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THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

EPA
U.S. Environmental Protection Agency

NSF
NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**MICROFILTRATION USED IN PACKAGED DRINKING WATER TREATMENT SYSTEMS**		
APPLICATION:	**REMOVAL OF *CRYPTOSPORIDIUM* OOCYSTS, *E. COLI*, AND *BACILLUS* SPORES IN MANCHESTER, NEW HAMPSHIRE**		
TECHNOLOGY NAME:	**MICROFILTRATION USING MICROZA ã 3-INCH UNIT MODEL 4UFD40004-45**		
COMPANY:	**PALL CORPORATION**		
ADDRESS:	**25 HARBOR PARK DRIVE**	PHONE:	**(516) 484-3600**
	PORT WASHINGTON, NY 11050	FAX:	**(516) 484-6844**
WEB SITE:	**www.pall.com**		
EMAIL:	**tony.wachinski@pall.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 ETV Drinking Water Systems (DWS) Pilot, one of 12 technology areas under ETV. The DWS Pilot recently evaluated the performance of the Pall Corporation Microza™ Microfiltration (MF) System Module used in package drinking water treatment system applications. This verification statement provides a summary of the test results for the Microza™ MF Unit. University of New Hampshire (UNH) Water Treatment Technology Center, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of the Pall Corporation Microza™ MF System equipped with a 3-inch filter module, took place between April 30 and August 9, 2000 in Manchester, New Hampshire. The source water was drawn from a canal connected to Lake Massabesic, the public reservoir that serves the Town of Manchester. The source water contained low alkalinity (3.5 mg/l), with turbidity levels that averaged 0.8 NTU and ranged between 0.07 and 3.8 NTU. The source water had a close to neutral pH at 6.4 (ranged from 5.5 to 7.2), and a TOC concentration in mg/l of between 4.68 and 5.09 with an average of 4.83. The average feed water temperature was 19 °C. Large blooms of algae, diatoms, and zooplankton occurred in the raw water during the testing. These blooms usually do not occur in such abundance at this time of year. Use of a source water with high concentrations of algae and/or iron bacteria in the feed water is not typical for MF technology and presented a worst case scenario feed water and a severe use condition for the Pall unit.

The test unit produced an average of 2.3 gpm of filtrate when operating at an average recovery rate of 90%. The average transmembrane pressure and specific flux during the verification study were 14.22 psi and 3.60 gfd/psi, respectively. Microbial seeding challenges involving *Cryptosporidium* oocysts, *E. coli*, and *Bacillus* spores were performed on May 3rd, June 21st and August 9th, 2000. The first test on May 3rd was performed at the beginning of a filter run to assess the performance on a clean membrane. The other two challenge tests were performed when the transmembrane pressure (TMP) approached its 30 psi limit to assess the performance of the membrane under stress from maximum allowed differential pressure. As a result of the three *Cryptosporidium* oocyst seeding studies, the membrane demonstrated 6.6, 4.1, and 5.6 log_{10} removals of *Cryptosporidium* oocysts, respectively. *Cryptosporidium* oocysts were not detected in the filtrate. As a result of three *E. coli* challenges, the membrane demonstrated 6.7, 3.9, 6.5 log_{10} removal of *E. coli*, respectively. *E. coli* was detected in the filtrate in two of the *E. coli* challenge events. The results of two of the *Bacillus* spore challenges (the results of the *Bacillus* spore seeding on June 21st were inconclusive) indicate a 4.0 and 7.1 log_{10} removal of *Bacillus* spores, respectively. *Bacillus* spores were not detected in the filtrate during two of the challenges. Turbidity levels were reduced 96% on average. The algae in the source water reduced run times by at least 75% as estimated by the manufacturer, who anticipated run times on the order of 30 days between cleanings. The frequency of membrane fouling indicates that some sort of pre-filter would be necessary in order to achieve longer run times at this location. For additional information on operation and maintenance of the system on a cleaner water source, refer to a previous ETV Report (#00/09/EPADW395) for testing of this system at a site in Pittsburgh, Pennsylvania.

TECHNOLOGY DESCRIPTION

The unit is identified as the 3-inch Microza™ Test Skid, model number 4UFD40004-45, LGV3L, serial number 2114562. The unit has a 3-inch diameter membrane filter module with 75 square feet of membrane contact area, and is designed to filter up to 4 gpm. The manufacturer reports that the maximum membrane pore size as determined by the use of ASTM Method F316-86 is less than 0.3 microns (µm) diameter. Power requirements for the unit are 240 volts, at 20 amps under full load.

