THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ULTRAFILTRATION**
APPLICATION:	**REMOVAL OF MICROBIAL CONTAMINANTS**
PRODUCT NAME:	**MEMCOR® L10V ULTRAFILTRATION MODULE**
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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 Siemens Memcor® L10V ultrafiltration (UF) module for removal of microbial contaminants under controlled laboratory challenge conditions. The challenge tests were conducted at NSF's testing laboratory in Ann Arbor, MI. Testing of the Siemens Memcor® L10V UF membrane module was conducted to verify microbial reduction performance under the membrane challenge requirements of the USEPA Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

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 Siemens Memcor L10V UF module was tested for removal of *Cryptosporidium parvum* oocysts, endospores of the bacteria *Bacillus atrophaeus*, and the MS2 coliphage virus according to the requirements of the EPA Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Five modules from five different production lots were challenged by all three organisms. Separate challenges were conducted for each organism. The modules were operated at a target flux of 80 gallons per square foot per day (gfd), which for the L10V equates to approximately 14 gallons per minute (gpm).

The LT2ESWTR specifies that log removal values (LRV) be calculated for each module for each organism, and then one LRV for each organism ($LRV_{C\text{-}TEST}$) be assigned from the set of LRV. However, the rule does not specify how the $LRV_{C\text{-}TEST}$ should be determined, instead, three different methods are suggested. All three methods were used to assign LRV for this verification. See the Verification of Performance section below for descriptions of each method. The $LRV_{C\text{-}TEST}$ for each method are presented in Table VS-i.

Table VS-i. $LRV_{C\text{-}TEST}$ for Each Organism

Challenge Organism	Method 1	Method 2	Method 3
C. parvum	5.67	5.67	5.51
B. atrophaeus	6.56	6.64	5.99
MS2	2.07	2.08	1.94

PRODUCT DESCRIPTION

The Memcor L10V UF membrane module is a member of the Memcor XP line of products. The module measures 4.7 inches in diameter by 45.5 inches in length. The membrane fibers are made of polyvinylidene fluoride (PVDF). Water flow through the membrane fibers is outside to inside. The modules operate in a dead-end mode, with no reject stream. The nominal pore size is 0.04 µm.

Siemens supplied five modules from five different production runs for testing. The modules were tested in a pilot unit supplied by Siemens.

VERIFICATION TEST DESCRIPTION

Challenge Organisms

The L10V modules were tested for removal of microorganisms using live *C. parvum* oocysts, endospores of the bacteria *B. atrophaeus* (ATCC 9372, deposited as *Bacillus subtilis* var. *niger*), and MS-2 coliphage virus (ATCC 15597-Bl). *B. atrophaeus* was selected for evaluation as a possible surrogate for *C. parvum*, due to the high cost and lack of availability of suitable numbers of *C. parvum* for challenge testing. Virus reduction was evaluated using MS-2 for possible virus removal credits. MS-2 is considered a suitable surrogate for pathogenic viruses because of its small size, at 24 nm in diameter. Separate challenge tests were conducted for each challenge organism, so each module was tested three times over the course of the testing activities.

Test Site and Challenge Water

The microbial challenge tests were conducted at NSF's testing laboratory in Ann Arbor, MI. Local tap water was treated by carbon filtration, reverse osmosis, ultraviolet disinfection, and deionization to make the base water for the tests. A water supply tank was filled with the base water, and sodium bicarbonate was added in sufficient quantity to provide alkalinity at a target of 100 ± 10 mg/L as calcium carbonate. The pH was then lowered with hydrochloric acid to a target range of 7.5 ± 0.5.

Methods and Procedures

The tests followed the procedures described in the *Test/QA Plan for the Microbial Seeding Challenge Study of the Siemens Memcor L10V, L20V, and S10V Ultrafiltration Modules.* The challenge protocol was adapted from the *ETV Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants,* and the USEPA *Membrane Filtration Guidance Manual* (MFGM).

