THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ULTRAVIOLET DISINFECTION**	
APPLICATION:	**DISINFECTION OF GRANULAR OR FABRIC FILTERED EFFLUENT AND MEMBRANE FILTERED EFFLUENT FOR WATER REUSE**	
TECHNOLOGY NAME:	**bersonInLine® 4250 UV System**	
COMPANY:	**Aquionics, Inc.**	
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NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of the Aquionics, Inc. bersonInLine® 4250 UV System (bersonInLine® System) for two water reuse applications: (1) disinfection of granular or fabric filtered secondary wastewater effluent, and (2) membrane filtered secondary wastewater effluent. HydroQual, Inc. (HydroQual) performed the verification test.

The EPA created the ETV Program to facilitate 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 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 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 verifiable quality are generated and that the results are defensible.

Technology Description

The following description of the technology is provided by the vendor and does not represent verified information.

The bersonInLine® System uses high-output, medium-pressure, mercury lamps that are oriented horizontally and perpendicular to the direction of flow. Each lamp has an ultraviolet (UV) output rating of approximately 120 watts (W) at 254 nm and a total power draw of 3,500 W. The lamps have an effective arc length of 350 mm. Each lamp is housed in a quartz sleeve with a wall thickness of 1.26 mm, resulting in a UV transmittance of approximately 90%. The sleeves penetrate both end plates of the reactor module and are secured with watertight seals. The reactor module, which provides a straight-through flow pattern, is a round, flanged, stainless steel unit that has an inside diameter of 350 mm and is 755 mm long. Intersecting this housing is a cylinder with the same diameter and end plates, which houses the lamp connections and drive mechanism of the cleaning system.

The test system consisted of two, full-scale bersonInLine® System modules in series with six lamps per module, mounted in a staggered array with centerline spacing of 75 mm. Each module was connected to an independent power supply cabinet with an ECtronic control unit and was supplied with 480 Volt (V) delta power at 60 amps. Each cabinet had three power supplies; each of which drove two lamps. The control panel allowed for direct lamp power manipulation in three, finite increments: 100%, 125%, and 140% of design power. The control panel contained information that allowed the operator to interpret the status of the system, including: an on/off indicator for each lamp, an alarm indicator that would detect overheating of the module housing, and an hour counter that displayed the hours that the lamps had been in operation. Each reactor had a UVector detector located on the top of the reactor housing that monitored the intensity of the top lamp. The output from the detector was displayed as a bar graph with UV intensity values of 100%, 90%, 80%, and 70% (the alarm set point).

Each reactor housing was equipped with an automatic sleeve cleaning system, consisting of teflon wipers that were driven the full length of the quartz sleeve with a motor and lead-screw drive. The wipers were not operational during the verification testing, as there was no validation test planned for this equipment. However, the wipers were operated for one cycle during lamp warm-up to remove any debris or residue, and to ensure the cleaning system was returned to the idle position.

The influent water was introduced at the first module's inlet flange. This flange contained a flow modifier insert that, in effect, extended the pipe length inside the reactor and kept the flow focused toward the lamp array. The flow modifier minimized the effect of the dead spaces, such as the access hatch, that were present upstream of the lamp array. The flow modifier did not change the operating flow range in the UV unit.

Verification Test Description

Test Site

The test site was located at the Parsippany-Troy Hills (PTRH) Wastewater Treatment Plant in Parsippany, New Jersey. The test site had two, 80,000-liter tanks for preparation of challenge water, and two, 71 hp centrifugal pumps to provide challenge water at flow rates up to 13,000 L/min or recirculation flow rates of 1,100 L/min for mixing the tanks. Influent flow was metered with a magnetic flow meter, which was calibrated by the tank drawdown method before testing began.

Methods and Procedures

All methods and procedures followed the *ETV Verification Protocol for Secondary Effluent and Water Reuse Disinfection Application* (protocol) dated October 2002. The bersonInLine® System was tested

under Element 1 of the protocol, Dose Delivery Verification for Reuse Applications. Testing was conducted for granular or fabric filtered effluent at a nominal transmittance of 55%, and for membrane filtered effluent at a nominal transmittance of 65%.

Before dose delivery verification testing began, the lamps were aged for 100 hours to allow the lamp intensity to stabilize. During the burn-in period, the lamps were not turned off or restarted. There were no lamp failures during the burn-in period.

Power consumption for the two-reactor train, inclusive of all lamps and circuitry, was monitored during the startup, characterization, and bioassay flow tests. The 480 V, three-phase power was monitored at the main disconnect panel with a power datalogger. During the startup phase, the power consumption was measured at all three power settings.

Headloss measurements for five flow rates were determined by monitoring the pressure drop across the reactor train with a manometer system. The hydraulic characterization included the measurement of velocity profiles at the inlet (first module) and outlet (second module) flanges. A pitot tube system, mounted at the flanges, provided nine monitoring positions for each location. The 720 pressure drop measurements were converted to velocity using calibration data for the pitot tube assemblies.

