

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM



U.S. Environmental Protection Agency



NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	MEMBRANE FILTRATION USED IN DRINKING WATER TREATMENT SYSTEMS		
APPLICATION:	REMOVAL OF ARSENIC		
TECHNOLOGY NAME:	WATTS PREMIER M-SERIES M-15,000 REVERSE OSMOSIS (RO) TREATMENT SYSTEM		
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The U.S. Environmental Protection Agency (EPA) supports 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 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 permittees), 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 Drinking Water Systems (DWS) Center, one of seven technology areas under the ETV Program. The DWS Center recently evaluated the performance of a membrane separations system for the reduction of arsenic in drinking water. This verification statement provides a summary of the test results for the Watts Premier M-Series M-15,000 Reverse Osmosis (RO) Treatment System. MWH, an NSF-qualified field testing organization (FTO), performed the verification testing. The verification report contains a comprehensive description of the test.

ABSTRACT

Verification testing of the Watts Premier M-Series M-15,000 RO Treatment System was conducted over a 31-day period from April 26, 2004, through May 26, 2004. This test was conducted at the Coachella Valley Water District (CVWD) Well 7802 in Thermal, California. The source water was a chlorinated groundwater supply. Based on the manufacturer's recommendations, the unit was operated at an average inlet pressure of 135 pounds per square inch (psi), water recovery of 53%, flux of 34 gallons per square-foot per day (gfd), and a specific flux of approximately 0.36 gfd/psi at 25 degrees Celsius (°C). The total arsenic (As) concentration in the feed water averaged 14 micrograms per liter (µg/L) during the testing period. The M-15,000 RO Treatment System reduced the arsenic levels to below detection (1.0 µg/L) for all but the last two samples, which were 1.4 and 1.2 µg/L. Six sets of samples were speciated and the dominant form of arsenic was As(V).

The system operated for 27 days of the 31-day verification period, with three system shut downs due to operational issues associated with the pre-filter. The verification study indicated that arsenic can be removed by the M-15,000 RO Treatment System, but depending on the source water characteristics, the appropriate pre-filter selection is important to prevent clogging of the pre-filters.

TECHNOLOGY DESCRIPTION

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

The M-15,000 RO Treatment System contains six pressure vessels, each containing one 4" x 40" membrane module. Each stainless steel pressure vessel is four inches (10 cm) in diameter and approximately 45 inches (110 cm) long. The M-15,000 RO Treatment System is a skid-mounted unit that is constructed with a carbon steel frame and powder coating. The verification unit is 37 ¾" (length) x 28 ¾" (depth) x 53 ½" (height) and requires a minimum of 18" clearance on all sides for servicing, 40" clearance on top, and a floor sink drain of 1 ¼" diameter within 10' of the processing unit. The main components of the RO unit are a 3 Hp feed pump, carbon bloc (for removal of chlorine) or sediment pre-filter pretreatment, six pressure vessels, and an in-line conductivity meter. The M-15,000 RO Treatment System unit may use either a carbon pretreatment for removal of chlorine or a sediment pre-filter as standard equipment for the system. The membranes are not tolerant of chlorine and, therefore, when the system is used on a chlorinated water source, the carbon pretreatment should be used.

VERIFICATION TESTING DESCRIPTION

Test Site

The verification testing site was the CVWD Well 7802 located in Thermal, California. The feed water for the verification study was a chlorinated source, with an average free chlorine residual of 0.47 milligrams per liter (mg/L). The chlorine enters the distribution system at the discharge manifold, and was fed from a Hammond's tablet feeder using calcium hypochlorite tablets as the chlorine source. The average feed water quality during the verification testing is provided in the table below.

In addition to being a suitable fit for water quality, the site also had sufficient access (1 acre site); full electrical supply with backup diesel powered generator; 6' privacy/security wall; all utilities readily available including raw water supply, power, and a drain (blow-off structure) for the discharge of the water from the ETV verification testing; and safety facilities, including an emergency shower and eyewash.

Average Feed Water Quality during Verification Testing

Parameter	Units	# of		Parameter	Units	# of	
		Samples	Average			Samples	Average
Total Arsenic	µg/L	27	14	Turbidity	NTU ³	5	0.40
Dissolved Arsenic	µg/L	5	14	Conductivity	umoh/cm	54	231
As (III)	µg/L	5	3.7	TDS	mg/L	27	140
As(V) ¹	µg/L	5	11	TSS	mg/L	5	< 10
TOC	mg/L	5	< 0.50	Manganese	µg/L	5	< 2.0
Calcium	mg/L	5	4.8	Iron	mg/L	5	0.019
Chloride	mg/L	5	8.5	Barium	µg/L	5	7.1
Hardness	mg/L	5	18	Silica	mg/L	5	15
Alkalinity	mg/L	5	83	Fluoride	mg/L	5	0.80
Free Chlorine	mg/L	18	0.47	Sulfate	mg/L	5	20
Total Chlorine	mg/L	18	0.51	Chromium	µg/L	5	13
pH ²	--	27	9.21 ³	Vanadium	µg/L	5	49
Temperature	°C	54	27.5				

¹ As (V) is a calculated value.