This model is specifically targeted for applications requiring a relatively low flow rate, such as would be required for a package plant, or for a small commercial operation, school, campground, or swimming pool. It would also be appropriate for a common water supply system for a small community. The Microza™ MF module consists of pressure-driven hollow fibers of polyvinylidene fluoride (PVDF). The maximum pressure differential across the membrane fibers is 30 psi. The unit is portable, light weight, and mounted on a steel skid with casters. The operation of the system and the monitoring of operational parameters are controlled by a Supervisory Control and Data Acquisition (SCADA) system, mounted on the filter unit. The unit, therefore, should be operated in an enclosure.

US EPA ARCHIVE DOCUMENT

VERIFICATION TESTING DESCRIPTION

Test Site

A canal connected to Lake Massabesic, the water source for Manchester, New Hampshire was chosen as the site to challenge the MF filter unit. Lake Massabesic is a natural lake and is located roughly 3.5 miles east of the downtown Manchester business area. The lake has a surface area of about 2,500 acres. The storage capacity of the lake is close to 15 billion gallons, and is the runoff repository for a 42-square mile (26,880 acres) watershed. During testing the canal became stagnant and subject to seasonal warming and subsequent algal growth. Large blooms of algae, diatoms, and zooplankton occurred in the raw water during the testing. Use of a source water with high concentrations of algae and/or iron bacteria in the feed water is not typical for MF technology and presented a worst case scenario feed water and a severe use condition for the Pall unit.

Methods and Procedures

Water quality data were collected on the source water and the filtrate produced by the Pall Microza™ MF System and analyzed using *Standard Methods for the Examination of Water and Wastewater, 20th Edition* (APHA, 1998) and/or EPA approved methods. Turbidity, temperature, pH, flow rate, particle counts, and pressure were measured and logged in the field. The analysis of TOC and UV absorbance were performed at the laboratory at UNH. Alkalinity, hardness, TSS, and TDS, were analyzed at either Research Laboratories Inc., or at Analytics Environmental Laboratory Inc., State certified testing laboratories in Portsmouth, NH. Analysis for detection of *Cryptosporidium* was performed at Analytical Services, Inc. in Williston, Vermont. Analysis of *E. coli*, and *Bacillus* spores were performed at the microbiology laboratory at UNH in conjunction with Analytical Services, Inc.

VERIFICATION OF PERFORMANCE

System Operation

The system was operated for thirteen (13) separate filter runs for a total of 436 hours between April 30, 2000, and July 26, 2000. Table VS-1 presents the system performance data for the thirteen (13) filter runs. The average filtrate flow rate was 2.3 gpm, with a maximum value of 6.3 gpm and a minimum value of 1.8 gpm. Transmembrane pressure averaged 14 psi, with a maximum value of 30 psi, and a minimum value of 2.9 psi. The specific flux averaged 3.6 gfd/psi, with a maximum value of 14 gfd/psi and a minimum value of 1.3 gfd/psi. A summary of the system performance data is in the table below.

Table VS-1. System Performance Data for 13 Filter Runs

	Feed Flow (gpm)	Feed Pressure (psi)	Feed Temperature (°C)	Feed Turbidity (NTU)	Filtrate Flow (gpm)	Filtrate Pressure (psi)	Filtrate Turbidity (NTU)	Retentate Pressure (psi)	Transmembrane Pressure (psi)	Specific Flux (gfd/psi)
Average	2.50	17.47	18.88	0.80	2.30	4.20	0.03	15.35	14.22	3.60
Minimum	1.80	0.04	11.44	0.07	1.80	0.00	0.00	0.00	2.87	1.27
Maximum	9.80	36.13	35.26	3.79	6.26	31.68	0.32	34.43	30.23	14.19
Std Dev	0.63	6.61	3.14	0.28	0.43	2.83	0.01	7.18	5.25	1.36
95% Conf. Interval	(2.49, 2.51)	(17.35, 17.59)	(18.82, 18.94)	(0.79, 0.81)	(2.29, 2.31)	(4.15, 4.25)	(0.03, 0.03)	(15.22, 15.48)	(14.12, 14.32)	(3.57, 3.63)

Note: Results corrected for AS and RF procedures.

Reverse filtration (RF) and air scrub (AS) operation were initially set to repeat every 30 and 60 minutes respectively for a set duration of 60 seconds. The effectiveness of this cleaning procedure varied with the

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water quality. It was found that the intensity of the operation had a greater impact on performance than the frequency. In other words, adjustments in the duration of the AS and RF procedures produced improved operational results rather than increasing the frequency. A chemical cleaning took place every time the transmembrane pressure exceeded 30 psi, or if the system shut down due to fouling of the membrane. Four chemical cleaning events took place during the testing period. The chemical cleanings were performed using the manufacturer's recommended procedures and it took approximately three hours to accomplish each cleaning. The membrane passed the integrity test after each cleaning operation was performed.

