stored with the conditioning water still in them. The manifold inlets and outlets were closed off by valves to ensure that all of the chloroform remained on the carbon.

3.2.5 Challenge Protocols and Sampling Plans

3.2.5.1 TDS Reduction System Performance Check

After the RO membrane conditioning period was complete, they underwent a short-term TDS reduction test to verify that they were operating properly. The challenge was conducted as follows:

1. The product water storage tanks were drained, and test unit operation was started at 50 ± 3 psi inlet pressure using the water described in section 3.2.3.1 without any challenge chemicals added.
2. Immediately after the units began operation, influent samples were collected for analysis of pH, temperature, total chlorine, turbidity, and TDS.
3. The systems were allowed to operate until the automatic shut-off mechanisms activated.
4. The entire contents of the storage tanks were emptied into separate containers, and three 250 mL samples were collected from each container for TDS analysis.

Removal of 75% or more of the TDS was required for the use of each membrane for the chemical challenges.

3.2.5.2 RO Membrane Challenge Testing

As discussed in section 3.1.1, the RO membrane systems were divided into ten pairs. The inorganic chemical challenges were conducted first, followed by the organic chemicals. Figure 3-1 shows a pair of test units plumbed to the test rig.

The challenge tests were conducted as follows:

1. At the start of each challenge period, the system storage tanks were emptied.

2. The initial dynamic inlet water pressure was set at 50 ± 3 psi, and system operation was started using the test water described in section 3.2.3.1 with the proper challenge chemical(s) added.
3. Influent and effluent water samples were collected for analysis of the challenge chemical(s) and TDS immediately after the units began operation. Influent samples were also collected for analysis of pH, temperature, total chlorine, and turbidity. All influent and effluent samples for challenge chemical analysis were collected and analyzed in triplicate, except where indicated below. To collect the triplicate samples, the volumes necessary to obtain the triplicate samples were first collected into a polyethylene container, and then the triplicate samples were collected from that volume. However, due to the volatility of benzene and chloroform, true triplicate samples were not collected for these chemicals. Instead, three consecutive replicate samples were collected directly into the sample bottles that were delivered to the NSF Chemistry Laboratory. TDS samples were collected as single samples.

Figure 3-1. RO Membrane Systems Installed at a Test Station

4. While under operation for the first storage tank fill period, duplicate samples were collected from the reject water line of one of the test units for challenge chemical(s) analysis at start-up, approximately halfway through, and approximately three-fourths of the way through the period.
5. The units were operated continuously until the shut-off valves activated. The faucets were then fully opened, and a minimum of one liter, the volume required for sample analysis, or the amount needed to fully deactivate the shut-off valve, was dispensed to drain from each system. Full deactivation was estimated by monitoring resumption of the flow of reject water as the product water was dispensed. The shut-off valve was considered fully deactivated when the flow of reject water appeared to have fully resumed.
6. Step 5 was repeated until five storage tank fill periods were complete. After the third storage tank fill period ended, influent and effluent samples were collected for analysis of the challenge chemical(s) and TDS.
7. Approximately halfway through the last tank fill period, duplicate reject water samples were collected for challenge chemical(s) analysis. The samples were collected from the same system from which the reject water samples were collected in step 4. This sample served to check whether any chemical adsorption/absorption observed during the first storage tank fill period was still occurring, or the membrane became saturated with the chemical.
8. After the fifth storage tank fill, effluent samples were collected from each system for challenge chemical(s) and TDS analysis. Influent samples were collected for analysis of the challenge chemical(s), TDS, pH, temperature, total chlorine, and turbidity. If a system did not resume operation after sample collection, the additional volume necessary to resume operation was dispensed from each system.
9. The units were then allowed to operate until the shut-off valves activated, and then rest under pressure for at least eight hours. After the rest period, the faucets were fully opened, and the first draw out of each faucet was collected for single challenge chemical and TDS analysis. After collection of the first draw water, the rest of the contents of each storage tank were collected into suitable containers, and three samples were collected from each volume for triplicate challenge chemical analysis. Table 3-2 gives a summary of the sampling plan.

Table 3-2. Summary of Sampling Plan for RO Membrane Challenges

	Influent Sample Numbers			Effluent Sample Numbers (per system)	
Sample Point	Water Chemistry Parameters	Challenge Chemical	TDS	Challenge Chemical	TDS
Start Up	1 for each parameter	3	1	3	1
1st Tank Reject Water Samples					
Start Up				2 (from one system)	
Half Tank				2 (from one system)	
Three-fourths Tank				2 (from one system)	
3rd Tank Fill		3	1	3	1
5th Tank Fill	1 for each parameter	3	1	3	1
Reject Water – Halfway Through 5th Tank Fill				2 (from one system)	
Post-Rest – First Draw				1	1
Post-Rest – Rest of Tank				3	

3.2.5.3 Post-Membrane Carbon Filter Challenge Testing

The post-membrane carbon filter in the Purefecta™ is downstream from the storage tank, so it was tested at the flow rate measured at the faucet outlet during the RO membrane conditioning step. Each challenge was 15 hours. The filters were operated on an "on/off" operation cycle where the "on" portion was the time required to empty the storage tank when full, and the "off" portion of the cycle was the time required to fill the storage tank at 80 psi inlet pressure, as measured during the RO membrane conditioning period. Figure 3-2 shows a pair of carbon filters being tested.

The challenge tests were conducted as follows:

1. The proper "on/off" cycle parameters were entered into the test station computer.
2. The initial dynamic inlet water pressure was set at 60 ± 3 psi, and filter operation was started using the water described in section 3.2.3.2 with the proper challenge chemical added. The flow rate was adjusted as necessary using a valve downstream of each filter on the effluent line.
3. Influent and effluent samples were collected for challenge chemical analysis immediately after operation began. All effluent samples were collected during the last half of the "on" portion of the operation cycle, so that the dwell water was flushed out prior to sample collection. All challenge chemical samples were collected and analyzed in triplicate. The sample volumes were those required to obtain the triplicate samples.
4. Single influent samples were also collected for analysis of pH, TDS, temperature, TOC, total chlorine, and turbidity whenever challenge chemical samples were collected.
5. After 7.5 and 15 hours of operation, second and third sets of influent and effluent samples were collected for challenge chemical analysis. The flow of challenge water through the filters was started manually if they were not in the "on" portion of the operation cycle. Table 3-3 gives a summary of the sampling schedule.

Figure 3-2. Post-Membrane Carbon Filters Installed at a Test Station.