The pilot unit holds three modules, but each module was tested separately. Each module was tested in the same housing. The other two housings were closed off. The target flux for the tests was 80 gallons per square foot per day (gfd), which equals a flow rate of 14 gallons per minute (gpm) for the L10V module.

Before and after each challenge test, the modules were subjected to a two minute pressure decay test using the program in the pilot unit's programmable logic controller (PLC). Siemens defined a passing pressure decay test as less than or equal to 1.5 psi per minute. The PLC gives a warning message if this decay rate is exceeded.

Prior to the start of each challenge test, the module and pilot unit were flushed for approximately two minutes, and at the end of the flush a negative control sample was collected from the filtrate sample tap. The duration of each microbial challenge test was 30 minutes. Feed and filtrate grab samples were collected for challenge organism enumeration after three minutes of operation, after 15 minutes of operation, and after 30 minutes of operation. The challenge organisms were intermittently injected into the feed stream using a peristaltic pump at each sampling point. The injection point was downstream of the pilot unit's feed tank, as shown in Figure 2.2. The injection time for MS-2 and *B. atrophaeus* was approximately 5 minutes. During each injection period, the challenge organism was fed to the feed stream for at least 3 minutes prior to collection of the feed and filtrate samples during the fourth and/or fifth minutes. The injection time for *C. parvum* was only three minutes, due to the cost and limited availability of live oocysts. The feed and filtrate samples for the *C. parvum* challenges were collected during the third minute of injection.

The MFGM suggests that feed and filtrate samples not be collected until at least three hold-up volumes of water containing the challenge organism have passed through the membrane to establish equilibrium. The hold-up volume is defined as the "unfiltered test solution volume that would remain in the system on the feed side of the membrane at the end of the test." Siemens has calculated that the hold-up volume for the Memcor XP pilot unit with only one membrane cartridge in place is 7 gallons, not including the unit's feed tank. These challenges were conducted at flow rates of approximately 14 gpm, so for both organisms the equilibrium requirement was met prior to sample collection. For the *B. atrophaeus* challenges, 42 gallons of the spiked test water passed through the membranes prior to sample collection. For the *C. parvum* challenges, 28 gallons of spiked test water passed through the membranes prior to sample collection.

VERIFICATION OF PERFORMANCE

The MS-2 challenges were conducted first on all five cartridges, followed by *B. atrophaeus* and then *C. parvum*. However, the MS-2 challenges for Modules 2 and 3 were re-run in between the *B. atrophaeus* and *C. parvum* challenges. The Module 2 challenge was run again because the MS-2 feed counts at 15 minutes were low. The Module 3 challenge was re-run because the pre-test flush sample had high MS-2 counts. Note that no MS-2 was detected in the retest flush sample.

The LT2ESWTR and MFGM specify that a LRV for the test ($LRV_{C\text{-}TEST}$) be calculated for each module tested, and that the LRV for each module are then combined to yield a single $LRV_{C\text{-}TEST}$ for the product. If fewer than 20 modules are tested, as was the case for this verification, the $LRV_{C\text{-}TEST}$ is simply the

lowest LRV for the individual modules. However, the rule does not specify a method to calculate $LRV_{C\text{-}TEST}$ for each module. Suggested options in the MFGM include the following: calculating a LRV for each feed/filtrate sample pair, then calculating the average of the LRV (Method 1); averaging all of the feed and filtrate counts, and then calculating a single LRV for the module (Method 2); or calculating a LRV for each feed/filtrate sample pair, and then selecting the LRV for the module as the lowest (most conservative of the three options, Method 3).

All three approaches for calculating the LRV are reported here. Note the LT2ESWTR and MFGM do not specify whether the averages should be calculated as the arithmetic mean or geometric mean. For this verification, geometric means were calculated.

All pressure decay rates were below 0.06 psig/min, indicating that there were no membrane integrity issues during the tests.

C. parvum Reduction

The *C. parvum* feed concentrations ranged from $3.2x10^5$ to $7.5x10^5$ oocysts/L. The *C. parvum* LRV from the three different calculation methods are presented in Table VS-i. The $LRV_{C\text{-}TEST}$ for each method is in bold font. All filtrate samples were negative for *C. parvum*, so the LRVs are simply a function of the measured feed concentrations. The flow rates measured during the *C. parvum* challenges translated into fluxes ranging from 79.4 to 81.9 gfd.

