EPA/600/R-13/096s
May 2013

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Verification Statement

TECHNOLOGY TYPE:	**UV DISINFECTION IN DRINKING WATER**
APPLICATION:	**INACTIVATION OF MICROBIOLOGICAL CONTAMINANTS**
PRODUCT NAME:	**NEOTECH D438™ UV WATER TREATMENT SYSTEM**
VENDOR:	**NEOTECH AQUA SOLUTIONS INC.**
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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 NeoTech Aqua Solutions, Inc. D438™ UV water Treatment System (Model 438™). NSF performed all verification testing activities at its Ann Arbor, MI location.

EPA created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The ETV Program's goal 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 NeoTech Aqua Solutions, Inc. D438™ UV Water Treatment System was tested to validate the UV dose delivered by the system using biodosimetry and a set line approach. The set line for 40 mJ/cm^2 measured Reduction Equivalent Dose (RED) was based on validation testing at three (3) set points. A set point is defined at a single flow rate and irradiance output that delivers the targeted UV dose. The results of the three set point tests were used to develop the setline that defined the maximum flow rate and minimum irradiance output required to ensure that a 40 mJ/cm^2 measured RED is achieved. The microorganism used for the validation was MS2 coliphage virus. NeoTech Aqua Solutions selected flow rates for testing of 150, 250, and 435 gpm based on the unit design and preliminary screening tests. The lowest irradiance tested was 7.9 mW/cm^2 which occurred with full power to the unit, at a flow rate of 151 gpm, and a feed water ultraviolet transmissionUltraviolet Transmission (UVT) of 91%.

The measured RED was adjusted for RED bias and uncertainty to determine the validation factor for calculating log inactivation of *Cryptosporidium.* The validation factor (VF) and validated dose calculations were performed as specified in the USEPA Ultraviolet Design Guidance Manual (UVDGM-2006). Based on the results of these tests and the calculated validation factor, the NeoTech D438™ achieved a minimum of 3.5-log reduction credit for *Cryptosporidium* at the test flow rates and corresponding irradiance levels. The validation factors for log inactivation credit for *Giardia* were also calculated and the NeoTech D438™ also achieved a minimum of 3.5-log reduction credit for *Giardia* at the test conditions.

TECHNOLOGY DESCRIPTION

The vendor provided the following description, which was not verified. The Model D438™ uses two (2) low pressure mercury amalgam lamps and one intensity sensor mounted in a stainless steel flow chamber. The inside of the flow chamber is coated with a highly reflective material that according to NeoTech reduces the amount of light energy required to achieve a targeted dose. The inlet pipe size is 3 inch diameter, the unit is designed for an operating pressure of up to 145 psi, and operating power consumption is 300 W. The low pressure lamps have an expected lamp life of 9000 hours. The sensor is a UVIM 3-1660-002 unit with a measuring field angle of 180° and measuring range of 0 to 160 mW/m^2. The system has a control panel that provides data on the lamp condition, operating hours, and irradiance measured by the sensor. The operating manual provides schematics and tables with parts, dimensions and other specifications for the reactor, the sensors, the lamps and the quartz sleeves.

VERIFICATION TESTING DESCRIPTION

Test Site and Equipment

The verification test was conducted using a full scale unit installed at the NSF Engineering Laboratory in Ann Arbor Michigan. The water source for this test was City of Ann Arbor Michigan municipal drinking water that was de-chlorinated using activated carbon. Lignosulfonic Acid (LSA) was used to lower the UV transmittance (UVT) for the full power low UVT test runs. UVT was measured continuously using an in-line UVT meter (calibrated daily) to confirm that proper UVT was attained.

NSF used a test rig and system setup that is designed to conform to the specifications described in the UVDGM-2006. The UV reactor inlet and outlet connections were installed in accordance with the NeoTech installation and assembly instructions. Two 90° elbows were attached directly to the inlet and outlet of the system to eliminate stray UV light. The feed water pump was a variable speed pump. Flow rate was controlled by adjusting the power supplied to the pump and by a control valve. A turbine water flow meter was used to monitor flow rate. The meter was calibrated and achieved an accuracy of ± 2% over the range of flow rates. A chemical feed pump (injector pump) was used to inject MS2 coliphage

upstream of an inline static mixer. The inline mixer ensured sufficient mixing of the microorganism prior to the influent sampling port, which was located upstream of the 90° elbow at the inlet to the unit. The effluent sampling port was located downstream of the 90° elbow and a second inline static mixer. The sampling location met the UVDGM-2006 requirement to ensure good mixing of the treated water prior to the effluent sampling port. A power platform that measures amperage, volts, watts, and power factor was used to monitor power use by the test unit. The unit was wired into the platform and power consumption was recorded for each test run.

