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:	**ECOWATER SYSTEMS ERO-R450E**
COMPANY:	**ECOWATER SYSTEMS, INC.**
ADDRESS:	**1890 WOODLANE DRIVE**
	WOODBURY, MN 55125
PHONE:	**800-808-9899**
EMAIL:	**INFO@ECOWATER.COM**

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 EcoWater Systems ERO-R450E 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 EcoWater Systems ERO-R450E 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 ERO-R450E employs a reverse osmosis (RO) membrane and activated carbon filters to treat drinking water. Treated water is stored in a 3.1-gallon capacity storage tank. The system was first tested with only the RO membrane component in place. The target challenge concentration for each chemical for the RO membrane tests was 1 mg/L. Following the RO membrane challenges, the post-membrane carbon filter component was challenged alone with each organic chemical the RO membrane did not remove to below 30 μg/L. The carbon filter was also challenged with cesium and mercury because the membranes did not remove these two substances as well as total dissolved solids (TDS) in general. The target challenge concentration for the carbon filter tests 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 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. The 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 ERO-R450E as a whole, considering both the RO membrane challenge and post-membrane carbon filter challenge results combined, reduced all of the challenge chemicals but cesium by 94% or more.

TECHNOLOGY DESCRIPTION

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

The ERO-R450E is a three-stage POU drinking water treatment system, employing an RO membrane, and activated carbon filters both upstream and downstream of the membrane. The system includes a 3.1-gallon maximum capacity pressurized bladder tank for storing the treated water, and a faucet to mount on the kitchen sink. The influent water first passes through a carbon filter designed to remove chlorine and particulate matter, such as rust and silt. The second stage of treatment is the reverse osmosis membrane, which reduces a wide variety of contaminants. The permeate water is sent to the storage tank. When the user opens the faucet, the partially treated water leaves the storage tank, passes through a second carbon filter to remove organic chemicals and any taste and odor chemicals, and then exits the faucet.

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.

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 November 2004 through March 2005.

Methods and Procedures

Verification testing followed the procedures and methods detailed in the *Test/QA Plan for Verification Testing of the EcoWater Systems ERO-R450E 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 evaluated.

The system was first tested with only the RO membrane component in place. The complete ERO-R450E system, including the storage tank, was used for the RO membrane challenges, but the carbon filters were removed, leaving empty housings. 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 membrane test units 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 or membrane seals. One pair of RO membrane components was also challenged with the inorganic chemicals. The inorganic chemical challenges were conducted prior to the organic chemical challenges to eliminate the possibility of damage to the membranes that could bias the inorganic chemical test results. The reduction of TDS was also measured during the challenges to evaluate whether any organic chemicals damaged the membrane material or membrane seals.

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 challenge testing, the RO membrane components were service-conditioned for seven days by feeding the systems the 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, the post-membrane carbon filters were challenged with the chemicals that the RO membranes did not remove to below 30 μg/L. The carbon filter was also challenged with cesium and mercury because the membranes did not remove these two substances as well as total dissolved solids (TDS) in general. The filters were attached to a separate manifold that was of the same design as the manifold in the full RO system. The pre-membrane carbon filter was not tested because it is only designed to remove chlorine to protect the RO membrane. Two carbon filters 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 possible contaminant 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 375 gallons (EcoWater System's design capacity for the filter is 750 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 94% or more of all challenge chemicals except cesium and mercury. The membrane removed 82% of cesium, and only 9% of the mercury challenge.

Table 2. RO Membrane Challenge Data

Chemical	Mean Influent (μg/L)	Mean Effluent (μg/L)	Percent Reduction (%)
Cadmium	960	33	97
Cesium	930	170	82
Mercury	1100	1000	9
Strontium	960	33	97
Aldicarb	1000	20	98
Benzene	980	7.1	> 99
Carbofuran	1100	19	98
Chloroform	1100	61	94
Dichlorvos	1300	69	95
Dicrotophos	1100	57	95
Fenamiphos	930	4	> 99
Mevinphos	1200	46	96
Oxamyl	980	10	99
Strychnine	1100	10	> 99

The TDS reduction by each membrane component for all challenge tests was 87% or higher. The effluent TDS levels for some of the chemical challenges rose from one sample point to the next over the challenge period, but no TDS levels were significantly higher than the maximum TDS levels measured during TDS reduction tests conducted on each unit after conditioning. Thus, the rising TDS levels likely do not

indicate that the membrane components were becoming significantly compromised due to exposure to the chemicals. The increase may have been due to the challenge protocol design. The challenges began with empty storage tanks, so there was no back-pressure on the membranes when the start-up samples, which all had the lowest observed TDS levels, were collected. Most of the challenge chemical levels were also lowest in the start-up samples. The rest of the samples were collected after the membranes had been operating facing back-pressure from the storage tanks. RO membranes perform better without back-pressure, so the higher TDS levels are likely more indicative of the performance of the RO system under normal operating conditions.

The post-membrane carbon filter components were challenged with chloroform, dichlorvos, dicrotophos, and mevinphos based on the criteria that the RO membrane challenge effluents were above 30 μg/L. The carbon filters were also challenged with cesium and mercury. The target challenge levels were the maximum effluent levels measured during the RO membrane challenges. The carbon filters were operated at 1.15 gpm on an operating cycle where the "on" portion was five minutes and eleven seconds, and the "off" portion was one hour and ten minutes.

The carbon challenge results are shown below in Table 3. Note that the percent reduction of dicrotophos was limited by the detection limit for the chemical. The carbon filter removed 89% or more of all of the challenge chemicals but cesium, which was effectively not removed at all by the carbon.

Table 3. Post-Membrane Carbon Filter Challenge Data

Chemical	Mean Influent (μg/L)	Mean Effluent (μg/L)	Percent Reduction (%)
Cesium	230	220	4.3
Mercury	760	35	95
Chloroform	100	0.7	> 99
Dichlorvos	100	3.9	96
Dicrotophos	90	ND (10)	89
Mevinphos	40	2.1	95

The RO membrane and carbon challenge data combined shows that the two treatment technologies working in concert within the ERO-R450E system removed 97% or more of all challenge chemicals but cesium.

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

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, 10/25/05	*Original signed by Robert Ferguson, 11/07/05*
Andrew P. Avel Date	Robert Ferguson Date
Acting Director	Vice President
National Homeland Security Research Center	Water Systems
United States Environmental Protection Agency	NSF International

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Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 04/14b/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)