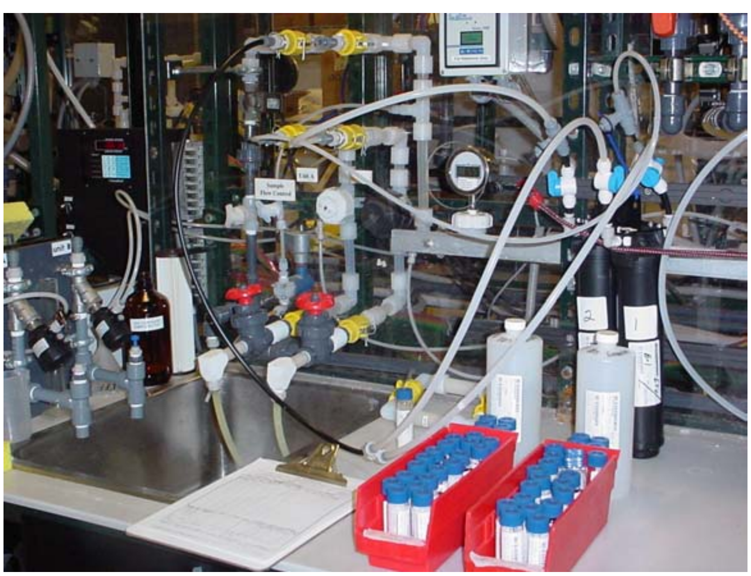


Table 3-3. Summary of Sampling Plan for Post-Membrane Carbon Filter Challenges			
Sample Point	Influent Water Chemistry Sample Numbers	Challenge Chemical Influent Sample Numbers	Challenge Chemical Effluent Sample Numbers
Start Up	1 for each parameter	3	3
7.5 Hours	1 for each parameter	3	3
15 Hours	1 for each parameter	3	3

3.3 Analytical Methods

3.3.1 Water Quality Analytical Methods

The following are the analytical methods used during verification testing. All analyses followed procedures detailed in NSF's Standard Operating Procedures (SOPs). The reporting limits, and the acceptable precision and accuracy for each parameter are shown in Table 3-4.

- pH – All pH measurements were made with an Orion Model SA 720 meter. The meter was operated according to the manufacturer's instructions, which are based on Standard Methods method 4500-H^+.
- Temperature – Water temperature was measured using an Omega model HH11 digital thermometer.

Table 3-4. QC Limits and Method Reporting Limits for Analyses

Parameter	Reporting Limit	Acceptable Precision (RPD)	Acceptable Accuracy (% recovery)
pH	NA	10%	90-110%
TDS (conductivity)	2 mg/L	10%	80-120%
TDS (gravimetric)	5 mg/L	10%	90-110%
TOC	0.1 mg/L	10%	80-120%
Total Chlorine	0.05 mg/L	10%	90-110%
Turbidity	0.1 NTU	10%	95-105%
Aldicarb	1.0 µg/L	20%	70-130%
Benzene	0.5 µg/L	20%	80-120%
Cadmium	0.3 µg/L	20%	70-130%
Carbofuran	1 µg/L	20%	70-130%
Cesium	1 µg/L	20%	70-130%
Chloroform	0.5 µg/L	20%	80-120%
Dicrotophos	10 µg/L	RSD < 30%	70-130%
Dichlorvos	0.2 µg/L	RSD < 30%	70-130%
Fenamiphos	2 µg/L	RSD < 30%	70-130%
Mercury	0.2 µg/L	20%	70-130%
Mevinphos	0.4 µg/L	RSD < 30%	70-130%
Oxamyl	1.0 µg/L	20%	70-130%
Strontium	2 µg/L	20%	70-130%
Strychnine	5 µg/L	20%	80-120%

- TDS (by conductivity) – TDS for the TDS reduction system check test was measured through conductivity according to Standard Method 2510 using a Fisher Scientific Traceable™ Conductivity Meter.
- TDS (gravimetrically) – The TDS in the carbon filter conditioning and challenge water was measured gravimetrically. The method used was an adaptation of USEPA Methods 160.3 and 160.4. An appropriate amount of sample was placed in a pre-weighed evaporating dish. The sample was evaporated and dried at 103-105 °C to a constant weight. The dish was then weighed again to determine the total solids weight.
- Total Chlorine – Total chlorine was measured according to Standard Method 4500-Cl G with a Hach Model DR/2010 spectrophotometer using AccuVac vials.

3.3.2 Challenge Chemical Analytical Methods

The following are the analytical methods used during verification testing. All analyses followed procedures detailed in NSF SOPs. The reporting limits, and the acceptable precision and accuracy for each parameter are shown in Table 3-4.

- Aldicarb, Carbofuran, and Oxamyl were measured by high pressure liquid chromatography (HPLC) according to USEPA Method 531.1 or 531.2.
- Dichlorvos, Dicrotophos, Fenamiphos, and Mevinphos were measured by gas chromatography/mass spectrometry (GC/MS) according to USEPA Method 525.2.
- Cadmium, Chromium, Mercury, and Strontium were measured by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) according to USEPA Method 200.8.
- Benzene and Chloroform were measured by purge and trap capillary gas chromatography according to USEPA Method 502.2.
- There is no standard analytical method for strychnine. NSF developed a method to measure it using reverse phase HPLC with ultraviolet lamp detection.

Chapter 4
Results and Discussion

4.1 RO Membrane Conditioning

As discussed in section 3.2.4.1, the RO membrane test units were conditioned for seven days prior to the chemical challenges. The units were conditioned simultaneously at four different test stations, with six units plumbed to each station. All of the water quality parameters in section 3.2.3.1 were maintained within the allowable ranges. The individual data values for these parameters can be found in Table A-1 of Appendix A.

4.1.1 RO Membrane Test System Operation Data

As described in section 3.2.4.1, the storage tank fill times, first liter dispense times, and times to dispense the entire tanks were measured and recorded for the three systems whose tanks filled the fastest. The first liter flow rates were calculated for each of the three systems from the first liter dispense times. The results are given below in Table 4-1. This data was used to determine the operation parameters for the carbon filter challenges.

Table 4-1. RO Membrane System Operation Data

Unit	Tank Fill Time (minutes)	1st Liter Time (seconds)	1st Liter Flow Rate (gpm)	Tank Dispense Time
16	69	20	0.79	4 min., 44 sec.
3	70	22	0.72	4 min., 44 sec.
18	75	21	0.75	4 min., 36 sec.

4.2 Post-Membrane Carbon Filter Conditioning

As described in section 3.2.4.2, the post-membrane carbon filters were conditioned with water containing 300 ± 90 µg/L of chloroform until 250 gallons of the conditioning water had passed through them. Eight filters were conditioned first, and then another six were conditioned later. Influent and effluent samples were collected for analysis at start-up, after approximately 125 gallons, and after approximately 250 gallons. All effluent samples were non-detect (< 0.5 µg/L) for chloroform, except one for Unit 11. This unit had an effluent chloroform level of 6.4 µg/L in the 250-gallon sample. The influent water data are given in Table A-2 of Appendix A.

4.3 TDS Reduction System Performance Check

After the RO membranes were conditioned, all underwent the TDS reduction test described in section 3.2.5.1. The maximum effluent TDS level measured was 30 mg/L, corresponding to greater than 96% reduction of TDS for all units. The average TDS reduction for the Purefecta™ , as measured during certification testing, was 89.3%, so test units were representative of expected membrane performance. The TDS reduction data for each RO membrane system can be found in Table A-3 of Appendix A.

4.4 RO Membrane Chemical Challenges

The RO membrane challenges were conducted according to the procedure in section 3.2.5.2. The tank-fill times were approximately 70 minutes, so the systems were in operation for approximately seven hours per challenge. After each tank-fill period, 2 to 3.5 liters were drawn out of the storage tanks for sample analysis and to disengage the automatic shut-off valve.

4.4.1 Inorganic Chemicals Challenge

The inorganic chemicals challenge data are shown in Table 4-2. Each challenge chemical data point is the arithmetic mean of the triplicate sample analyses, except for the post-rest first liter draws, which were only single samples. All individual sample values constituting the triplicate analyses are presented in Table A-4 of Appendix A. As discussed in section 3.1.1, the challenge water also contained TDS at a target concentration of 750 mg/L to serve as an RO membrane integrity check. The TDS reduction data are also presented in Table 4-2. The TDS data points are from single sample analyses. The challenge water chemistry data are presented in Table A-6 of Appendix A.