Methods and Procedures

The tests followed the procedures described in the *Test/Quality Assurance Plan for The NeoTech UV Ultraviolet Water Purification System Model D438™, August 2010* (TQAP). The TQAP was adapted from the *Generic Protocol for Development of Test/Quality Assurance Plans for Validation of Ultraviolet (UV) Reactors,* July 2010 (GP). This generic protocol is based on the USEPA's UVDGM-2006. The TQAP was updated based on the GP of August 2011 prior to the start of the validation test.

The approach used to validate UV reactors is based on biodosimetry which determines the log inactivation of a challenge microorganism during full-scale reactor testing for specific operating conditions of flow rate, UVT, and UV intensity (measured by the duty sensor). MS2 coliphage ATCC 15597-B1 was used in collimated beam bench scale testing and for the full-scale reactor dose validation tests. A dose-response equation for the challenge microorganism (MS2 coliphage for this test) was determined using a collimated beam bench-scale test. The observed log-inactivation values from full-scale testing were input into the collimated beam derived UV dose-response equations to estimate a RED. The RED value was adjusted for uncertainties and biases to produce the validated dose of the reactor for the specific operating conditions tested.

The UV lamp was new and therefore the system was operated for 100 hours with the lamps turned on at full power prior to the start of the test.

VERIFICATION OF PERFORMANCE

System Operation

Each set point represented a given flow rate - irradiance pair with testing under two conditions: (1) lowered UVT-max power, and (2) high UVT-reduced power. The first test condition involved reducing the UVT while operating the UV system at full power, until the UV intensity measured by the unit UV sensor equaled the target UV intensity set point. The second test condition was run with high UVT and with the power reduced until the unit UV intensity measured by the sensor was equal to the target UV intensity set point. Three target flow rate - irradiance set points (150 gpm - 7.5 mW/cm^2; 250 gpm - 10 mW/cm^2; 435 gpm - 13 mW/cm^2) were tested for the set line with each condition being performed in duplicate. The irradiance targets were based on expected irradiance at UVTs of 91%, 94%, and 97%.

The validation tests were run on two days, August 2 and 3, 2012. The first day of testing was dedicated to the test condition with the UVT lowered to the target levels (91%, 94%, and 97%) and the lamps operating at full power. The second day of testing was dedicated to the test condition where high UVT feed water (98%) was used and the lamp power was reduced to achieve the target irradiance level. Collimated beam tests were run in duplicate on both test days with minimum UVT water (91%) on Day 1 and with maximum UVT water (98%) on Day 2. Thus, for this validation test, there are two sets of duplicate collimated beam test data, one set at low UVT and one set at high UVT.

Test Results

Sensor Assessment

The test unit duty sensor was evaluated according to the UV sensor requirements in the UVDGM-2006 prior to the verification testing. All UV intensity sensors (the duty and two reference sensors) were new sensors provided by NeoTech. Evidence of calibration of the sensors traceable to NIST standards was provided by NeoTech.

The same duty sensor was used for monitoring intensity (irradiance) for all test runs. The control panel provided direct readings of intensity in mW/cm^2. The duty sensor was compared against two reference sensors before and after the validation test runs. These data demonstrate that the duty sensor was within the range of 5.1% to 8.8% of the average of the two reference sensors. The two reference sensors showed a variance of 2.9% at 100% power and 1.3% to 6.8% at the reduced power level.

Set Line for 40 mJ/cm^2 RED_{meas}

The three set point conditions selected for this validation all achieved a minimum RED_{meas} of 40 mJ/cm^2, which was the target minimum RED_{meas} for developing the set line. Figure 1 shows the set line. The unit is validated for a minimum RED_{meas} of 40 mJ/cm^2 for any flow rate and intensity combination above and to the left of the set line. The maximum flow rate demonstrated was 434 gpm. A UV system cannot operate above the highest validated flow rate and claim a 40 mJ/cm^2 RED_{meas}. The lowest intensity demonstrating a RED_{meas} of 40 mJ/cm^2 was 7.9 mW/cm^2. A UV system cannot operate below the lowest validated irradiance and claim a 40 mJ/cm^2 RED_{meas}.

Set Point 1 - 151 gpm, 7.9 mW/cm^2; Set Point 2 - 251 gpm, 10.4 mW/cm^2; Set Point 3 - 434 gpm, 13.2 mW/cm^2.

