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:	***GIARDIA* AND *CRYPTOSPORIDIUM* REMOVAL**		
TECHNOLOGY NAME:	**MODEL A35 ULTRAFILTRATION SYSTEM**		
TEST LOCATION:	**PITTSBURGH, PA**		
COMPANY:	**AQUASOURCE NORTH AMERICA**		
ADDRESS:	**2924 EMERYWOOD PARKWAY** **RICHMOND, VA 23060**	PHONE: FAX:	**(804) 672-8160** **(804) 672-8135**
WEB SITE:	**http:\\www.infilcodegremont.com**		
EMAIL:	**beamguardm@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 Package Drinking Water Treatment Systems (PDWTS) program, one of 12 technology areas under ETV. The PDWTS program recently evaluated the performance of a membrane filtration system used in package drinking water treatment system applications. This verification statement provides a summary of the test results for the Aquasource North America Model A35 Ultrafiltration System. Gannett Fleming, Inc., an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of the Aquasource Ultrafiltration Treatment System Model A35 was conducted from December 1 to December 31, 1998. The treatment system underwent microbial challenge testing on January 22, 1999, and demonstrated a 5.5 $\log_{10}$ removal of *Giardia* cysts and a 6.5 $\log_{10}$ removal of *Cryptosporidium* oocysts. Source water characteristics were: turbidity average 0.078 Nephlometric Turbidity Units (NTU), pH 8.5, and temperature 8.0°C. During the thirty-day verification test, the system was operated at a flux recommended by the manufacturer of 112 liter per square meter per hour ($l/m^2/h$) (65.9 gallon per square foot per day [gfd]) at 8.0°C which equates to 155 $l/m^2/h$ at 20 °C (91.2 gfd at 68°F). The average transmembrane pressure was 0.65 bar (b) (9.4 pounds per square inch [psi]). The feed water recovery of the treatment system during the study was 94%. Chemical cleaning of the treatment system was conducted as part of the verification testing.

TECHNOLOGY DESCRIPTION

Ultrafiltration (UF) processes are generally used to remove microbial contaminants such as *Giardia* and *Cryptosporidium* and other particulate contaminants from drinking water. The Aquasource UF membrane is a hollow fiber made of cellulose acetate. It has a 0.02µm nominal pore size and utilizes inside-out flow. Water is applied under pressure to the inside of the hollow fiber membrane. The membrane consists of a thin film acting as a sieve. The membrane is a physical barrier, providing removal of particulate contaminants. Permeate (filtered water) is collected from the outside of the fiber and carried to the permeate outlet.

The Aquasource Ultrafiltration Treatment System Model A35 system is a skid mounted, stand alone system. The required connections are for the water supply, a sewer connection for the discharge of backwash and chemical cleaning wastes and electrical service. The treatment system consists of two membrane modules, supply pump, backwash reservoir and pump, chemical cleaning equipment and necessary gauges and controls. The unit is equipped with a 200 µm prefilter to remove large debris from the feed water prior to introduction to the membranes. The treatment system is capable of operating in an automatic mode with limited operator intervention.

For this test program, a dead end flow configuration was used. The particles that are removed from the feed water clog the hollow fiber membrane. At a preset time, determined by raw water quality, the treatment system was backwashed. This was accomplished by reversing the flow direction and forcing the permeate back through the fibers from outside to inside. The permeate was chlorinated using a small diaphragm pump which adds sodium hypochlorite to the permeate prior to backwash. During backwash, the particles were removed and the backwash water was carried to waste.

VERIFICATION TESTING DESCRIPTION

Test Site

The verification testing site was the Pittsburgh Water and Sewer Authority's (PWSA's) open air Highland Reservoir No. 1, Pittsburgh, Pennsylvania. The source water for the verification testing was treated surface water drawn from the Allegheny River. It underwent coagulation with ferric chloride, sedimentation, filtration, and disinfection using free chlorine at PWSA's Aspinwall treatment plant prior to being pumped to the Highland Reservoir No. 1. The influent to the treatment unit was drawn from the reservoir effluent lines. The verification testing was limited to the performance of the equipment to remove *Cryptosporidium* oocysts and *Giardia* cysts, because the source water was obtained from an open reservoir.