Table 4-2. RO Membrane Inorganic Chemicals Reduction Data

Sample	Cadmium (µg/L)	Cesium (µg/L)	Mercury (µg/L)	Strontium (µg/L)	TDS (mg/L)
Start-up Influent	1000	1000	1100	840	740
Start-up Effluent, Unit 1	0.6	15	190	2	30
Start-up Effluent, Unit 2	1.8	31	460	2	32
3rd Tank Influent	1000	1000	1100	850	760
3rd Tank Effluent, Unit 1	1.8	40	740	2	760(1)
3rd Tank Effluent, Unit 2	2.5	50	760	3	36
5th Tank Influent	1000	1100	1100	860	750
5th Tank Effluent, Unit 1	1.7	37	810	2	29
5th Tank Effluent, Unit 2	2.3	48	840	2	34
Post-Rest 1st Draw, Unit 1	1.8	38	730	2	34
Post-Rest 1st Draw, Unit 2	2.5	52	760	3	34
Post-Rest 2nd Sample, Unit 1	1.8	37	750	2	NA
Post-Rest 2nd Sample, Unit 2	2.4	50	750	2	NA
Mean Influent	**1000**	**1000**	**1100**	**850**	**750**
Mean Effluent, Unit 1	**1.5**	**33**	**640**	**2**	**31**
Mean Effluent, Unit 2	**2.3**	**46**	**710**	**2**	**34**
Percent Reduction, Unit 1	**> 99**	**97**	**42**	**> 99**	**96**
Percent Reduction, Unit 2	**> 99**	**95**	**35**	**> 99**	**95**
Overall Mean Effluent	**1.9**	**40**	**680**	**2**	**33**
Overall Percent Reduction	**> 99**	**96**	**38**	**> 99**	**96**
Units Tested	1, 2	1, 2	1, 2	1, 2	

(1) Sample result not included in mean effluent and percent reduction calculations, see section 5.7.4.3 for further discussion.

The RO membrane performed very well against cadmium, cesium, and strontium, removing 96% of the cesium, and more than 99% of the cadmium and strontium. The RO membrane did not perform well against the mercury challenge, but this was expected. There are no POU RO systems certified by NSF for mercury reduction because mercury is not well removed by RO membranes using the test water specified in NSF/ANSI Standard 58.

The reject water sample data are given in Table 4-3. The values presented are the arithmetic means of the duplicate sample analyses, except where indicated. The individual sample results are presented in Table A-7 of Appendix A. The chemical levels are somewhat higher than expected, given that the Purefecta™ has an efficiency rating (as defined by NSF/ANSI Standard 58) of 26%. The efficiency is the amount of influent water that is delivered as permeate. This efficiency means the reject water should have approximately 25% more of the challenge chemical than the influent water, assuming 100% rejection by the membrane. The efficiency will be higher at the start of unit operation, since the storage tank is empty, and thus is not supplying any back-pressure. However, by halfway and three-fourths of the way through the tank-fill period, the measured reject water challenge chemical levels are still greater than 25% above the influent levels, indicating that the test units achieved greater than 26% efficiency.

Table 4-3. Inorganic Chemicals Challenge Reject Water Data

Sample	Cadmium (μg/L)	Cesium (μg/L)	Mercury (μg/L)	Strontium (μg/L)
Start-Up	2100	2000	1200	1700
1/2 Through 1st Tank	1800	1700	1300	1400
3/4 Through 1st Tank	1700 (1)	1700 (1)	1200	1400 (1)
1/2 Through 5th Tank	1500	1500	1200	1200
Unit Sampled	1	1	1	1

(1) Result is from only one of the duplicate analyses, due to analytical errors.

4.4.2 Organic Chemical Challenges

The organic chemical challenge data are shown below in Table 4-4. Each data point is the arithmetic mean of the triplicate sample analyses, except for the post-rest first draw samples, which were only single samples. All individual sample values constituting the triplicate analyses are presented in Table A-5 in Appendix A. The water chemistry data for these challenges are presented in Table A-6 in Appendix A.

As discussed in section 3.1.1, the challenge water also contained TDS to serve as a membrane integrity check. The TDS reduction data are presented in Table 4-5.

The reject water data are shown in Table 4-6. The values presented are the arithmetic means of the duplicate sample analyses, except where indicated. The individual sample results are presented in Table A-8 of Appendix A.

The RO membrane removed all chemicals but chloroform by 96% or more. At start-up, the membranes removed greater than 99% of the chloroform, but the effluent levels rose from sample point to sample point after that. The maximum effluent was 310 μg/L, from the unit 2

Table 4-4. RO Membrane Organic Chemical Challenge Data

Sample	Aldicarb (µg/L)	Benzene (µg/L)	Carbofuran (µg/L)	Chloroform (µg/L)	Dichlorvos (µg/L)	Dicrotophos (µg/L)	Fenamiphos (µg/L)	Mevinphos (µg/L)	Oxamyl (µg/L)	Strychnine (µg/L)
Start-Up Influent	960	1100	900	1100	1000	1000(1)	680	1300	970	1100
Start-Up Effluent, Unit 1	4	ND (0.5)	ND (1)	0.7	27	ND (10)	ND (2)	15	3	15
Start-Up Effluent, Unit 2	5	0.7	ND (1)	1.3	33	ND (10)	ND (2)	13	4	ND (5)
3rd Tank Influent	920	1200	980	1200	1100	740	900	1300	980	1100
3rd Tank Effluent, Unit 1	7	20	7	71	26	ND (10)	2	18	5	29
3rd Tank Effluent, Unit 2	8	20	5	110	22	ND (10)	3	21	5	ND (5)
5th Tank Influent	980	1100	980	1100	1200	790	650	1500	1000	1100
5th Tank Effluent, Unit 1	8	67	7	230	18	ND (10)	2	19	5	32
5th Tank Effluent, Unit 2	8	78	6	320	16	ND (10)	2	22	5	7
Post-Rest 1st Draw, Unit 1	8	96	7	260	31	ND (10)	2	12	5	34
Post-Rest 1st Draw, Unit 2	8	85	6	310	19	ND (10)	ND (2)	21	4	6
Post-Rest 2nd Sample, Unit 1	8	61	7	150(1)	20	ND (10)	3	20	5	33
Post-Rest 2nd Sample, Unit 2	8	48	6	250	23	ND (10)	3	23	5	6
Mean Influent	**950**	**1100**	**950**	**1100**	**1100**	**790**	**740**	**1400**	**980**	**1100**
Mean Effluent, Unit 1	**7**	**49**	**6**	**140**	**23**	**ND (10)**	**2**	**17**	**5**	**29**
Mean Effluent, Unit 2	**7**	**46**	**5**	**200**	**23**	**ND (10)**	**2**	**20**	**5**	**6**
Percent Reduction, Unit 1	**> 99**	**96**	**> 99**	**87**	**98**	**99**	**> 99**	**99**	**> 99**	**97**
Percent Reduction, Unit 2	**> 99**	**96**	**> 99**	**82**	**98**	**99**	**> 99**	**99**	**> 99**	**> 99**
Overall Mean Effluent	**7**	**48**	**6**	**170**	**23**	**ND (10)**	**2**	**19**	**5**	**18**
Overall Percent Reduction	**> 99**	**96**	**> 99**	**85**	**98**	**99**	**> 99**	**99**	**> 99**	**98**
Units Tested	1, 2	3, 4	5, 6	7, 8	11, 12	9, 10	13, 14	15, 16	17, 18	19, 20

Note: The detection limit values were used for calculating the mean effluents and percent reductions.
(1) Number only the average of two of the triplicate analysis numbers, due to analytical errors.

post-rest first draw sample. This corresponds to 72% reduction, using the mean influent for the percent reduction calculation. The rising effluent level trend was also evident for benzene. Both of these substances are volatile, so perhaps volatility played a role in their passage through the membrane. They may have adsorbed onto and diffused through the membrane material, or perhaps they began to break down the membrane.