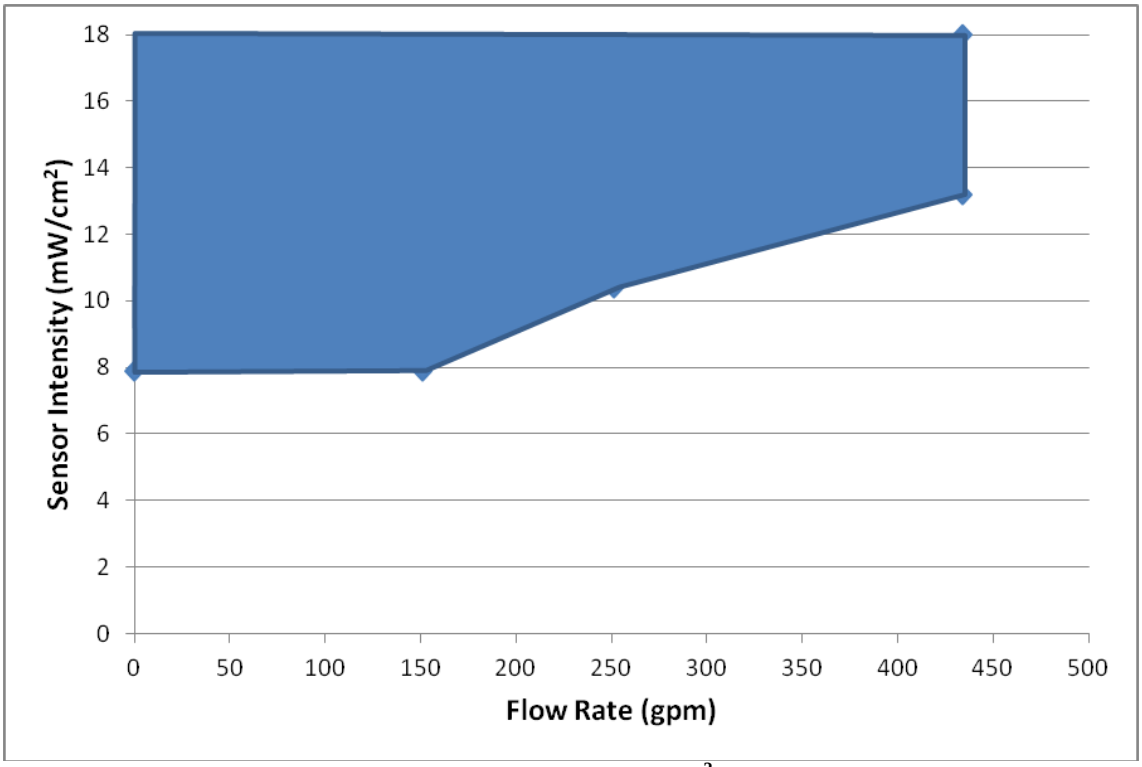

Figure 1. Set Line for 40 mJ/cm^2 RED_{meas}.

Deriving the Validation Factor and Log Credit for *Cryptosporidium*

As described in UVDGM, several uncertainties and biases are involved in using experimental testing to define a validated dose and validated operating conditions. The VF for *Cryptosporidium* was determined quantitatively to account for key areas of uncertainty and variability.

The equation for the VF is:

$$VF = B_{RED} \times [1+ (U_{Val} / 100)]$$

where:

VF = Validation Factor;
B_{RED} = RED bias factor; and
U_{Val} = Uncertainty of validation expressed as a percentage.

The highest B_{RED} value found among the replicates at a given set point was selected for the B_{RED} value for use in the VF calculation per the UVDGM-2006. U_{Val} is calculated based on the U_S (uncertainty of sensor value), U_{DR} (uncertainty of the fit of the dose-response curve and U_{SP} (uncertainty of set-point). The QC requirement that the duty sensor measurements should be within 10% of the average of two or more reference sensors eliminates the need to calculate the U_S factor per the UVDGM-2006. The U_{DR} factor calculation was greater than 30% for one set of collimated beam tests (U_{DR} of 32.58%), so U_{DR} is included in the calculation of uncertainty. The U_{SP} and U_{DR} factors are used for calculating U_{Val} per the equation:

$$U_{Val} = (U_{SP}^2 + U_{DR}^2)^{1/2}$$

The highest U_{DR} at 1.0-log inactivation for all collimated beam tests is selected for use in calculating the uncertainty (U_{VAL}). In this case the highest U_{DR} is 32.58% from the Day 1 set of collimated beam data. After establishing the VF, the validated dose is calculated as:

$$\text{Validated dose} = \text{RED} / \text{VF}$$

The NeoTech D438™ achieved a minimum of 3.5-log reduction credit for the low power runs at 251 gpm at 10.4 mW/cm^2 and a 4.0-log reduction credit for all of the test runs at the set points at 151 gpm - 7.9 mW/cm^2 and 434 gpm - 13.2 mW/cm^2. The set line for a minimum 3.0-log reduction credit for *Cryptosporidium* is shown in Figure 2.