² pH is reported as the median, not the average.

³ Nephelometric Turbidity Unit(s).

Methods and Procedures

Water quality was monitored from three water streams: feed water, permeate, and concentrate. Conductivity, pH, turbidity, chlorine (free and total), temperature, alkalinity, hardness analyses were conducted on-site, using equipment set up in the pump house at CVWD Well 7802 and in accordance with *Standard Methods for the Examination of Water and Wastewater, 20th edition*. Conductivity and feed water temperature were monitored twice per day, while pH was monitored once per day. Alkalinity, hardness, chlorine, and turbidity were monitored once per week on-site using methods approved by NSF. The following additional samples were sent to MWH Laboratories for analysis: arsenic (total, dissolved, and As⁺³), total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), silica, barium, calcium, chloride, sulfate, iron, manganese, fluoride, chromium, and vanadium. Total arsenic and TDS samples were collected once per day; dissolved arsenic, As⁺³, TSS, TDS, TOC, silica, barium, calcium, chloride, sulfate, iron, manganese, fluoride, chromium, and vanadium samples were collected once per week. One sample was collected during the verification test for silt density index (SDI) analysis. Complete descriptions of the verification testing results and quality assurance/quality control procedures are included in the verification report.

VERIFICATION OF PERFORMANCE

System Operation

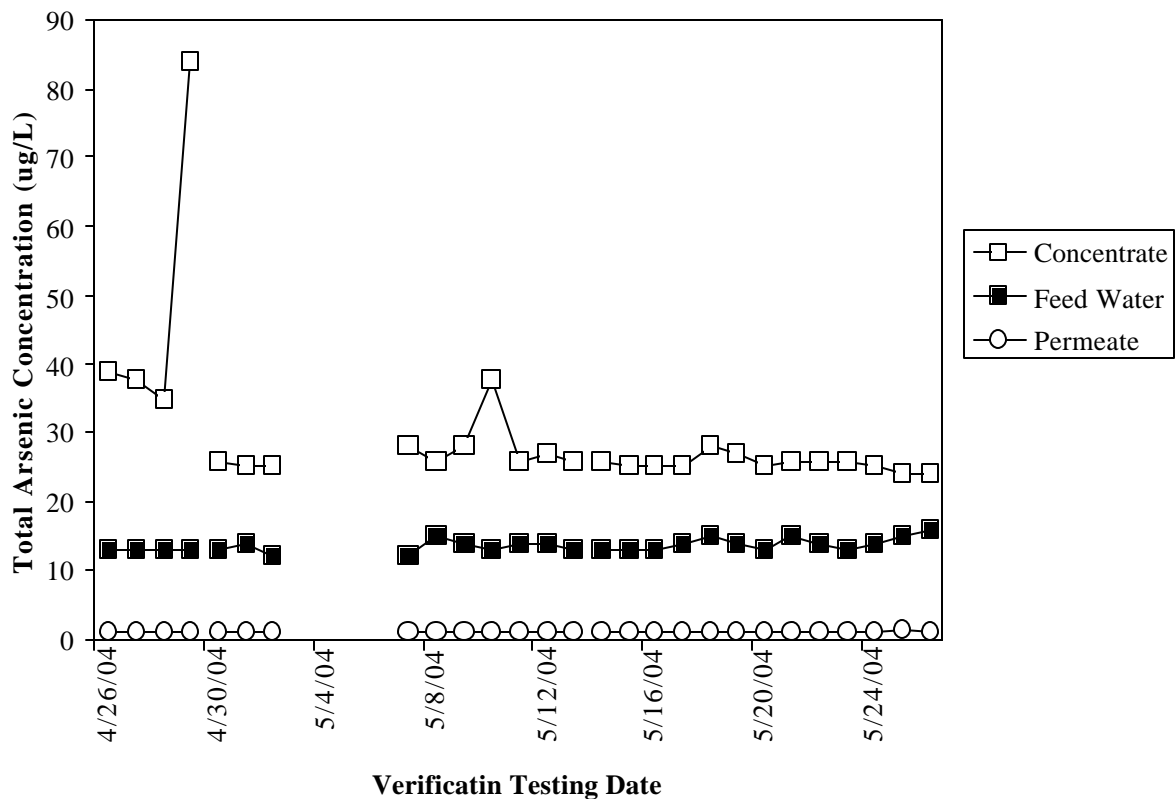
RO is a pressure-driven process, with the pressure used for separation by allowing fresh water to move through a membrane, leaving various dissolved constituents of the water behind. In the M-15,000 RO Treatment System, feed water is initially passed through a pre-filter (sediment filter or carbon bloc for chlorine removal) to remove particles that have the potential to damage the membrane. There is a sampling port just prior to the pre-filter to collect the feed water samples. After passing through the pre-filter, the feed water is blended with re-circulated concentrate water and is then referred to as the inlet water. The inlet water is then sent through a booster pump and after leaving the discharge side of the pump, the water line is split and feeds the two separate banks of membranes (six membranes in total), starting with membrane 1 and 4. For the first bank of membranes, concentrate from membrane 1 feeds membrane 2 and concentrate from membrane 2 feeds membrane 3. For the second bank of membranes, concentrate from membrane 4 feeds membrane 5 and concentrate from membrane 5 feeds membrane 6.