The absorption theory is lent some weight by an examination of the reject water data in Table 4-6. The average concentrations for benzene and chloroform are lower than for the other chemicals. The reject water concentrations for all other chemicals are above the influent challenge levels, indicating that they did not adsorb onto the membrane or surfaces in contact with the water. The organic chemical challenges reject water data also indicates that the test units operated at greater than 25% efficiency, as discussed above in section 4.4.1.

If benzene or chloroform did begin to degrade the integrity of the RO membrane, it is not evident through an examination of the TDS reduction data in Table 4-5, nor is it evident that any other chemicals adversely affected membrane performance. More research would be needed to determine why the amounts of benzene and chloroform passing through the membrane increased through the challenge period.

Table 4-5. TDS Reduction Data for Organic Chemical Challenges

Sample	Aldicarb TDS (mg/L)	Benzene TDS (mg/L)	Carbofuran TDS (mg/L)	Chloroform TDS (mg/L)	Dichlorvos TDS (mg/L)	Dicrotophos TDS (mg/L)	Fenamiphos TDS (mg/L)	Mevinphos TDS (mg/L)	Oxamyl TDS (mg/L)	Strychnine TDS (mg/L)
Start-Up Influent	860	730	750	740	760	750	1000	760	760	760
Start-Up Effluent, Unit 1	16	21	130	22	19	30	120	16	14	34
Start-Up Effluent, Unit 2	99	15	23	20	13	27	1000(1)	14	13	17
3rd Tank Influent	840	750	730	740	750	750	830	770	750	750
3rd Tank Effluent, Unit 1	38	18	17	16	16	20	570	17	13	36
3rd Tank Effluent, Unit 2	21	12	100	20	14	23	270(1)	15	12	15
5th Tank Influent	730	750	740	750	740	760	750(1)	770	750	750
5th Tank Effluent, Unit 1	15	19	18	16	17	19	11	16	14	37
5th Tank Effluent, Unit 2	22	13	20	21	14	22	15	15	12	15
Post-Rest 1st Draw, Unit 1	18	20	17	16	17	20	11	17	14	38
Post-Rest 1st Draw, Unit 2	17	13	13	22	14	23	14	15	12	15
Mean Influent	**810**	**740**	**740**	**740**	**750**	**750**	**750**	**770**	**750**	**750**
Mean Effluent, Unit 1	**22**	**20**	**46**	**18**	**17**	**22**	**11**	**17**	**14**	**36**
Mean Effluent, Unit 2	**40**	**13**	**39**	**21**	**14**	**24**	**15**	**15**	**12**	**16**
Percent Reduction, Unit 1	**97**	**97**	**94**	**98**	**98**	**97**	**99**	**98**	**98**	**95**
Percent Reduction, Unit 2	**95**	**98**	**95**	**97**	**98**	**97**	**98**	**98**	**98**	**98**

(1) Sample results not included in mean effluent and percent reduction calculations. See section 5.7.4.3 for further discussion.

Table 4-6. Organic Chemical Challenge Reject Water Data

Sample	Aldicarb (μg/L)	Benzene (μg/L)	Carbofuran (μg/L)	Chloroform (μg/L)	Dichlorvos (μg/L)	Dicrotophos (μg/L)	Fenamiphos (μg/L)	Mevinphos (μg/L)	Oxamyl (μg/L)	Strychnine (μg/L)
Start-Up	1800	970	1300	980	2700	1400	1500	2000	1700	1900
1/2 through 1st Tank	1500	1100	1600	990	1800	1200	1400	2100	1500	1800
3/4 through 1st tank	1500	1000	1500	970	1800	1700	1200	1800	1500	1700
1/2 through 5th Tank	1400	970	1400	1000	1300	880	1100	1400	1300	1500
Unit Sampled	1	3	5	7	9	12	13	15	17	19

4.5 Post-Membrane Carbon Filter Challenges

Based on the RO membrane challenge results, and the criteria discussed in section 3.1.2, the post-membrane carbon filter was challenged with mercury, benzene, chloroform, dichlorvos, mevinphos, and strychnine. The target challenge levels were the maximum effluent levels measured during the RO membrane challenges. Based on the data in Table 4-2, the carbon filters were operated at 0.8 gpm on an operation cycle where the "on" portion was four minutes and thirty seconds, and the "off" portion was one hour and ten minutes.

The carbon challenge results are shown below in Table 4-7. Each data point is the arithmetic mean of the triplicate sample analyses, except for the footnoted Mevinphos data points. The lab technician did not use the proper preservative for the Mevinphos samples, and the preservative interfered with the internal standard, making it impossible to determine the amount of Mevinphos in some of the samples. See section 5.7.4.3 for further discussion. All individual sample values constituting the triplicate analyses are presented in Table A-9 in Appendix A. The water chemistry data for these challenges can be found in Table A-10 of Appendix A.

The carbon filters reduced all substances by 99% or more, except for strychnine. The percent reduction of strychnine was limited by the detection limit for the chemical.

Sample	Mercury (µg/L)	Benzene (µg/L)	Chloroform (µg/L)	Dichlorvos (µg/L)	Mevinphos (µg/L)	Strychnine (µg/L)
Target Influent Level	840	96	320	33	23	30
Start-Up Influent	830	83	320	28	21	37
Start-Up Effluent, Unit 1	1.4	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)(1)	ND (5)
Start-Up Effluent, Unit 2	1.7	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
7.5 Hours Influent	1100	82	300	28	19	28
7.5 Hours Effluent, Unit 1	3.4	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)(1)	ND (5)
7.5 Hours Effluent, Unit 2	3.6	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)(1)	ND (5)
15 Hours Influent	970	85	330	31	21	27
15 Hours Effluent, Unit 1	2.8	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)(2)	ND (5)
15 Hours Effluent, Unit 2	3.0	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)(2)	ND (5)
Mean Influent	**960**	**83**	**320**	**29**	**20**	**31**
Mean Effluent, Unit 1	**2.6**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
Mean Effluent, Unit 2	**2.8**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
Percent Reduction, Unit 1	**> 99**	**> 99**	**> 99**	**> 99**	**99**	**84**
Percent Reduction, Unit 2	**> 99**	**> 99**	**> 99**	**> 99**	**99**	**84**
Overall Mean Effluent	**2.7**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
Overall Percent Reduction	**> 99**	**> 99**	**> 99**	**> 99**	**99**	**84**

Table 4-7. Post-Membrane Carbon Filter Challenge Data

Note: The detection limit values were used for calculating the mean effluents and percent reductions.
(1) Mean calculated from only two sample analyses, see section 5.7.4.3 for further discussion.
(2) Only one sample analyzed for data point, see section 5.7.4.3 for further discussion.

4.6 Conclusions

The RO membrane was not able to remove more than 90% of the chloroform or mercury challenges. However, the membrane and post-membrane carbon filter challenge data combined shows that the two treatment technologies working in concert within the Purefecta™ system removed 99% or more of all challenge chemicals, except for cesium, which was not used to test the carbon filter.