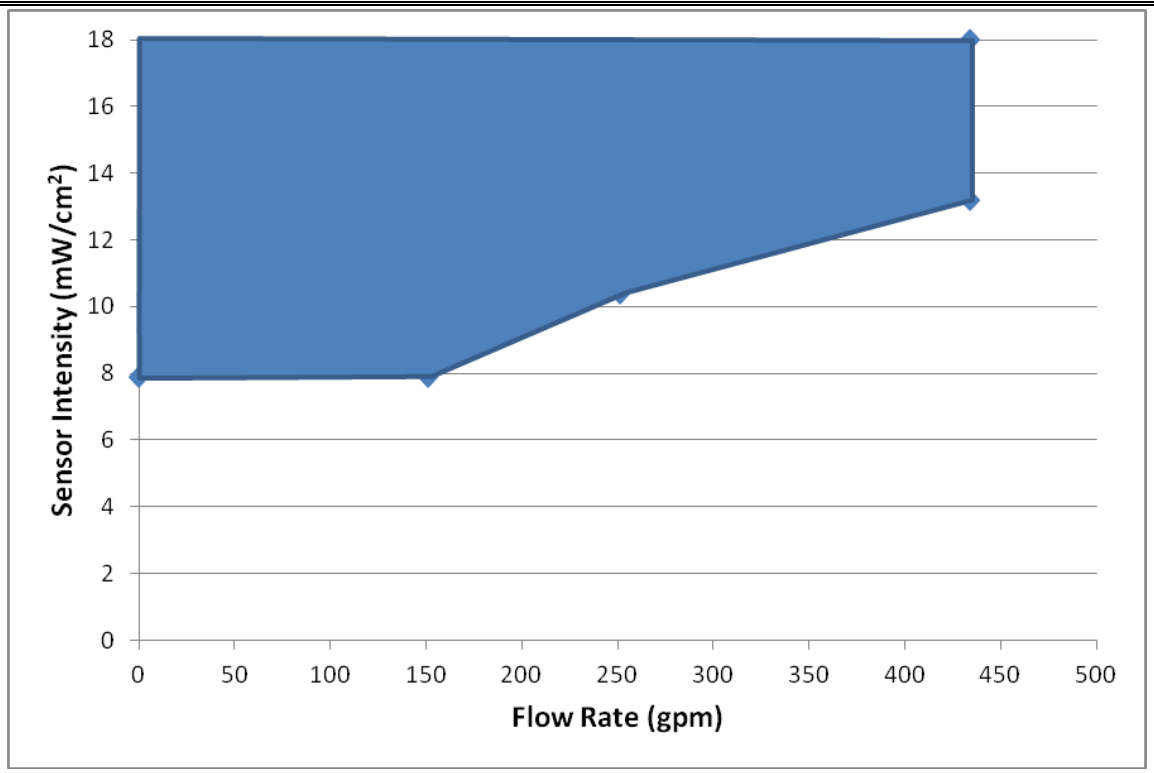

Figure 2. Set Line for Minimum 3.0-log *Cryptosporidium* Reduction Credit.

Deriving the Validation Factor and Log Credit for *Giardia*

The VF for *Giardia* was determined quantitatively to account for key areas of uncertainty and variability, using the same procedures and equations described above. The RED bias factor for *Giardia* was obtained from Appendix G of the UVDGM-2006. The U_{DR} and U_{SP} uncertainties were the same as those used for the *Cryptosporidium* calculations.

The NeoTech D438™ achieved a minimum of 3.5-log reduction credit for the low power runs at 251 gpm at 10.4 mW/cm^2 and a 4.0-log reduction credit for all of the test runs at the set points of 151 gpm - 7.9 mW/cm^2 and 434 gpm - 13.2 mW/cm^2. The set line for a minimum 3.0-log reduction credit for *Giardia* is the same as the set line for a minimum 3.0-log reduction credit for *Cryptosporidium*, as shown in Figure 2.

QUALITY ASSURANCE/QUALITY CONTROL

The NSF QA Department performed a QA review of the analytical data. A complete description of the QA/QC procedures is provided in the verification report.

Original signed by Cynthia Sonich-Mullin on 06/05/2013	*Original signed by David Purkiss on 06/17/2013*
Cynthia Sonich-Mullin Date Director	David Purkiss Date Water Systems General Manager
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Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 10/33/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