The microorganism MS2, an F-specific RNA bacteriophage, was used for all bioassay tests. The dose-response calibration of the MS2 stock batch and seeded influent samples was achieved using a collimated beam apparatus.

Before each flow test series, the modules were manually cleaned and inspected. The sleeve cleaning system was operated for one cycle, water flow was started, and the lamps were turned on to verify all lamps were operating.

A batch of challenge water was prepared immediately before each flow test series by filling the tank with potable water (65 percent transmittance (65%T)) or filtered secondary effluent (55%T), and adding sodium thiosulfate to remove residual chlorine. Once onsite testing verified the absence of residual chlorine, instant coffee was progressively added to reduce the transmittance to the target level. Finally, MS2 bacteriophage was added to the tank to achieve the target level of 10^5 to 10^7 pfu/mL, and the tank was mixed for 30 minutes. Five flow conditions (1,052, 2,101, 3,941, 7,355, and 10,510 L/min) were replicated at least four times for each transmittance.

Influent and effluent samples were collected simultaneously and in triplicate, resulting in six samples for each flow test. The concentration of viable MS2 bacteriophage in flow test and dose-response samples was enumerated, using a microbiological technique based on ISO 10705-1. Transmittance of the challenge waters was measured on every influent sample and on the seeded influent samples used for dose-response analysis. Quality assurance/quality control (QA/QC) requirements included field duplicates, laboratory duplicates, and spiked samples, as well as appropriate equipment/instrumentation calibration procedures. Details on all field procedures, analytical methods, and QA/QC procedures are provided in the full verification report.

Verification Performance

Power Consumption and Headloss Results

The power consumption for the two-module system, which included power use by the auxiliary circuitry in the control panels, was 34 kilowatts (kW) at the beginning of lamp life setting or 2.8 kW per lamp. The highest power setting available showed a power consumption of 45 kW.

Headloss though the lamp modules exists at any non-negligible flow rate, due to the hydraulic resistance from obstacles such as lamps and mounting hardware. In ideal, turbulent systems, the headloss increases as a function of the square of flow velocity. The headloss (cm) as a function of flow (L/min) for the two-module bersonInLine® System used in this test is approximated by the relation:

$$headloss\ (cm) = 3.14 \times 10^{-8}\ (flow)^2 + 1.18 \times 10^{-3}\ (flow) + 2.72$$

The headlosses are measured for the flow rates used in this verification test and are dependent on the flow modifier used at the inlet flange. In order to extend the results of this verification test to a commercial installation, the commercial units must contain an identical flow modifier.

The protocol required the influent flow velocities to be between 0.8 and 1.2 of the theoretical value. For the influent data, the minimum and maximum of the velocity/theoretical ratios were all within the 0.8 to 1.2 range. Based on this analysis, the influent piping to the system provided appropriate control of inlet hydraulic conditions. For the effluent data, the minimum and maximum of the measured velocity to theoretical velocity ratio showed a greater range of variability than for the influent data. The effluent velocities exceeded the target value of 1.2 for the ratio of the measured velocity to the theoretical value at the highest flow rate.

Dose Response Calibration Curve

Thirteen, valid, dose-response tests were conducted during this verification test. The delivered doses were corrected for 2.5% reflectance at the surface of the sample. The calibration curve for the MS2 bacteriophage stock, using a second-order polynomial equation, is:

$$Dose = 2.071(survival)^2 - 12.57(survival) + 2.191$$

$$Survival = Log_{10}\left(\frac{N}{N_0}\right)$$

$N_0 =$ MS2 concentration in undosed sample

$N =$ MS2 concentration in dosed sample

The calibration curve was validated using QC criteria for the acceptance of the dose-response data that was based on statistical analysis of MS2 dose-response data from several independent labs. The dose-response data generated for this verification test met the established criteria.

Dose-Flow Assays

Demonstrating the effective delivered dose for a specific UV system's reactor is the technical objective of the protocol. The delivered dose for a specific UV system is the UV dose that provides the equivalent degree of inactivation of a target pathogen, as measured with a collimated-beam apparatus. The collimated beam apparatus can accurately monitor the UV intensity reaching the fluid and the exposure time to an organism.

Therefore, the MS2 bacteriophage log survival ratios measured on samples from the field test unit and presented in the final report for the bersonInLine® System are converted to an effective delivered dose using the calibration curve from the dose-response data. MS2 bacteriophage is used for the testing because it has a high tolerance for UV light, typically requires a larger delivered dose for inactivation than most bacterial and viral organisms, and has a consistent dose-response over repeated applications. This allows development of dose-response and delivered dose relationships that encompass dose levels required for most disinfection applications. The calculated, effective, delivered dose is used to design a

UV reactor for a specific application, based on site-specific criteria for inactivation of a target microorganism.

