THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**MEMBRANE FILTRATION USED IN PACKAGED DRINKING WATER TREATMENT SYSTEMS**
APPLICATION:	**PHYSICAL REMOVAL OF PARTICULATE CONTAMINANTS IN ESCONDIDO, CALIFORNIA**
TECHNOLOGY NAME:	**ULTRAFILTRATION SYSTEM MODEL A35**
COMPANY:	**AQUASOURCE NORTH AMERICA**
ADDRESS:	**PO BOX 70295** **RICHMOND, VA 23255-0295**
PHONE:	**(804) 672-8160**
FAX:	**(804) 672-8135**
WEB SITE:	**http:\\www.infilcodegremont.com**
EMAIL:	**DimitriouM@idi-online.com**

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

ETV works in partnership with recognized standards and testing organizations; stakeholders groups which consist 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.

NSF International (NSF) in cooperation with the EPA operates the Drinking Water Treatment Systems (DWTS) Pilot, one of 12 technology areas under ETV. The DWTS Pilot recently evaluated the performance of an ultrafiltration membrane system used in package drinking water treatment system applications. This verification statement provides a summary of the test results for the Aquasource Ultrafiltration System Model A35 (Aquasource UF unit). Montgomery Watson, a NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of the Aquasource UF unit was conducted over two test periods at the Aqua 2000 Research Center in San Diego, California. The first test period, from March 5,1999 to April 19, 1999 represented winter/spring conditions. The second test period, from August 25, 1999 to September 28, 1999 represented summer/fall conditions. The source water was a blend of Colorado River and State Project Water. Verification testing was conducted at manufacturer specified operating conditions. The membrane unit was operated at a constant flux of 60 gfd (100 L/hr-m^2) with feedwater recoveries ranging from 88 to 94 percent, depending on the backwash frequency. During Test Period 1, membrane fouling due to algae bloom was observed towards the end of the operating period. During Test Period 2, the system ran without any noticeable loss of specific flux. The manufacturer recommended cleaning procedure was effective in recovering membrane productivity. The membrane system achieved significant removal of particulate contaminants and bacteria (described later).

TECHNOLOGY DESCRIPTION

The Aquasource UF unit is comprised of two M1A35 hollow fiber UF membrane modules mounted on a transportable skid. The skid is constructed of reinforced fiberglass and steel, and can be shipped by truck. The unit is completely self-contained, including all the components required for operation. The only connections to the Aquasource UF unit are a raw water connection to the feed pump, drain lines for filtrate tank overflow and backwash waste, and electrical power. The unit requires approximately 30 ft^2 (2.8 m^2) of floor space.

The Aquasource UF unit has an Allen Bradley touchscreen programmable logic controller (PLC). The touchscreen includes schematic displays of the treatment train showing which pumps are operating and which valves are open. The PLC maintains a constant filtrate flow during filtration by automatically adjusting feed pump speed and controls pumps and valves during backwash. The operating parameters for the Aquasource UF unit are adjusted by entering values in screens of the PLC touchscreen. The Aquasource unit has electronic flow, pressure and temperature measurement and a data logger which stores operating information digitally. This information can be accessed both locally, with a personal computer connected by cable, or remotely over phone lines.

The Aquasource UF unit has two alternating operating modes. These are filtration and backwash. During filtration, raw water is driven under pressure through pores in the UF membrane. Treated water is collected from the filtrate side of the membrane. At the end of the filtration cycle, the system initiates a backwash. During backwash, the feed pump shuts down, valves are repositioned, and the backwash pump starts. The backwash pump draws treated water from the filtrate storage tank, chlorinates it, and forces the water under pressure in the reverse direction through the fibers. With the flow of water now from the outside of the fiber to the inside of the fiber, the backwash water exits the inside of the fibers at the fiber ends, carrying with it particulate material accumulated during filtration. Chlorine added to the backwash water assists in oxidizing organics that have accumulated on the membrane surface. The long-term operation of the package unit frequently results in the accumulation of materials on the membrane surface which are not effectively removed by backwash. This is called membrane fouling and is quantified by a gradual increase in the pressure required to maintain the desired flux. Once a critical upper pressure has been reached, normal operation is discontinued and the membrane undergoes chemical cleaning. Chemical cleaning involves the use of detergent and chlorine solutions to restore efficient operation of the membrane.

The Aquasource UF unit has two M1A35 membrane modules. These 4 inch (10 cm) diameter modules use the same fiber as the larger surface area L1B35 modules which are used in full-scale applications. The M1A35 is a hollow fiber configuration, manufactured from a cellulose acetate derivative, with

nominal molecular weight cut-off of 100,000 Daltons. This corresponds with a pore diameter of approximately 0.01 micron.