Chapter 5
QA/QC

5.1 Introduction

An important aspect of verification testing is the QA/QC procedures and requirements. Careful adherence to the procedures ensured that the data presented in this report was of sound quality, defensible, and representative of the equipment performance. The primary areas of evaluation were representativeness, precision, accuracy, and completeness.

Because the ETV was conducted at the NSF testing lab, all laboratory activities were conducted in accordance with the provisions of the *NSF International Laboratories Quality Assurance Manual*.

5.2 Test Procedure QA/QC

NSF testing laboratory staff conducted the tests by following an NSF SOP created specifically for the tests. NSF QA Department Staff performed an informal audit during testing to ensure the proper procedures were followed.

All water quality measurements were within the specifications in sections 3.2.3.1 and 3.2.3.2, except for TDS in the RO membrane conditioning and challenge water. Two of the influent TDS samples from the Aldicarb challenge, and two of the influent TDS samples from the Fenamiphos challenge were above the allowable upper limit of 825 mg/L (see Table 4-7). However, the high TDS levels were not significant deviations. It is unlikely that these deviations affected the chemical challenge tests in any way.

5.3 Sample Handling

All samples analyzed by the NSF Chemistry Laboratory were labeled with unique ID numbers. These ID numbers appear on the NSF laboratory reports for the tests. All samples were analyzed within allowable hold times.

5.4 Analytical Methods QA/QC

The calibrations of all analytical instruments, and the analyses of all parameters complied with the QA/QC provisions of the NSF International Laboratories Quality Assurance Manual.

The NSF QA/QC requirements are all compliant with those given in the USEPA Method or Standard Method for the parameter. Also, every analytical instrument has an NSF SOP governing its use.

5.5 Documentation

All laboratory activities were documented using specially prepared laboratory bench sheets and NSF laboratory reports. Data from the bench sheets and laboratory reports were entered into Microsoft Excel spreadsheets. These spreadsheets were used to calculate average influents and effluents, and percent reductions for each challenge chemical. One hundred percent of the data entered into the spreadsheets was checked by a reviewer to confirm all data and calculations were correct.

5.6 Data Review

NSF QA/QC staff reviewed the raw data records for compliance with QA/QC requirements. NSF ETV program staff checked 100% of the data in the NSF laboratory reports against the laboratory bench sheets.

5.7 Data Quality Indicators

The quality of data generated for this ETV can be established through four indicators of data quality: representativeness, accuracy, precision, and completeness.

5.7.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter represented by the data, or the expected performance of the RO system under normal use conditions. Representativeness was ensured by consistent execution of the test protocol for each challenge chemical, including timing of sample collection, sampling procedures, and sample preservation. Representativeness was also ensured by using each analytical method at its optimum capability to provide results that represent the most accurate and precise measurement it is capable of achieving.

5.7.2 Accuracy

Accuracy was quantified as the percent recovery of the parameter in a sample of known quantity. Accuracy was measured through use of both matrix spikes of a known quantity, and certified standards during calibration of an instrument. The following equation was used to calculate percent recovery:

$$\text{Percent Recovery} = 100 \times [(X_{known} - X_{measured})/X_{known}]$$

where: X_{known} = known concentration of the measured parameter
$X_{measured}$ = measured concentration of parameter

The accuracy of the benchtop chlorine, pH, TDS, and turbidity meters were checked daily during the calibration procedures using certified check standards. For samples analyzed in batches (gravimetric TDS, TOC, all challenge chemicals), certified QC standards and/or matrix spikes were run with each batch.

The percent recoveries of all matrix spikes and standards were within the allowable limits for all analytical methods.

5.7.3 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. One sample per batch was analyzed in duplicate for the gravimetric TDS, TOC and challenge chemical analyses. Duplicate drinking water samples were analyzed as part of the daily calibration process for the benchtop chlorine, pH, TDS, and turbidity meters.

Precision of the duplicate analyses was measured by use of the following equation to calculate relative percent deviation (RPD):

$$RPD = \left| \frac{S_1 - S_2}{S_1 + S_2} \right| \times 200$$

where:

S_1 = sample analysis result; and
S_2 = sample duplicate analysis result.

All RPDs were within NSF's established allowable limits for each parameter.

5.7.4 Completeness

Completeness is the proportion of valid, acceptable data generated using each method as compared to the requirements of the test/QA plan. The completeness objective for data generated during verification testing is based on the number of samples collected and analyzed for each parameter and/or method.

Table 5-1. Completeness Requirements

Number of Samples per Parameter and/or Method	Percent Completeness
0-10	80%
11-50	90%
> 50	95%

Completeness is defined as follows for all measurements:

$$\%C = (V/T) \times 100$$

where:

%C = percent completeness;
V = number of measurements judged valid; and
T = total number of measurements.

5.7.4.1 Number of Systems Tested

Twenty units were tested, as called for in the test/QA plan, giving a completeness measurement of 100% for this category.

5.7.4.2 Water Chemistry Measurements

One hundred percent of the planned samples were collected and reported for every parameter but TOC. During the carbon filter mercury challenge one TOC sample was missed. A total of 18 TOC samples were to be collected during the carbon filter challenges, plus six more during the carbon filter conditioning periods. The missed sample gives a completeness of 96%.

5.7.4.3 Challenge Chemicals

Five TDS samples were reported, but not included in the percent reduction calculations in Table 4-3 and Table 4-6 because there was likely a sampling error associated with the sample. The samples were the third tank unit 1 effluent sample from the inorganic chemicals challenge, and the start-up and third tank effluent TDS samples from both test units for the RO membrane fenamiphos challenge. These five TDS analyses were not included in the percent reduction calculations because they were all much higher than expected. The inorganic chemicals challenge third tank unit 1 effluent sample had a reported level of 760 mg/L, the same as the influent. The unit 1 TDS levels from the start-up and fifth tank samples were 30 mg/L and 29 mg/L, respectively, indicating that the unit was functioning properly, and that the third tank sample was an aberration.

Of the fenamiphos challenge effluent TDS samples in question, one result was equal to the influent (unit 2 start-up), while the other three were over 100 mg/L. The effluent fenamiphos levels from the same start-up and third tank sample points were at or near the detection limit of 2 μg/L, which indicates that the test units were functioning properly. Also, the fifth tank and post-rest effluent TDS sample results were all less than 15 mg/L. It is highly unlikely that the test units improved in performance over a matter of hours such that the effluent TDS levels dropped over tenfold. It is likely that there was a sampling error, or the samples were somehow contaminated. Discarding these five samples gives a completeness of 96% for this parameter.

One reject water sample from the inorganic chemicals challenge was likely subject to a dilution error, so the results were not used to calculate the mean reject water levels in Table 4-4. The reported cadmium, cesium, and strontium results for the "3/4 through 1st tank" sample are only the second duplicate sample. The first duplicate sample results were approximately twice as high as the second sample. The same sample was analyzed separately for mercury, and the first and second samples both gave results of 1200 μg/L. If the amount of the chemicals in the first sample was actually twice that of the second sample, it is likely that it also would have been evident in the mercury analysis. A total of eight reject water samples were collected during the inorganic chemicals challenge. The one sample whose results were discarded gives a completeness of 87.5% for the reject water samples.

Two challenge chemical data points in Table 4-5 are the mean of only two of the triplicate sample analyses, due to likely dilution errors during analysis. The unit 1 post-rest second sample from the chloroform reduction challenge is reported as 150 μg/L. This number is the mean of 120 μg/L and 180 μg/L. The third number triplicate analysis number is more than four times higher than the mean of 150 μg/L, at 690 μg/L. The start-up influent for dichlorvos is reported as 1000 μg/L. The two triplicate analyses constituting this mean are both 1000 μg/L. The third triplicate number not used is 540 μg/L, which is approximately half of the other two numbers. Both the 690 μg/L and 540 μg/L are reported in the appendix in Table A-5. The one sample result discarded for each chemical out of the 35 samples collected (excluding the reject water samples), gives a completeness percentage of 97%.