Methods and Procedures

All field analyses (i.e. pH, turbidity, chlorine residual, temperature) were conducted daily using portable field equipment according to Standard Methods for the Examination of Water and Waste Water, 18th Ed., (APHA, et. al., 1992). Likewise, Standard Methods, 18th Ed., (APHA, 1992) and Methods for Chemical Analysis of Water and Wastes (EPA, 1979) were used for analyses conducted in PWSA's laboratory. These analyses included total alkalinity, total hardness, total organic carbon (TOC), dissolved organic carbon (DOC), total dissolved solids (TDS), total suspended solids (TSS), algae (number and species), Ultraviolet Absorbance at 254 nanometers (UVA_{254}), total coliform, and heterotrophic plate counts (HPC). Total alkalinity, total hardness and TDS analyses were conducted monthly. All other laboratory parameters were analyzed weekly.

Microbial challenge was performed using *Giardia* cysts and *Cryptosporidium* oocysts. Procedures developed by EPA for use during the Information Collection Rule (ICR) were employed for the identification and enumeration of *Giardia* cysts and *Cryptosporidium* oocysts (EPA, ICR Microbial Laboratory Manual, EPA, April 1996). The protozoans were added to a fifty (50) gallon (190 liter) drum. This drum was filled with the feed water. A total of 8,720,000 of *Giardia* cysts and 91,770,000 of *Cryptosporidium* oocysts were added to the feed water reservoir. The turbidity of the feed water was 0.09 NTU during the microbial removal challenge testing. This stock suspension was constantly mixed using a drum mixer. A diaphragm pump was used to add the protozoans to the membranes on the pilot unit. The pump was operated at about 0.85 gallons per minute (gpm), (3.2 liter per minute) and was capable of overcoming the pressure in the feed water line of the pilot unit. Samples of the permeate were collected using a polypropylene wound filter with a nominal pore size of 1.0 µm. One thousand liters (264 gallons) of permeate water was filtered through the sampling vessel at one gpm (3.8 liter per minute). In addition, aliquots of the stock suspension were collected and analyzed to calculate concentrations of the microbes in the feed water. Backwash was delayed until the end of the collection period. Samples of the backwash were collected and analyzed to verify that the parasites were added to the system and removed by the filters.

VERIFICATION OF PERFORMANCE

System Operation

The treatment system was fully automated and capable of normal operations without manual intervention. The unit automatically operates in the filtration and backwash modes. All operational data, flows, pressures, turbidity and particle counts were recorded on data logging software. Manual intervention was required for chemical cleaning and to occasionally refill the tank of sodium hypochlorite used during backwash. A representative of the manufacturer conducted daily checks of the system although this was not necessary for operational control.

The flux selected by the manufacturer for the ETV study was 112 liter per square meter per hour ($l/m^2/h$) (65.9 gallon per square foot per day [gfd]) at 8.0°C which equates to 155 $l/m^2/h$ at 20 °C (91.2 gfd at 68°F). The flow rate was recorded twice per day and the water temperature was recorded once per day. The flow rate of the treatment system averaged 26.8 liter per minute (lpm) (7.09 gallon per day [gpm]).

The average feed pressure was 0.84 b (12 psi). The average filtrate pressure was 0.20 b (2.9 psi). The amount of pressure lost as the water is filtered through the membrane is referred to as transmembrane pressure (TMP). It is calculated by averaging the feed water pressure and the retentate pressure and subtracting the filtrate pressure from that average. The average TMP for the system was 0.65 b (9.4 psi). For this test program, a filtration cycle of 60 minutes was used. Every 60 minutes the system was backwashed. Each backwash required 60 minutes to complete; 15 seconds for various valve operations

and 45 seconds for the backwash itself. Approximately 25 gallons (95 liters) of permeate were used to backwash the membranes.

The feed water recovery of the treatment system during the study was 94%. This figure was calculated by comparing the amount of water needed to backwash the membranes to the total amount of water filtered by the system.

The effectiveness of the chemical cleaning process was measured by the recovery of specific flux and loss of original specific flux. Chemical cleaning was conducted at the end of the test period as required by the ETV Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contamination (EPA/NSF April, 1998). Data collected before and after the chemical cleaning was used to calculate recovery of specific flux and the loss of original specific flux. Since the membrane had not accumulated a significant amount of material that could not be removed with backwashing due to the high quality of the feed water, the recovery of specific flux cleaning was negligible. Data from the beginning of the thirty-day testing period and just prior to cleaning was used to calculate the loss of original specific flux. The loss was 10 %.

System integrity was demonstrated as required by the ETV protocol. Tests were conducted on an intact membrane system and on one that had been intentionally compromised. The air pressure hold test detected a compromised membrane.

