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® S10V 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® L20V ultrafiltration 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® L20V ultrafiltration 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 S10V UF module was tested for removal of 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). *B. atrophaeus* served as a surrogate for *Cryptosporidium* oocysts, as well as other bacteria. Five modules from five different production lots were challenged with both 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 S10V equates to approximately 16.7 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
B. atrophaeus	7.10	7.13	6.62
MS2	2.98	3.00	2.57

PRODUCT DESCRIPTION

The Memcor S10V UF membrane module is a member of the Memcor CS line of products. The Memcor CS modules are submerged membranes that operate by pulling water through the membrane from the outside to the inside of the hollow fiber using vacuum pressure. The module measures 5.2 inches in diameter by 46.7 inches in length. The membrane fibers are made of polyvinylidene fluoride (PVDF). 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 S10V modules were tested for removal of microorganisms using endospores of the bacteria *Bacillus atrophaeus* (ATCC 9372, deposited as *Bacillus subtilis* var. *niger*), and MS-2 coliphage virus (ATCC 15597-Bl). *B. atrophaeus* served as a surrogate for *Cryptosporidium* oocysts, as well as other bacteria. *B. atrophaeus* endospores are ellipsoidal (football shaped), with an average diameter of 0.8 µm, and an average length of 1.8 µm. A full discussion of the rationale for using *Bacillus* endospores as a surrogate for *Cryptosporidium* can be found in the verification report. Virus removal testing was conducted 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 twice 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 sequentially 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 four modules, but only one module was tested at a time. For the other membrane slots, Siemens provided cartridge ends with fibers that had been epoxied shut. The target flux for the tests was 80 gallons per square foot per day (gfd), which equals a flow rate of 16.7 gallons per minute (gpm) for the S10V module.

Before and after each challenge test, each module was 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 then 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 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 for five-minute periods 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. 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. At the end of each challenge test, a second pressure decay test was conducted to confirm membrane integrity.

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 (equilibrium volume). 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 the hold-up volume of the Memcor XP pilot unit as 40 gallons, not including the unit's feed tank. The flow rates measured during ETV testing ranged from 16.70 to 16.96 gpm, so only approximately 50 gallons of the spiked test solution passed through the membrane modules before sample collection began. This volume was less than the equilibrium volume of 120 gallons, but the MS-2 filtrate counts suggest that the membranes were being subjected to the full challenge concentration when the filtrate samples were collected. The feed samples were collected upstream from the membrane holding chamber, so they are not indicative of the challenge concentration in the membrane chamber after 3 minutes of injection. However, most of the MS-2 filtrate counts for the S10V challenges were above $1x10^3$ PFU/mL. These filtrate counts were similar to those measured from the ETV challenge tests of the Siemens L10V and L20V membranes, which use the same UF fibers. So, the fact that the S10V filtrate counts were similar to those from the L10V and L20V tests indirectly indicates that the S10V cartridges were exposed to adequate MS-2 challenge concentrations after only 3 minutes of injection.

VERIFICATION OF PERFORMANCE

The LT2ESWTR and MFGM specify that an 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 0.7 psig/min, indicating that there were no membrane integrity issues during the tests.

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 $3.6x10^7$ to $6.1x10^7$ 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.

No *B. atrophaeus* endospores were found in the Module 1 filtrate samples, but they were found at low levels in the filtrate samples for the rest of the modules. The maximum observed filtrate count was 10 CFU/100 mL. The flow rates measured during the *B. atrophaeus* challenges translated into fluxes ranging from 80.3 to 81.2 gfd.

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

Module #	Method 1	Method 2	Method 3
Module 1	7.71	7.71	7.66
Module 2	7.39	7.36	7.09
Module 3	**7.10**(1)	**7.13**(1)	**6.62**(1)
Module 4	7.53	7.63	7.26
Module 5	7.24	7.28	6.81

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

MS-2 Reduction

The MS-2 feed concentrations ranged from $1.42x10^6$ PFU/mL to $9.0x10^6$ 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 $9.3x10^3$ PFU/mL for Module 1 30-minute sample. The flow rates measured during the MS-2 challenges translated into fluxes ranging from 80.2 to 81.4 gfd.

Table VS-iii. MS-2 LRV Calculations			
Module #	**Method 1**	**Method 2**	**Method 3**
Module 1	**2.98**	**3.00**	**2.57**
Module 2	3.19	3.20	3.09
Module 3	3.24	3.23	3.12
Module 4	3.16	3.17	2.94
Module 5	3.64	3.64	3.61

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 09/32/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