Water Quality Results

The system effectively removed microbiological and particulate contaminants from the feed water during the verification study. Microbial seeding challenges involving *Cryptosporidium* oocysts, *E. coli*, and *Bacillus* spores were performed on May 3rd, June 21st and August 9th, 2000. The first test on May 3rd was performed at the beginning of a filter run on a new clean membrane, and the other two tests were performed when the TMP approached its 30 psi limit. The membrane demonstrated 6.6, 4.1, and 5.6 $\log_{10}$ removals of *Cryptosporidium* oocysts, respectively, during the challenge studies. *Cryptosporidium* oocysts were not detected in the filtrate samples. The samples collected during the May 3rd *Cryptosporidium* challenge were analyzed outside the method's specified hold time; however, the deviation is not expected to influence the sample results because the samples were analyzed for total cyst concentration and not viability (see Quality Control Section of report for discussion). The membrane demonstrated 6.7, 3.9, 6.5 $\log_{10}$ removal of *E. coli*, respectively, during the challenge studies. *E. coli* was detected in the filtrate in two of the *E. coli* challenge events. The results of two of the *Bacillus* spore challenges (the results of the *Bacillus* spore seeding on June 21st were inconclusive) indicated a 4.0 and 7.1 $\log_{10}$ removal of *Bacillus* spores. *Bacillus* spores were not detected in the filtrate during two of the challenges. The $\log_{10}$ removals for *E. coli* and *Bacillus* spores were calculated based on a 100 mL sample. The $\log_{10}$ removals of the microorganisms seeded were limited by the concentration which was present in the stock feed solution, the percentage of the filtrate sampled, and the percent recovery of the analytical methodology.

The raw water particle count concentration of *Cryptosporidium*-sized particles (2 to 5 micron) and cumulative particles (>2 micron) averaged 3,120 and 5,601 counts/ml, respectively. The filtrate particle count concentration averaged 1.7 and 3.1 counts/ml, respectively. Percent reduction for both *Cryptosporidium*-sized particles (2 to 5 micron) and cumulative particles (>2 micron) was 99.94%. Turbidity was reduced from an average of 0.80 NTU in the feed water to 0.03 NTU in the filtrate.

Operation and Maintenance Results

The system evaluated in this study was highly automated, making day-to-day operation simple and straightforward. Aside from the chemical cleaning, labor was spent after start-up to adjust feed flow and adjust the reverse filtration and air scrub run time and frequency to enhance performance. The adjustments were accomplished via computer programming with the exception of valve adjustments performed manually to regulate the retentate flow. The water quality and the environmental conditions at the site required that three mechanical changes be made in the system. The demand for compressed air required that a larger compressor be used instead of the original supplied with the system. The maximum temperature setting allowed within the enclosed SCADA system was increased from the original factory setting to allow for the high air temperatures at the site. A solenoid valve that controlled one of the pneumatic flow control valves also failed and was replaced with another that was supplied with the membrane system.

The system operation was terminated seven times because the TMP termination criteria (30 psi) was reached. The terminations were believed to be a direct result of high concentrations of algae and/or iron bacteria in the feed water. Use of a source water with high concentrations of algae and/or iron bacteria in

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the feed water is not typical for MF technology and presented a worst case scenario feed water and a severe use condition for the Pall unit. For additional information on operation and maintenance of the system, refer to a previous ETV Report (#00/09/EPADW395), which documents operation and maintenance results on a cleaner water source.

The Operation and Maintenance manual is well written and easy to follow. Sections include: System Description, Module Installation and Rinse-Up, Safety Instruction, System Operation, System Control Interface, and Clean-In-Place Procedures. The only technical assistance required that was not covered in the manual was membrane fouling caused by algae in the source water, system shutdown caused by an undersized compressor and the adjustment of factory settings to compensate for the higher than anticipated temperatures within the SCADA system due to the abnormally high ambient temperatures at the site.

Original Signed by
E. Timothy Oppelt *04/08/02*

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

Original Signed by
Gordon Bellen *04/11/02*

Gordon Bellen Date
Vice President
Federal Programs
NSF International

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Availability of Supporting Documents

Copies of the *EPA/NSF ETV Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* dated May 1999, the Verification Statement, and the Verification Report (NSF Report #02/18/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.org/etv (electronic copy)

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

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