The samples for mevinphos analysis from that chemical's carbon filter challenge were improperly preserved with sodium thiosulfate instead of sodium sulfite. The sodium thiosulfate gave high sulfur levels in the samples, which caused a suppression of the internal standard added during the sample extraction process. This suppression in turn caused an exaggeration of the recovery standard during sample analysis, which made it impossible to accurately determine the Mevinphos levels in some of the effluent samples. Six samples were affected, out of a total of 63 that were collected during both the RO membrane and carbon filter mevinphos challenges. This corresponds to a completeness of 90% for mevinphos.

Chapter 6
References

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Appendix A

Conditioning and Chemical Challenges Data Tables

Table A-1. RO Membrane Conditioning Water Chemistry Data

Sample	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Group A Influent							
pH	7.1	7.4	7.5	7.4	7.4	7.6	7.2
Temperature (°C)	25	24	25	25	25	25	25
Total Chlorine (mg/L)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
TDS (mg/L)	750	770	760	750	740	770	760
Turbidity (NTU)	0.1	ND (0.1)	0.1	0.1	0.1	ND (0.1)	ND (0.1)
Group B Influent							
pH	7.3	7.2	7.4	7.4	7.5	7.4	7.1
Temperature (°C)	25	25	25	25	25	24	24
Total Chlorine (mg/L)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
TDS (mg/L)	770	750	740	740	740	770	750
Turbidity (NTU)	ND (0.1)	ND (0.1)	0.1	0.1	ND (0.1)	ND (0.1)	ND (0.1)
Group C Influent							
pH	7.4	7.8	7.5	7.4	7.4	7.4	7.1
Temperature (°C)	24	25	25	25	24	24	24
Total Chlorine (mg/L)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
TDS (mg/L)	770	750	740	740	740	760	740
Turbidity (NTU)	ND (0.1)	0.1	ND (0.1)	0.1	ND (0.1)	ND (0.1)	ND (0.1)
Group D Influent							
pH	7.5	7.1	7.2	7.3	7.4	7.5	7.2
Temperature (°C)	25	24	25	25	24	24	24
Total Chlorine (mg/L)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
TDS (mg/L)	770	760	730	750	730	750	740
Turbidity (NTU)	ND (0.1)	0.1	ND (0.1)	0.1	ND (0.1)	ND (0.1)	ND (0.1)

Table A-2. Post-Membrane Carbon Filter Conditioning Influent Water Data

Sample Point	Chloroform (µg/L)	pH	Temperature (°C)	Total Chlorine (mg/L)	Total Organic Carbon (mg/L)	Turbidity (NTU)
Group 1						
Start-up	360	7.5	21	2.5	2.5	ND (0.1)
125 gallons	310	7.6	21	2.3	2.5	ND (0.1)
250 gallons	290	7.6	22	2.8	2.4	0.2
Group 2						
Start-up	370	7.4	21	2.8	2.0	ND (0.1)
125 gallons	350	7.3	21	2.4	2.2	ND (0.1)
250 gallons	350	7.4	21	2.2	2.1	ND (0.1)

Table A-3. RO Membrane TDS reduction System Check Data

Sample	pH	Temperature (°C)	Total Chlorine (mg/L)	Turbidity (NTU)	Influent TDS (mg/L)	TDS Effluent Sample 1 (mg/L)	TDS Effluent Sample 2 (mg/L)	TDS Effluent Sample 3 (mg/L)	Percent Reduction
Group 1 Influent	7.4	25	ND (0.05)	ND (0.1)	760				
Unit 1						16	16	16	98%
Unit 2						16	16	16	98%
Unit 9						19	19	19	98%
Unit 10						18	18	18	98%
Unit 23						14	14	14	98%
Unit 24						15	16	16	98%
Group 2 Influent	7.4	25	ND (0.05)	ND (0.1)	750				
Unit 3						16	16	16	98%
Unit 4						12	11	12	99%
Unit 5						14	14	14	99%
Unit 6						11	11	11	99%
Unit 7						16	16	16	98%
Unit 8						18	18	18	98%
Group 3 Influent	7.3	25	ND (0.05)	ND (0.1)	750				
Unit 11						17	17	17	98%
Unit 12						13	13	13	98%
Unit 13						11	12	11	99%
Unit 14						14	15	14	98%
Unit 15						15	16	16	98%
Unit 16						14	15	15	98%
Group 4 Influent	7.4	25	ND (0.05)	ND (0.1)	760				
Unit 17						13	13	13	98%
Unit 18						12	12	12	98%
Unit 19						31	31	31	96%
Unit 20						15	15	15	98%
Unit 21						14	15	15	98%
Unit 22						15	15	15	98%

Table A-4. RO Membrane Inorganic Chemicals Challenge Data

Sample	Cadmium (μg/L)	Cesium (μg/L)	Mercury (μg/L)	Strontium (μg/L)
Start-up Influent				
Triplicate Sample 1	970	1000	1100	800
Triplicate Sample 2	1000	1000	1100	840
Triplicate Sample 3	1100	1100	1100	890
Mean	**1000**	**1000**	**1100**	**840**
Start-up Effluent, Unit 1				
Triplicate Sample 1	0.6	15	190	2
Triplicate Sample 2	0.6	15	200	2
Triplicate Sample 3	0.6	15	190	2
Mean	**0.6**	**15**	**190**	**2**
Start-up Effluent, Unit 2				
Triplicate Sample 1	1.8	32	450	2
Triplicate Sample 2	1.7	29	490	2
Triplicate Sample 3	1.9	31	450	2
Mean	**1.8**	**31**	**460**	**2**
3rd Tank Influent				
Triplicate Sample 1	1000	1100	1100	840
Triplicate Sample 2	1000	1000	1100	850
Triplicate Sample 3	1000	1000	1100	850
Mean	**1000**	**1000**	**1100**	**850**
3rd Tank Effluent, Unit 1				
Triplicate Sample 1	1.8	40	710	2
Triplicate Sample 2	1.7	40	730	2
Triplicate Sample 3	1.8	40	780	2
Mean	**1.8**	**40**	**740**	**2**
3rd Tank Effluent, Unit 2				
Triplicate Sample 1	2.6	51	780	3
Triplicate Sample 2	2.5	49	710	3
Triplicate Sample 3	2.4	51	780	3
Mean	**2.5**	**50**	**757**	**3**
5th Tank Influent				
Triplicate Sample 1	1000	1100	1100	860
Triplicate Sample 2	1000	1100	1100	860
Triplicate Sample 3	1000	1000	1100	850
Mean	**1000**	**1100**	**1100**	**860**
5th Tank Effluent, Unit 1				
Triplicate Sample 1	1.7	37	840	2
Triplicate Sample 2	1.7	37	780	2
Triplicate Sample 3	1.6	37	800	2
Mean	**1.7**	**37**	**810**	**2**
5th Tank Effluent, Unit 2				
Triplicate Sample 1	2.3	48	840	2
Triplicate Sample 2	2.3	48	870	2
Triplicate Sample 3	2.4	49	820	2
Mean	**2.3**	**48**	**840**	**2**
Post-Rest 1st Draw, Unit 1	1.8	38	730	2
Post-Rest 1st Draw, Unit 2	2.5	52	760	3
Post-Rest 2nd Sample, Unit 1				
Triplicate Sample 1	1.8	37	750	2
Triplicate Sample 2	1.8	38	740	2
Triplicate Sample 3	1.7	36	750	2
Mean	**1.8**	**37**	**750**	**2**
Post-Rest 2nd Sample, Unit 2				
Triplicate Sample 1	2.4	50	740	2
Triplicate Sample 2	2.4	49	750	2
Triplicate Sample 3	2.4	51	760	2
Mean	**2.4**	**50**	**750**	**2**