Table VS-i. *C. parvum* LRV Calculations

Module #	Method 1	Method 2	Method 3
Module 1	5.81	5.81	5.76
Module 2	5.68	5.68	**5.51**
Module 3	5.68	5.69	5.61
Module 4	**5.67**	**5.67**	5.67
Module 5	5.70	5.70	5.67

B. atrophaeus Reduction

The LT2ESWTR indicates a maximum challenge concentration to achieve a reduction of 6.5 log_{10} ($3.16x10^6$ CFU/100 mL). The *B. atrophaeus* feed concentrations for these tests ranged from $6.0x10^6$ to $1.1x10^7$ CFU/100 mL, taking into account the expected percent recovery of the challenge organism, which is typically less than 100%.

The *B. atrophaeus* LRV from the three different calculation methods are presented in Table VS-ii. The $LRV_{C\text{-}TEST}$ for each method is in bold font. The LT2ESWTR specifies that the maximum possible $LRV_{C\text{-}TEST}$ awarded to a membrane product is 6.5 log_{10}, but the LRV above 6.5 are still presented here. The $LRV_{C\text{-}TEST}$ for Methods 1 and 2 are above 6.5, while that for Method 3 falls below 6.5, at 5.99.

Table VS-ii. *B. atrophaeus* LRV Calculations

Module #	Method 1	Method 2	Method 3
Module 1	6.67	6.67	6.35
Module 2	6.69	6.85	6.38
Module 3	6.99	6.99	6.98
Module 4	**6.56**(1)	**6.64**(1)	**5.99**
Module 5	6.86	6.86	6.80

(1) $LRV_{C\text{-}TEST}$ under these two methods should be capped at 6.5.

No *B. atrophaeus* endospores were found in any of the filtrate samples for the Modules 3 and 5, but *B. atrophaeus* was found in some of the filtrate samples for the other modules. The maximum observed filtrate count for all modules was 6 CFU/100 mL. The flow rates measured during the *B. atrophaeus* challenges translated into fluxes ranging from 80.2 to 84.0 gfd.

While the LRV for the *B. atrophaeus* challenges are higher than those for the *C. parvum* challenges, this observation is a function of the high feed concentrations of the organisms. *B. atrophaeus* can be considered to be a conservative surrogate for *C. parvum* because the endospores were found in the filtrate samples for three of the five modules tested, while no *C. parvum* was found in any filtrate samples. Other rationale for *B. atrophaeus* as a surrogate for *C. parvum* can be found in the full verification report.

MS-2 Reduction

The MS-2 feed concentrations ranged from $9.7x10^3$ PFU/mL to $7.8x10^4$ PFU/mL. The LRV for MS-2 reduction are shown in Table VS-iii. The $LRV_{C\text{-}TEST}$ for each method is in bold font. The maximum individual filtrate count was 187 PFU/mL for Module 2 at start-up. The flow rates measured during the MS-2 challenges translated into fluxes ranging from 80.6 to 83.7 gfd.

Table VS-iii. MS-2 LRV Calculations

Module #	Method 1	Method 2	Method 3
Module 1	2.88	2.88	2.83
Module 2	**2.07**	**2.08**	**1.94**
Module 3	2.65	2.66	2.42
Module 4	2.57	2.58	2.26
Module 5	2.32	2.33	2.09

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

NSF provided technical and quality assurance oversight of the verification testing as described in the verification report, including a review of 100% of the data. NSF QA personnel also conducted a technical systems audit during testing to ensure the testing was in compliance with the test plan. A complete description of the QA/QC procedures is provided in the verification report.

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Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 09/30/EPADWCTR) are available from the following sources:

1. ETV Drinking Water Systems Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140

2. Electronic PDF copy
   NSF web site: http://www.nsf.org/info/etv
   EPA web site: http://www.epa.gov/etv