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:	**WPM-1 MICROFILTRATION SYSTEM**
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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 Pall Corporation WPM-1 Microfiltration System. Gannett Fleming, Inc., an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of the Pall Corporation WPM-1 Microfiltration Pilot System was conducted from February 3 to March 5, 1999. The treatment system underwent microbial challenge testing on February 5, 1999, and demonstrated a 5.8 $\log_{10}$ removal of *Giardia* cysts and a 6.8 $\log_{10}$ removal of *Cryptosporidium* oocysts. Source water characteristics were: turbidity average 0.10 Nephlometric Turbidity Units (NTU), pH 7.7, and temperature 3.6°C. During the thirty-day verification test, the system was operated at a flux recommended by the manufacturer of 77 gallons per square foot per day (gfd) at 3.8°C which equates to 120 gfd at 20 °C. The average transmembrane pressure was 24 pounds per square inch (psi). The feed water recovery of the treatment system during the study was 96%. Chemical cleaning of the treatment system was conducted as part of the verification testing.

TECHNOLOGY DESCRIPTION

Microfiltration (MF) processes are generally used to remove microbial contaminants such as *Giardia* and *Cryptosporidium* and other particulate contaminants from drinking water. The Pall WPM-1 membrane is a hollow fiber type microfiltration membrane made of polyvinylidenefluoride (PVDF). It has a 0.1 micrometer (µm) nominal pore size and utilizes outside-in flow. Water is applied under pressure to the outside of the hollow fiber membrane. The membrane consists of a thin film acting as a sieve. The membrane is a mechanical barrier, providing removal of particulate contaminants. Permeate (filtered water) is collected from the inside of the fiber and carried to the permeate outlet.

The Pall Corporation WPM-1 MF Pilot System is a skid mounted, stand alone system. The only required connections are for the water supply, electrical service, and a sewer connection for the discharge of backwash and chemical cleaning wastes. The treatment system consists of one membrane module, supply pump, backwash reservoir and pump, chemical cleaning equipment and necessary gauges and controls. The unit is equipped with a 400 µm bag type 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, an Excess Recirculation (XR) flow configuration was used. XR flow utilizes water, which flows tangentially across the upstream side of the filter membrane. To maintain stable flow over the short term, a backwash cycle called a Reverse Filtration (RF) cycle was performed. At a preset time determined by raw water quality, the treatment system was backwashed. This was accomplished by reversing the flow direction; forcing the permeate back through the fibers from inside to outside. (The permeate was chlorinated using a small diaphragm pump which added sodium hypochlorite to the permeate prior to backwash.) Every other backwash included an air scrub (AS) to agitate the surface of the membrane and improve the removal of the particulate material.

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, sedimentation, filtration, and disinfection 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 10,768,000 *Giardia* cysts and 104,548,000 *Cryptosporidium* oocysts were added to the feed water reservoir. The turbidity of the feed water was 0.10 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 are recorded on data logging software. Manual intervention is required for chemical cleaning and to occasionally refill the tank of sodium hypochlorite used during backwash.

The system was operated at a flux recommended by the manufacturer of 77 gfd at 3.8°C (120 gfd at 20°C). 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 4.0 gpm (15 liter per minute) and ranged from 3.9 to 4.0 gpm (15 liter per minute).

The average feed pressure was 30 psi (2.1 bar [b]). The average retentate pressure was 28 psi (1.9 b). The filtrate pressure was recorded twice per day. The average filtrate pressure was 5.1 psi (0.35 b). 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 24 psi (1.6 b). For this test program, a RF interval of once every 30 minutes was used. Every other RF cycle, i.e. once every hour, utilized an AS cycle. The unit used approximately 3.0 gallons of permeate to backwash the membranes during a RF cycle. AS followed by RF required 6.2 gallons of permeate.

The percent water recovery of the treatment system during the study was 96%. 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. The chemical cleaning recovered 73% of the specific flux. Data from when the membranes were placed into service and just after cleaning was used to calculate the loss of original specific flux. The loss of original specific flux was 9.0%.

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 February 5, 1999, the Pall WPM-1 MF system demonstrated a 5.8 $\log_{10}$ removal of *Giardia* cysts and a 6.8 $\log_{10}$ 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 0.10 NTU, pH 7.7, temperature 3.6 ^{o}C.

During the thirty-day ETV operation of the Pall WPM-1 system, treatment reductions were seen in HPC, algae, turbidity, and particle counts. HPC concentrations averaged 11 colony forming units (cfu)/100ml in the feed water and 4 cfu/100ml in the permeate. The presence of HPC in the permeate may have been due to inadequate disinfection of the Tygon tubing used for water sampling and to the lid design of the RF tank which permitted some environmental contaminants to intrude into the permeate side of the system. Pall reports that the RF tank has been redesigned with a protective lid. Algae concentrations averaged 19 cells/ml in the feed water and <8 cells/ml in the permeate. The turbidity concentration in the feed water was 0.088 NTU and 0.026 NTU in the permeate. The Pall WPM-1 reduced feed water particle counts from an average 120 total counts per ml to an average of 0.54 total counts per ml in the filtrate. Total coliform reduction could not be demonstrated due to the absence of total coliforms in the feed water and permeate throughout the test. 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
Pall Corporation WPM-1 Microfiltration System

	Total Coliforms (cfu/100 ml)	HPC (cfu/100 ml)	Algae (cells/ml)	Turbidity (NTU)	Particle Counts (particles/ml)
Average[1]	0/0	11/4	19/<8	0.088/0.026	120/0.54
Minimum[1]	0/0	2/0	8/<8	0.060/0.024	----
Maximum[1]	0/0	22/12	32/<8	0.14/0.032	----
Standard Deviation [1]	0/0	10/5	9.1/0	0.018/0.0013	----
95% Confidence Interval[1]	N/A/ N/A	(2, 19)/ (0, 8)	(11, 27)/ N/A	(0.083, 0.092)/ (0.026, 0.026)	----

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).

Temperature of the feed water during the thirty-day ETV study was fairly stable with a high of 4.5°C, a low of 3.4°C, and an average of 3.8°C. The membrane pilot unit had little or no effect on total alkalinity, total hardness, TOC, TDS, and UVA_{254}.

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. The only interruption of the process occurred due to a power failure at the pumping station. After power was restored to the pumping station the treatment system was restarted and placed back into service.

The Operating and Maintenance (O&M) Manual provided by Pall Corporation was available for review on-site and was referenced occasionally during the testing. Particularly, the manual was consulted during the cleaning procedure. The manual was well organized and a valuable resource during the testing period.

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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 #00/09/EPADW395) are available from the following sources:
(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Drinking Water Systems ETV Pilot Manager (order hard copy)
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NSF web site: http://www.nsf.org/etv (electronic copy)

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