As described in the protocol, the final analysis of the flow test data is based on the lower 75% confidence interval (C.I.) results. The results for the two-module test system are shown in Figure 1, where they are fitted with a power function. For comparison, the average dose delivery curves are also shown, which track closely with the lower 75% C.I. curve.

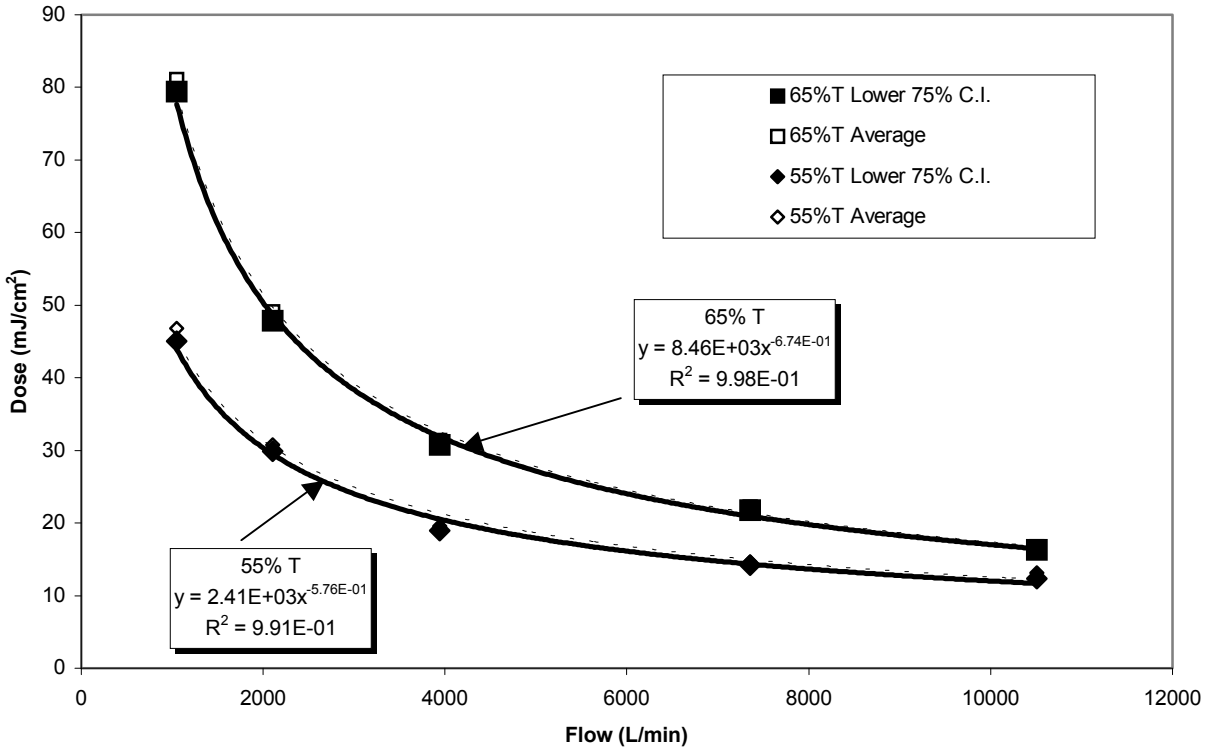

Figure 1. Dose delivery curves based on lower 75% C.I. for granular or fabric filtered effluent (55%T) and membrane filtered effluent (65%T).

Scalability

The protocol identified the elements of UV system design that are critical for designing larger systems, based on the data obtained from the verification. The appropriate data for these design elements were obtained during the verification.

The bersonInLine® modules used in the test were full-scale reactors sold commercially. Therefore, verification test data can be applied directly to systems using these modules with the same flow rates and flow modifier insert. The verification report provides a detailed discussion on application of the data for larger flow systems.

Quality Assurance/Quality Control

NSF performed QA/QC audits of the test site at PTRH and HydroQual laboratory during testing. These audits included: (a) a technical systems audit to assure the testing was in compliance with the test plan, (b) a performance evaluation audit to assure that the measurement systems used by HydroQual were

adequate to produce reliable data, and (c) a data quality audit of at least 10% of the test data to assure that the reported data represented the data generated during the testing. In addition to quality assurance audits performed by NSF, EPA QA personnel conducted a quality systems audit of NSF's QA Management Program and accompanied NSF during audits of the HydroQual facilities.

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Availability of Supporting Documents

Copies of the *ETV Verification Protocol for Secondary Effluent and Water Reuse Disinfection Application* (Protocol), dated October 2002, the Verification Statement, and the Verification Report are available from the following sources:

1. ETV Water Quality Protection 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)

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