Table A-5. RO Membrane Organic Chemical Challenge Data

Sample	Aldicarb (µg/L)	Benzene (µg/L)	Carbofuran (µg/L)	Chloroform (µg/L)	Dicrotophos (µg/L)	Dichlorvos (µg/L)	Fenamiphos (µg/L)	Mevinphos (µg/L)	Oxamyl (µg/L)	Strychnine (µg/L)
Start-up Influent										
Triplicate Sample 1	940	1000	880	1000	1000	1200	600	1400	970	1100
Triplicate Sample 2	960	1100	890	1100	1000	890	620	1200	960	1100
Triplicate Sample 3	970	1200	920	1100	540[1]	1000	820	1300	970	1100
Mean	**960**	**1100**	**900**	**1100**	**1000**	**1000**	**680**	**1300**	**970**	**1100**
Start-up Effluent, Unit 1										
Triplicate Sample 1	4	ND (0.5)	ND (1)	0.7	ND (10)	27	ND (2)	14	3	14
Triplicate Sample 2	4	ND (0.5)	ND (1)	0.7	ND (10)	28	ND (2)	16	3	15
Triplicate Sample 3	4	ND (0.5)	ND (1)	0.8	ND (10)	25	ND (2)	14	3	15
Mean	**4**	**ND (0.5)**	**ND (1)**	**0.7**	**ND (10)**	**27**	**ND (2)**	**15**	**3**	**15**
Start-up Effluent, Unit 2										
Triplicate Sample 1	5	0.7	ND (1)	1.4	ND (10)	33	ND (2)	9.2	4	ND (5)
Triplicate Sample 2	5	0.7	ND (1)	1.3	ND (10)	35	ND (2)	16	4	ND (5)
Triplicate Sample 3	5	0.7	ND (1)	1.1	ND (10)	32	ND (2)	13	4	ND (5)
Mean	**5**	**0.7**	**ND (1)**	**1.3**	**ND (10)**	**33**	**ND (2)**	**13**	**4**	**ND (5)**
3rd Tank Influent										
Triplicate Sample 1	920	1200	970	1200	780	1100	1000	1500	990	1100
Triplicate Sample 2	980	1200	970	1100	830	1100	820	1100	980	1100
Triplicate Sample 3	960	1200	990	1200	620	1100	880	1200	980	1100
Mean	**920**	**1200**	**980**	**1200**	**740**	**1100**	**900**	**1300**	**980**	**1100**
3rd Tank Effluent, Unit 1										
Triplicate Sample 1	7	17	7	67	ND (10)	27	2	15	5	29
Triplicate Sample 2	7	20	7	80	ND (10)	25	2	16	5	29
Triplicate Sample 3	7	22	7	65	ND (10)	25	2	22	5	30
Mean	**7**	**20**	**7**	**71**	**ND (10)**	**26**	**2**	**18**	**5**	**29**
3rd Tank Effluent, Unit 2										
Triplicate Sample 1	8	20	5	100	ND (10)	23	3	20	5	ND (5)
Triplicate Sample 2	8	21	5	120	ND (10)	22	ND (2)	20	5	ND (5)
Triplicate Sample 3	8	20	5	110	ND (10)	20	3	24	5	ND (5)
Mean	**8**	**20**	**5**	**110**	**ND (10)**	**22**	**3**	**21**	**5**	**ND (5)**
5th Tank Influent										
Triplicate Sample 1	1000	1100	990	1100	800	1200	640	1200	1000	1100
Triplicate Sample 2	990	980	980	1200	800	1200	720	1300	1000	1100
Triplicate Sample 3	960	1200	970	1100	770	1100	590	2000	1000	1100
Mean	**980**	**1100**	**980**	**1100**	**790**	**1200**	**650**	**1500**	**1000**	**1100**
5th Tank Effluent, Unit 1										
Triplicate Sample 1	8	68	7	230	ND (10)	17	3	19	5	32
Triplicate Sample 2	8	70	7	220	ND (10)	16	2	20	5	32
Triplicate Sample 3	8	64	7	230	ND (10)	22	ND (2)	17	5	33
Mean	**8**	**67**	**7**	**230**	**ND (10)**	**18**	**2**	**19**	**5**	**32**
5th Tank Effluent, Unit 2										
Triplicate Sample 1	8	69	6	340	ND (10)	14	ND (2)	23	5	7
Triplicate Sample 2	8	83	6	310	ND (10)	15	ND (2)	18	5	7
Triplicate Sample 3	8	82	6	300	ND (10)	18	2	24	5	6
Mean	**8**	**78**	**6**	**320**	**ND (10)**	**16**	**2**	**22**	**5**	**7**
Post-Rest 1st Draw, Unit 1	8	96	7	260	ND (10)	31	2	12	5	34
Post-Rest 1st Draw, Unit 2	8	85	6	310	ND (10)	19	ND (2)	21	4	6
Post-Rest 2nd Sample, Unit 1										
Triplicate Sample 1	8	68	7	690[1]	ND (10)	17	4	19	5	32
Triplicate Sample 2	7	57	7	120	ND (10)	21	3	21	5	33
Triplicate Sample 3	8	58	7	180	ND (10)	23	3	21	5	33
Mean	**8**	**61**	**7**	**150**	**ND (10)**	**20**	**3**	**20**	**5**	**33**
Post-Rest 2nd Sample, Unit 2										
Triplicate Sample 1	8	54	6	290	ND (10)	20	3	24	5	6
Triplicate Sample 2	8	49	6	250	ND (10)	23	3	21	5	6
Triplicate Sample 3	8	42	6	220	ND (10)	27	3	24	5	6
Mean	**8**	**48**	**6**	**250**	**ND (10)**	**23**	**3**	**23**	**5**	**6**

(1) Sample results not included in mean calculations. See section 5.7.4.3 for discussion.