VERIFICATION TESTING DESCRIPTION

Test Site

The verification test site was the City of San Diego's Aqua 2000 Research Center at 14103 Highland Valley Road in Escondido, California. The Research Center includes office and lab trailers, a covered concrete test pad and a dedicated operations staff with substantial membrane experience. The source water for testing was Lake Skinner water via the San Diego Aqueduct. Lake Skinner water consists of Colorado River water and State Project water, two of the major raw drinking water supplies in Southern California.

Methods and Procedures

Turbidity, pH, chlorine and temperature analyses were conducted daily at the test site according to Standard Methods for the Examination of Water and Wastewater, 19th Ed. (APHA, et. al., 1995). Standard Methods, 19th Ed. (APHA, 1995) and Methods for Chemical Analysis of Water and Wastes (EPA, 1979) were used for analyses conducted at The City of San Diego Laboratory. These included alkalinity, total and calcium hardness, total dissolved solids (TDS), total suspended solids (TSS), total organic carbon (TOC), ultraviolet absorbance at 254 nanometers (UV254), total coliform and heterotrophic plate count (HPC). Total and calcium hardness analyses were conducted every other week. All other analyses were conducted weekly. Online Hach 1900 WPC particle counters and 1720D turbidimeters continuously monitored these parameters in both the raw water and membrane system filtrate. The particle counters were set up to enumerate particle counts in the following size ranges: 2-3 um, 3-5 um, 5-15 um, and > 15 um. Data from the online particle counters and turbidimeters were stored at 1-minute intervals on a computer. Simulated distribution system (SDS) disinfection-by-product (DBP) formation tests were conducted during each test period. For this testing, the uniform formation conditions of the EPA Information Collection Rule were followed. DBP analyses were conducted according to EPA Method 502.2 for trihalomethanes and EPA Method 552.2 for haloacetic acids.

VERIFICATION OF PERFORMANCE

System Operation

Verification testing was conducted at manufacturer specified operating conditions. The membrane unit was operated at a constant flux of 60 gfd (100 L/hr-m^2) with feedwater recoveries ranging from 88 to 94 percent, depending on the backwash frequency. The PLC automatically maintained constant flux by increasing pump speed as transmembrane pressure increased due to fouling. Backwash frequency was initially set to every 60 minutes, but was increased to every 30 minutes near the end of Test Period 1 because of fouling due to algae. Backwash volume was consistent, averaging 24 gallon (90 L) over both test periods. Backwash chlorine concentration averaged 7 mg/L over both test periods. The system initially ran for 31 days in Test Period 1 with decrease in specific flux from 12 to 8.5 gfd/psi (300 to 210 L/hr-m^2). It then fouled to specific flux 4.8 gfd/psi (70 L/hr-m^2/bar) over a period of 7 day likely due to an algae bloom in the source water. After cleaning, the unit fouled overnight at the same operation conditions, again due to algae. The system was cleaned a second time and put into service at reduced flux of 51 gfd (87 L/hr-m^2) and backwash frequency of every 30 minutes. The unit ran for three days under these conditions until Test Period 1 was terminated. The system ran all of Test Period 2 at an average specific flux of 12 gfd/psi (300 L/hr-m^2/bar) and no loss of specific flux was observed throughout the testing period.

Membrane cleaning was performed according to manufacturer recommended procedure. Proprietary cleaning solutions were prepared in a 5-gallon cleaning tank and recirculated across the feed side of the membrane at approximately 50 gpm (190 lpm). Flux-pressure profiles were performed after each cleaning step to evaluate recovery of specific flux. The manufacturer recommended cleaning procedure was effective in recovering specific flux. Loss of original, new membrane flux was 21 percent after the first cleaning in Test Period 1 and only increased to 22 percent after the second cleaning in Test Period 1. Specific flux was recovered to new membrane conditions upon cleaning at the end of Test Period 2, possibly due to warmer weather conditions, and hence warmer cleaning solutions.

Air pressure-hold tests were conducted near the beginning and end of each test period to assess membrane integrity. Air pressure-hold tests were conducted by opening the feed side of the membrane to atmosphere and pressurizing the filtrate side of the membrane. Once pressurized, the loss of held pressure on the filtrate side was monitored over 10 minutes. All air pressure-hold tests had minimal loss (< 1 psi every 5 minutes) of held pressure, indicating the membranes were intact during both test periods.