Water Quality Results

During the microbial challenge testing that occurred on January 22, 1999, the Aquasource Model A35 UF System demonstrated a 5.5 $\log_{10}$ removal of *Giardia* cysts and a 6.5 $\log_{10}$ removal of *Cryptosporidium* oocysts. The $\log_{10}$ removals were limited by the amount of the parasites which were present in the stock feed solution, the percentage of the permeate that could be sampled, and the percent recovery of the analytical methodology. There were no *Giardia* cysts or *Cryptosporidium* oocysts observed in the permeate. During the microbial challenge testing, the feed water characteristics were: turbidity average 0.09 NTU, pH 8.2, temperature 1.7 ^{o}C.

During the thirty-day ETV operation of the Aquasource Model A35 UF System reductions were seen in HPC, algae, turbidity and particle counts. HPC averaged 260 CFU/100ml in the feed water and 11 CFU/100ml in the permeate. Algae concentrations averaged 90 cells/ml in the feed water and five cells/ml in the permeate. This reported average was the result of one cell observed in one of the four samples with a level of detection of eight cells/ml. The presence of HPC and algae in the permeate may have been due to the inability to completely disinfect the Tygon sample lines. The average turbidity concentration in the feed water was 0.078 NTU and 0.022 NTU in the permeate. Particle counts were reduced from an average of 86 total counts/ml in the feed water to an average 0.56 total counts/ml in the permeate. A reduction in TSS of 0.075 mg/l on average was observed. This represented a 50% reduction in TSS, although given the low concentration of TSS in the feed water it may be hard to extrapolate this percent removal to other locations. Total coliform reduction could not be demonstrated due to the absence of total coliforms in the feed water and permeate throughout the test.

Temperature of the feed water during the thirty-day ETV study was somewhat variable with a high of 11.0^{o}C, a low of 3.2^{o}C, and an average of 8.0^{o}C. The membrane pilot unit had little or no effect on total alkalinity, total hardness, TDS, TOC and UVA_{254}. The following table presents the water quality reductions of the feed water and filtered water samples collected during the 30 days of operation:

Feed Water Quality / Filtered Water Quality
Aquasource Model A35 UF Treatment System

	Total Coliforms (cfu/100 ml)	HPC (cfu/100 ml)	Algae (cells/ml)	Turbidity (NTU)	Particle Counts (particles/ml)
Average[1]	0/0	260/11	90/5	0.078/0.022	86/0.56
Minimum[1]	0/0	70/2	40/<8	0.060/0.021	----
Maximum[1]	0/0	460/30	136/8	0.10/0.029	----
Std. Dev.[1]	0/0	160/13	39/2	0.011/0.0036	----
95% Confidence Interval[1]	N/A*	(103, 417)/ (0, 24)	(51, 129)/ (3, 7)	(0.073, 0.081)/ (0.021, 0.023)	----

1 – Concentration of feed water/concentration of filtered water.
N/A* = Not Applicable because standard deviation = 0
---- = Statistical measurements on cumulative data not calculated.
Note: Calculated averages for less than results (<) utilize half of the Level of Detection (Gilbert, 1987).

Operation and Maintenance Results

Maintenance requirements on the treatment system did not appear to be significant but were difficult to quantify due to the short duration of the study. There was a failure of the system during the verification testing. A solenoid valve on the backwash system of the prefilter stuck closed and caused the unit to automatically shut down. The manufacturer's representative was notified and rectified the problem the following day by manually exercising the valve. The unit was off line for slightly more than 27 hours. The failure appeared to be caused by environmental conditions: freezing of the solenoid valve due to extremely low temperatures in the trailer housing the treatment system. This was caused by a failure of the enclosure's heating system. Changes were made in the method of heating the trailer in order to prevent any more failures due to environmental conditions.

The Operating and Maintenance (O&M) Manual provided by Aquasource was available for review on-site and was referenced occasionally during the testing. Particularly, the manual was consulted during the cleaning procedure and to diagnose the alarm codes during the aforementioned system shutdown. The manual was well organized and a valuable resource during the testing period.

Original Signed by
E. Timothy Oppelt *5/24/00*

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

Original Signed by
Tom Bruursema *5/31/00*

Tom Bruursema Date
General Manager
Environmental and Research Services
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 a NSF Certification of the specific product mentioned herein.

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 #00/07/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 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/etv (electronic copy)

3. EPA web site http://www.epa.gov/etv (electronic copy)