Permeate from all membranes is collected from the bottom of the housing and exits the unit as drinking water. There is a permeate sample port for each of the six membranes, as well as the blended permeate from all six of the membranes. During the verification test, permeate samples were collected from the blended permeate sample port. Concentrate from membranes 3 and 6 is split, some being purged to waste and some re-circulating back to the head of the system, just after the pre-filter where it is blended with the feed water to create the inlet water. The concentrate that is re-circulated back to the head of the system is referred to as recycle water.

The M-15,000 RO Treatment System was set up in accordance with the manufacturer's recommendations the week prior to the verification test. The unit was tested to make sure all systems were operating in accordance with their recommended ranges. Based on discussions between the FTO and the manufacturer, the set points were adjusted to achieve a 50% permeate recovery. Once the set points were adjusted, the system flow rates were stable for the remainder of the verification period. The feed water pressure was stable throughout the testing period, however, the inlet pressure varied from 102 to 145 psi, due to clogging of the carbon bloc pre-filter. Once the pre-filter was replaced with a sediment filter, the inlet pressures stabilized (140 to 150 psi) for the remainder of the verification testing.

Water Quality Results

The M-15,000 RO Treatment System removed the feed water total arsenic from 14 µg/L (on average) to non-detectable levels (<1.0 µg/L) for all but the last two samples collected, which were 1.4 and 1.2 µg/L. As shown in the figure below, the unit was able to produce a consistent, high quality permeate with total arsenic levels below 1.0 µg/L in 95% of the samples over the range of feed water of 12 to 16 µg/L. Throughout most of the verification test, the total arsenic mass balance was very close, with the exception of April 29, 2004, and May 10, 2004, where the arsenic concentration in the concentrate stream was significantly higher (greater than the 95% confidence interval), at 84 µg/L and 38 µg/L respectively. The permeate conductivity and TDS slowly increased throughout the verification testing, starting around 6.4 umoh/cm and increasing to 76.6 umoh/cm for conductivity and starting at <10 mg/L and increasing to 45 mg/L for TDS. During the verification testing, a total of five weekly samples were collected for inorganic analyses. Based on these five samples, the M-15,000 RO Treatment System removed on average: >72% barium, >79% calcium, 85% fluoride, 85% chloride, >92% chromium, >90% sulfate, >93% vanadium, 38% iron, and 62% silica. Manganese was also sampled and analyzed during the verification testing, but the percent removal could not be determined due to non-detectable (<2 µg/L) levels for all of the feed water and permeate samples.



Temporal Plot of Total Arsenic

Operation and Maintenance Results

The system ran continuously for 27 of the 31-day verification testing period. For one 4-day period, the system was shut down due to operational issues. Clogging of the carbon bloc pre-filter is believed to be the cause of the shut down. The unit automatically shut down on two separate occasions, also believed to be related to clogging of the carbon bloc pre-filter. On May 13, 2004 the carbon bloc pre-filter was replaced with a 20-micron sediment pre-filter. The system ran continuously after the sediment filter was installed, until the end of the verification testing on May 26, 2004, when the system was manually shut down.

Quarterly maintenance was conducted upon completion of the verification testing. The maintenance procedure took approximately 45 minutes to change out the O-rings on the pre-filter and brine line, and replace the pre-filter and two of the six RO membranes. Upon completion of the maintenance procedures, the system was started back up and both water quality and operational conditions were recorded. The specific flux immediately prior to the maintenance was 0.34 gfd/psi and upon start up after the maintenance was 0.33 gfd/psi, thus a 97% recovery of specific flux was achieved upon completion of the maintenance procedures.

Consumables and Waste Generation

There were no “consumable” chemical items used for the verification testing; however, the pre-filter to the system would be a consumable product and would have to be disposed of as solid waste. The concentrate waste stream produced from the verification test was blended back with the permeate water for an equivalent water quality to the feed water from the CVWD Well 7802. This water was then sent to a blow-off structure for disposal. The estimated concentrate production rate was 17,300 gallons per day, based on the targeted 50% permeate recovery.

Quality Assurance/Quality Control

NSF provided technical and quality assurance oversight of the verification testing as described in the verification report, including an audit of nearly 100% of the data. NSF 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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Office of Research and Development		NSF International	
United States Environmental Protection Agency			

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Arsenic Removal* dated September 2003, the *ETV Protocol for Equipment Verification Testing for Removal of Inorganic Constituents* dated April 2002, the verification statement, and the verification report (NSF Report # 04/16/EPADWCTR) are available from the following sources:

(NOTE: Appendices are not included in the verification report. Appendices are available from NSF upon request.)

1. ETV Drinking Water Systems Center 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)