THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ULTRAFILTRATION MEMBRANE MODULE**
APPLICATION:	**REMOVAL OF MICROBIAL CONTAMINANTS IN DRINKING WATER**
PRODUCT NAME:	**TARGA® 10-48-35-PMC™ ULTRAFILTRATION MEMBRANE MODULE, AS USED IN THE VILLAGE MARINE TEC. EXPEDITIONARY UNIT WATER PURIFIER**
VENDOR:	**KOCH MEMBRANE SYSTEMS, INC.**
ADDRESS:	**850 MAIN STREET WILMINGTON, MA 01887**
PHONE:	**MAIN - 888-677-5624 CUSTOMER SERVICE – 800-343-0499**
FAX:	**978-657-5208**
EMAIL:	**INFO@KOCHMEMBRANE.COM**

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 Koch Membrane Systems, Inc. Targa® 10-48-35-PMC™ Ultrafiltration (UF) Membrane, as used in the Village Marine Tec. Expeditionary Unit Water Purifier. NSF performed all of the testing activities and also authored the verification report and this verification statement. The verification report contains a comprehensive description of the test.

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

Testing of the Koch Membrane Systems, Inc. Targa® 10-48-35-PMC™ Ultrafiltration (UF) Membrane was conducted as part of the ETV verification of the US Navy Office of Naval Research's (ONR) Expeditionary Unit Water Purifier (EUWP), manufactured by Village Marine Tec. The EUWP uses the Targa 10-48-35-PMC membrane module in the UF treatment step. During field verification testing of the EUWP, removal of *Bacillus* endospores was measured as a surrogate for removal of *Cryptosporidium parvum* oocysts (see the full verification report for a discussion about the appropriateness of using *Bacillus* endospores as a surrogate for *C. parvum*). The observed log reductions were below what had previously been observed during lab challenge testing of the same UF membrane fibers, indicating that either there were membrane integrity problems, or that there were endospores present on the filtrate side of the UF modules that were sloughing off. To test whether there was poor membrane integrity within the UF modules, NSF and EPA had the field testing organization randomly select two UF modules from the field tested EUWP and send them to NSF to conduct additional microbial challenges under controlled laboratory conditions.

The UF modules were challenged with approximately 4 $\log_{10}$ per milliliter (mL) of *B. atrophaeus* endospores, and 5 $\log_{10}$ per liter (L) of formalin-fixed *C. parvum* oocysts. Each challenge test was 30 or 45 minutes in length, and was conducted at a target flux of 38 gallons per day per square foot (gfd), which is the target flux for UF module operation in the EUWP. The membranes removed a minimum of 2.4 $\log_{10}$ per mL of *B. atrophaeus*, and 4.3 $\log_{10}$ per L of *C. parvum*.

PRODUCT DESCRIPTION

The following technology description was provided by the manufacturer and has not been verified.

The UF modules used in the EUWP are Koch Targa 10-48-35-PMC membrane modules, with endcaps designed and manufactured by Village Marine Tec. The Targa 10-48-35-PMC is a 10.75 inch x 48 inch module (not including the endcaps). The membrane fibers are made of polysulfone, with a nominal fiber inner diameter of 0.9 millimeters. The nominal membrane surface area for the module, using the fiber inner diameter, is 554 square feet. The nominal molecular weight cutoff rating for the membrane is 100,000 Daltons.

VERIFICATION TESTING DESCRIPTION

Selection of Modules

After completion of field testing of the EUWP UF system at Selfridge Air National Guard Base in July and August of 2007, two UF modules from the EUWP were chosen at random for the lab challenge tests. The modules chosen were serial numbers KM840643-4015 and KM849697-5021. Prior to the summer 2007 field test, each UF module was individually integrity tested using a pressure decay test. The pressures were measured from 0 to 10 minutes, with a starting applied pressure of approximately 15 psig. KM840643-4015 had a pressure decay rate of 0.21 psig/min. This module was checked for compromised fibers; one was found and plugged. KM840643-4015 was then retested, and the new pressure decay rate was 0.17 psig/min. KM849697-5021 had a pressure decay rate of 0.13 psig/min. No fibers were plugged for this module. For the tests described in this VS, KM840643-4015 was designated as Module 1, and KM849697-5021 was designated as Module 2.

Test Site

The testing site was the Drinking Water Treatment Systems Laboratory at NSF in Ann Arbor, Michigan. A description of the test apparatus can be found in the verification report.