Table A-6. RO Membrane Challenge Water Chemistry Data

Sample	Inorganics Challenge	Aldicarb Challenge	Benzene Challenge	Carbofuran Challenge	Chloroform Challenge	Dicrotophos Challenge	Dichlorvos Challenge	Fenamiphos Challenge	Mevinphos Challenge	Oxamyl Challenge	Strychnine Challenge
Start-up Influent											
pH	6.3	7.6	7.5	7.4	7.4	7.8	7.3	7.7	7.8	7.6	7.7
Temperature (°C)	25	25	25	25	25	25	25	25	25	25	25
Total Chlorine (mg/L)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
Turbidity (NTU)	ND (0.1)	ND (0.1)	ND (0.1)	0.1	0.1	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)
5th Tank Influent											
pH	6.2	7.6	7.7	7.3	7.5	7.4	7.1	7.4	7.6	7.6	7.4
Temperature (°C)	25	25	25	25	25	25	25	25	25	25	25
Total Chlorine (mg/L)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
Turbidity (NTU)	ND (0.1)	ND (0.1)	ND (0.1)	0.1	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)

Table A-7. RO Membrane Inorganic Chemicals Challenge Reject Water Data

Sample	Cadmium (μg/L)	Cesium (μg/L)	Mercury (μg/L)	Strontium (μg/L)
Start-up				
Duplicate Sample 1	2000	2000	1200	1700
Duplicate Sample 2	2100	2000	1200	1700
Mean	**2100**	**2000**	**1200**	**1700**
1/2 Through First Tank				
Duplicate Sample 1	1800	1700	1200	1400
Duplicate Sample 2	1700	1700	1300	1400
Mean	**1800**	**1700**	**1300**	**1400**
3/4 Through First Tank				
Duplicate Sample 1	3400(1)	3600(1)	1200	3300(1)
Duplicate Sample 2	1700	1700	1200	1400
Mean	**1700**	**1700**	**1200**	**1400**
1/2 Through 5th Tank				
Duplicate Sample 1	1400	1400	1200	1100
Duplicate Sample 2	1500	1500	1200	1200
Mean	**1500**	**1500**	**1200**	**1200**

(1) Sample results not included in mean calculations. See section 5.7.4.3 for discussion.

Table A-8. RO Membrane Organic Chemical Challenge Reject Water Data

Sample	Aldicarb (μg/L)	Benzene (μg/L)	Carbofuran (μg/L)	Chloroform (μg/L)	Dicrotophos (μg/L)	Dichlorvos (μg/L)	Fenamiphos (μg/L)	Mevinphos (μg/L)	Oxamyl (μg/L)	Strychnine (μg/L)
Start-up										
Duplicate Sample 1	1800	1000	1300	990	1900	2600	1300	1900	1700	1900
Duplicate Sample 2	1800	940	1300	970	850	2700	1700	2000	1700	1900
Mean	**1800**	**970**	**1300**	**980**	**1400**	**2700**	**1500**	**2000**	**1700**	**1900**
1/2 Through First Tank										
Duplicate Sample 1	1400	1100	1600	1000	840	1700	1300	2300	1500	1800
Duplicate Sample 2	1500	1100	1600	980	1600	1800	1400	1800	1500	1800
Mean	**1500**	**1100**	**1600**	**990**	**1200**	**1800**	**1400**	**2100**	**1500**	**1800**
3/4 Through First Tank										
Duplicate Sample 1	1400	890	1500	940	1500	1900	1100	1800	1500	1700
Duplicate Sample 2	1500	1100	1400	1000	1800	1600	1300	1700	1500	1700
Mean	**1500**	**1000**	**1500**	**970**	**1700**	**1800**	**1200**	**1800**	**1500**	**1700**
1/2 Through 5th Tank										
Duplicate Sample 1	1400	980	1400	1100	940	1200	930	1500	1300	1400
Duplicate Sample 2	1400	960	1300	970	810	1400	1300	1300	1300	1500
Mean	**1400**	**970**	**1400**	**1000**	**880**	**1300**	**1100**	**1400**	**1300**	**1500**

Table A-9. Post-Membrane Carbon Filter Challenge Data

Sample	Mercury (μg/L)	Benzene (μg/L)	Chloroform (μg/L)	Dichlorvos (μg/L)	Mevinphos (μg/L)	Strychnine (μg/L)
Target Influent Level	840	96	320	33	23	30
Start-up Influent						
Triplicate Sample 1	860	76	330	26	21	37
Triplicate Sample 2	840	87	310	29	21	37
Triplicate Sample 3	800	87	330	28	20	37
Mean	**830**	**83**	**320**	**28**	**21**	**37**
Start-up Effluent, Unit 1						
Triplicate Sample 1	1.5	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 2	1.4	ND (0.5)	ND (0.5)	ND (0.2)	X	ND (5)
Triplicate Sample 3	1.3	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Mean	**1.4**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
Start-up Effluent, Unit 2						
Triplicate Sample 1	1.8	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 2	1.6	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 3	1.6	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Mean	**1.7**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
7.5 Hours Influent						
Triplicate Sample 1	1100	83	310	28	19	27
Triplicate Sample 2	1000	79	290	30	18	28
Triplicate Sample 3	1100	83	300	27	20	28
Mean	**1100**	**82**	**300**	**28**	**19**	**28**
7.5 Hours Effluent, Unit 1						
Triplicate Sample 1	3.4	ND (0.5)	ND (0.5)	ND (0.2)	X	ND (5)
Triplicate Sample 2	3.4	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 3	3.5	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Mean	**3.4**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
7.5 Hours Effluent, Unit 2						
Triplicate Sample 1	3.6	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 2	3.6	ND (0.5)	ND (0.5)	ND (0.2)	X	ND (5)
Triplicate Sample 3	3.6	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Mean	**3.6**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
15 Hours Influent						
Triplicate Sample 1	960	78	330	31	21	27
Triplicate Sample 2	990	85	340	31	22	27
Triplicate Sample 3	960	93	330	30	21	27
Mean	**970**	**85**	**330**	**31**	**21**	**27**
15 Hours Effluent, Unit 1						
Triplicate Sample 1	2.7	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 2	2.9	ND (0.5)	ND (0.5)	ND (0.2)	X	ND (5)
Triplicate Sample 3	2.9	ND (0.5)	ND (0.5)	ND (0.2)	X	ND (5)
Mean	**2.8**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**
15 Hours Effluent, Unit 2						
Triplicate Sample 1	3.1	ND (0.5)	ND (0.5)	ND (0.2)	X	ND (5)
Triplicate Sample 2	3.0	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Triplicate Sample 3	3.0	ND (0.5)	ND (0.5)	ND (0.2)	ND (0.2)	ND (5)
Mean	**3.0**	**ND (0.5)**	**ND (0.5)**	**ND (0.2)**	**ND (0.2)**	**ND (5)**

X – No analysis result due to sampling error. See section 5.7.4.3 for further discussion

Table A-10. Post-Membrane Carbon Filter Challenge Water Chemistry Data

Sample	Mercury Challenge	Benzene Challenge	Chloroform Challenge	Dichlorvos Challenge	Mevinphos Challenge	Strychnine Challenge
Start-up Influent						
pH	7.5	7.3	7.4	7.3	7.4	7.2
Temperature (°C)	20	20	20	20	20	21
Total Chlorine (mg/L)	2.5	2.6	2.3	2.6	2.7	2.3
TOC (mg/L)	2.4	2.0	2.5	2.4	2.4	2.1
TDS (mg/L)	310	290	320	290	290	320
Turbidity (NTU)	0.1	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	0.1
7.5 Hour Influent						
pH	7.4	7.3	7.4	7.3	7.5	7.4
Temperature (°C)	20	20	20	20	20	20
Total Chlorine (mg/L)	2.2	2.1	2.7	2.8	1.8	2.5
TOC (mg/L)	#	1.9	2.2	2.3	2.3	2.1
TDS (mg/L)	290	310	280	280	300	310
Turbidity (NTU)	ND (0.1)	ND (0.1)	ND (0.1)	0.1	0.2	0.1
15 Hour Influent						
pH	7.5	7.3	7.5	7.3	7.3	7.3
Temperature (°C)	21	20	21	20	20	21
Total Chlorine (mg/L)	2.6	2.4	2.5	2.7	2.1	2.4
TOC (mg/L)	2.2	2.0	2.2	2.4	2.6	2.1
TDS (mg/L)	200	290	300	290	300	300
Turbidity (NTU)	ND (0.1)	0.1	ND (0.1)	ND (0.1)	0.3	0.1

Technician missed sample collection