Source Water Results

The source water for the ETV testing consisted of a blend of Colorado River water and State Project water delivered to the test site via the San Diego Aqueduct. The source water had the following average water quality during the two test periods: TDS 500/500 mg/L, hardness 240/230 mg/L, alkalinity 120/120 mg/L, TOC 2.5/3.6 mg/L, pH 8.3/8.2, temperature 17/28 and turbidity 1.3/1.4 NTU.

Particle Removal Results

Total suspended solids in the filtrate were removed to below the detection limit for the analysis (1 mg/L), for all samples analyzed. Filtrate turbidity was 0.05 NTU or less 95 percent of the time. The test system removed greater than 3 logs of both Cryptospordium-sized (3-5 um) particles and Giardia-sized (5-15 um) particles, 95 percent of the time. Four hour average raw water and filtrate particle levels and daily average particle removal in these size ranges for Test Periods 1 and 2 are presented in the following table:

Aquasource M1A35 UF System Particle Concentrations and Particle Removals for Test Periods 1/2

	3-5 um Particles			5-15 um Particles		
	Raw Water (#/mL)	Filtrate (#/mL)	Log Removal	Raw Water (#/mL)	Filtrate (#/mL)	Log Removal
Average	2300/2000	0.15/0.26	4.1/4.0	1400/1200	0.11/0.21	4.1/3.8
Standard Deviation	630/490	0.08/0.19	0.16/0.29	650/520	0.06/0.18	0.23/0.33
95% Confidence Interval	2200-2400/ 1900-2100	0.14-0.16/ 0.25-0.29	4.0-4.2/ 3.9-4.1	1300-1500/ 1100/1300	0.10-0.12/ 0.13-0.24	4.0-4.2/ 3.7-3.9
Minimum	640/780	0.06/0.08	3.8/3.4	290/290	0.05/0.06	3.7/3.2
Maximum	5200/5000	0.83/0.89	4.5/4.4	3900/5800	0.62/1.3	4.6/4.4

Microbial Removal Results

Total Coliforms and HPC were analyzed on a weekly basis during both ETV test periods. Raw water total coliforms averaged 15 and 57 MPN/100mL during Test Periods 1 and 2, respectively. No total coliforms were detected in the filtrate. HPC were significantly reduced. HPC averaged 120 and 640 cfu/mL in the raw water for Test Periods 1 and 2. Filtrate levels of HPC averaged 1 and 70 cfu/mL. The presence of HPC in the filtrate is most likely due to growth of bacteria in the filtrate piping rather than passage of bacteria through the membrane.

Disinfection by-Product Precursor Removal Results

The Aquasource UF unit demonstrated no significant removal of simulated distribution system (SDS) disinfection-by-product (DBP) precursor materials. From the data collected (one comparison per test period), and the variability of TTHM and HAA testing, the SDS DBP results do not demonstrate any reduction in these DBPs.

Operation and Maintenance Results

Operation was initiated by entering the target flow and backwash frequency in the appropriate PLC touchscreen. These parameters were automatically maintained at set levels by the system controls. Backwash times were manually adjusted on the PLC touchscreen to achieve a backwash volume of approximately 24 gallon (90 liter). Backwash pump speed was manually adjusted on the variable frequency drive controller to achieve a backwash pressure of between 36 and 40 psi (2.5 and 2.8 bar). As the membrane system fouled, the backwash volume tended to decrease and backwash pressure tended to increase, so these parameters required manual readjustment with the time interval between readjustment depending on rate of specific flux loss. The sodium hypochlorite dosing pump required initial manual adjustment to achieve a target chlorine dose in the backwash water of 5-8 mg/L.

Operation of the membrane unit consumed 0.08 gal (0.30 L) of 10% sodium hypochlorite per day to chlorinate backwash water. No other chemicals were consumed during routine operation of the system. During a typical chemical cleaning, 2.7 pounds (1.2 kg) of a proprietary formula were consumed in both prewash and wash steps. The manufacturer supplied an Operations and Maintenance manual that was helpful in explaining the setup, operation and maintenance of the ETV test system.

Original Signed by
E. Timothy Oppelt *9/28/00*

E. Timothy Oppelt
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original Signed by
Tom Bruursema *10/17/00*

Tom Bruursema
General Manager
Environmental and Research Services
NSF International

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants*, dated April 20, 1998 and revised May 14, 1999, the Verification Statement, and the Verification Report (NSF Report #00/03/EPADW395) are available from the following sources:
(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

1. Drinking Water Treatment Systems ETV Pilot Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)