Methods and Procedures

The testing methods are detailed in the document *Test/QA Plan for the Microbial Seeding Challenge Study of the Koch Membrane Systems Targa 10-48-35-PMC UF Membrane*. Two UF membrane modules were tested for removal of pathogenic protozoa using two different surrogate organisms – endospores of the bacteria *Bacillus atrophaeus* (ATCC 9372, deposited as *B. subtilis* var. *niger*), and formalin-fixed *C. parvum* oocysts. *Bacillus* endospores were chosen as a challenge organism because field testing of the EUWP also examined *Bacillus* endospore removal. Note that the test protocol was not designed to achieve the regulatory requirements for membranes under the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). This verification did not address long-term performance, membrane cleaning, or full-scale field maintenance and operation issues. These items are addressed in the verification reports for the full EUWP system.

The testing was conducted in December 2007 and February 2008. In December 2007 the UF membranes were challenged with both *Bacillus* endospores and *C. parvum*. In February 2008, the membranes were challenged again with *C. parvum* to confirm that the oocysts found in one filtrate sample from the December 2007 test was not due to sample contamination.

The UF modules were not sanitized immediately prior to testing. The UF modules were cleaned in September 2007 following EUWP field testing. The cleaning procedure used was that prescribed in the EUWP operation and maintenance manual. Prior to the challenge tests, the modules were flushed for approximately 15 minutes using deionized water.

Before and after testing, the membranes underwent a pressure decay membrane integrity test following the procedure in ASTM Standard D6908 – *Standard Practice for Integrity Testing of Water Filtration Membrane Systems*.

Each UF module was tested individually. The membranes were challenged with both organisms simultaneously. In the EUWP, the Targa 10-48-35-PMC is operated at a target flux of 38 gfd, with a reject flow rate of 10% of the feed flow. To approximate these operation conditions, the target feed flow rate was set at 16.2 gallons per minute (gpm), and the target filtrate flow rate was 14.6 gpm. For the December 2007 tests, the membranes were challenged with each organism for 30 minutes, with feed and filtrate samples collected at start-up, 15 minutes, and 30 minutes. For the February 2008 *C. parvum* retest, the membranes were challenged for 45 minutes, with feed and filtrate samples collected at 15, 30, and 45 minutes. All samples were analyzed for the challenge organism(s) in triplicate.

VERIFICATION OF PERFORMANCE

For presentation of the challenge organism data, the observed triplicate feed and filtrate counts were averaged by calculating geometric means. Non-detect results were treated as one organism per unit volume for the purpose of calculating the means.

Table VS-1 presents the *B. atrophaeus* endospores data. Note that endospores were found in the module flush samples, despite the UF system chemical cleaning that was conducted after the August 2007 field test of the EUWP UF system. The modules were forward flushed for 15 minutes on December 10 using deionized water, and the flush samples were collected at the end of this flush. The modules were flushed again on December 11 for approximately one minute immediately prior to conducting the microbial challenges. The module flush samples had no *C. parvum*, but greater than 1 $\log_{10}$ of endospores (25 and 15 CFU/100 mL). Tryptic Soy Agar (TSA) was supposed to be substituted for nutrient agar in the SM9218 enumeration method for the endospores, in order to be able to distinguish the challenge endospores from wild-type endospores already present in the membrane modules from the field testing. *B. atrophaeus* gives orange colonies with a distinctive morphology on TSA. However, due to

miscommunication between the DWS Center and the NSF Microbiology Lab, the *B. atrophaeus* endospores were enumerated on nutrient agar, so they could not be distinguished from the wild-type endospores.

The log removal value (LRV_{test}) for the endospore challenges show log removals between 2 and 3, but this data cannot be considered a true picture of UF module performance due to the flush sample counts. It is possible that many of the endospores in the filtrate samples did not come through the membranes, but rather were already present on the filtrate side due to contamination from the previous field tests. At time 0 the endospore counts for both modules were higher than those at 15 and 30 minutes, indicating that the endospores continued to be rinsed out of the filtrate side after the start of the challenges. The UF modules were chemically cleaned at the end of the August 2007 field test, but it is possible that the cleaning procedure did not completely remove all of the endospores.

Table VS-1. December 2007 *B. atrophaeus* Endospores Reduction Data

		Feed		Filtrate		
	Sample Point	Geometric Mean (CFU/mL)	Log_{10}	Geometric Mean (CFU/mL)	Log_{10}	Log Reduction
Module 1	Flush			24.8	1.4	
	Start-Up	$1.74x10^4$	4.24	69	1.8	2.4
	15 Minutes	$1.57x10^4$	4.20	13	1.1	3.1
	30 Minutes	$1.66x10^4$	4.22	14	1.2	3.0
	Overall Geometric Mean	$1.66x10^4$	4.22	23	1.4	2.8
Module 2	Flush			15	1.2	
	Start-Up	$2.02x10^4$	4.31	175	2.2	2.1
	15 Minutes	$1.65x10^4$	4.22	57	1.8	2.4
	30 Minutes	$1.75x10^4$	4.24	47	1.7	2.5
	Overall Geometric Mean	$1.80x10^4$	4.26	78	1.9	2.4

Table VS-2 presents the December 2007 *C. parvum* challenge data, and Table VS-3 the February 2008 *C. parvum* challenge data. For the December 2007 test, all filtrate samples were below the detection limit, except for the Module 2 30-minute sample. Because oocysts were found in this sample, *C. parvum* retests were conducted in February 2008. No *C. parvum* was detected in the Module 1 filtrate samples from the December 2007 challenge, but it was found in both the 30-minute and 45-minute samples from the retest. *C. parvum* was also found in the Module 2 30-minute filtrate sample, as was the case with the December 2007 challenge. However, no *C. parvum* was detected in the Module 2 45-minute filtrate sample. In spite of the *C. parvum* filtrate counts, the UF membrane still removed greater than 4 logs of the oocysts.

Table VS-2. December 2007 *C. parvum* Reduction Data

		Feed		Filtrate		
	Sample Point	Geometric Mean (Cysts/L)	Log_{10}	Geometric Mean (Cysts/L)	Log_{10}	Log Reduction
Module 1	Flush			<1	0.0	
	Start-Up	$1.2x10^5$	5.1	<1	0.0	5.1
	15 Minutes	$7.5x10^4$	4.9	<1	0.0	4.9
	30 Minutes	$7.1x10^4$	4.9	<1	0.0	4.9
	Overall Geometric Mean	$8.6x10^4$	5.0	<1	0.0	5.0
Module 2	Flush			<1	0.0	
	Start-Up	$1.1x10^5$	5.0	<1	0.0	5.0
	15 Minutes	$8.4x10^4$	4.9	<1	0.0	4.9
	30 Minutes	$8.4x10^4$	4.9	47	1.7	3.2
	Overall Geometric Mean	$9.2x10^4$	4.9	3.6	0.6	4.3

Table VS-3. February 2008 *C. parvum* Reduction Retest Data						
		Feed		Filtrate		
	Sample Point	Geometric Mean (Cysts/L)	Log_{10}	Geometric Mean (Cysts/L)	Log_{10}	Log Reduction
Module 1	Flush			<1	0.0	
	Start-Up	$6.3x10^4$	4.8	<1	0.0	4.8
	30 Minutes	$6.2x10^4$	4.8	2	0.4	4.4
	45 Minutes	$7.9x10^4$	4.9	1	0.0	4.9
	Overall Geometric Mean	$6.8x10^4$	4.8	0.7	0.0	4.7
Module 2	Flush			<1	0.0	
	Start-Up	$5.7x10^4$	4.8	<1	0.0	4.8
	30 Minutes	$5.6x10^4$	4.8	4	0.6	4.2
	45 Minutes	$5.1x10^4$	4.7	<1	0.0	4.7
	Overall Geometric Mean	$5.5x10^4$	4.7	1.6	0.2	4.5

The December 2007 and February 2008 pre-test and post-test pressure decay rate calculations are shown in Tables VS-4 and VS-5, respectively. Note that two pressure decay rates were calculated, one for the entire test, and another for just the span of 10 to 20 minutes. The 10 to 20 minute calculation was included because ASTM D6908 suggests allowing the pressure decay rate to stabilize before conducting the official pressure decay test. The higher pressure decay rate was not reflected in the *Bacillus* endospore and *C.parvum* reduction data. It is possible that the higher Module 1 pressure decay rate was due to air leaks out of the temporary plumbing on the test rig.

Table VS-4. December 2007 Pressure Decay Rates				
	Pre-Test		Post-Test	
Time (min.)	Module 1	Module 2	Module 1	Module 2
10-20 Minute Pressure Decay Rate (psig/min)	0.3	0.08	0.45	0.08
0-20 Minute Pressure Decay Rate (psig/min)	0.35	0.09	0.74	0.1

Table VS-5. February 2008 Pressure Decay Test Data				
	Pre-Test		Post-Test	
Time (min.)	Module 1	Module 2	Module 1	Module 2
10-20 Minute Pressure Decay Rate (psig/min)	0.3	0.2	0.4	0.2
0-20 Minute Pressure Decay Rate (psig/min)	0.6	0.25	0.4	0.2

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.

Original signed by Sally Gutierrez 09/29/09

Sally Gutierrez Date
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original signed by Robert Ferguson 09/11/09

Robert Ferguson Date
Vice President
Water Systems
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 an NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 09/26/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