THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ON-SITE DISINFECTION UNIT USED IN DRINKING WATER TREATMENT SYSTEMS**		
APPLICATION:	**ON-SITE DISINFECTANT GENERATION AND INACTIVATION OF PSEUDOMONAS**		
TECHNOLOGY NAME:	**OXI-2B**		
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The U.S. Environmental Protection Agency (EPA) has created 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 substantially 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; stakeholders groups which consist 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.

NSF International (NSF) in cooperation with the EPA operates the Drinking Water Treatment Systems (DWTS) pilot, one of 12 technology areas under ETV. The DWTS pilot recently evaluated the performance of an on-site disinfectant generation system used in package drinking water treatment system applications. This verification statement provides a summary of the test results for the OXI Company's OXI-2B System. ARCADIS Geraghty & Miller, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of OXI's on-site disinfectant generation system OXI-2B was conducted for 30 days between June 26 and August 17, 2000. The OXI-2B system is capable of producing at least 1 lb of chlorine in water using 2.7 lb of salt (NaCl) and 2.2 AC kilowatt hours (kWh) of power. In addition, the system was capable of producing a 4.2 log kill of *Pseudomonas aeruginosa* bacteria when chlorine is dosed to achieve a CT of 56 based on actual (field-confirmed) hydraulic retention time or a CT of 30 based on a T_{10} value in water with a pH between 7.0 and 8.0 and turbidity of 20 NTU or less, organic carbon concentrations between 1.8 and 2.6 mg/L and an alkalinity of less than 20 mg/L as $CaCO_3$.

TECHNOLOGY DESCRIPTION

The OXI-2B disinfectant generation unit consists of two electrolytic cell halves, a brine tank and pump, and a stand with the power supply and piping attached. The OXI-2B unit uses sodium chloride (NaCl) brine to produce an oxidant gas, that is drawn into a side stream of the water by means of a venturi. The key part of the unit consists of an anode and cathode compartment separated by a proprietary membrane. When a direct current (DC) voltage is imposed across the cell, the (Cl^-) ions are attracted to the positively-charged anode and will combine to form chlorine (Cl_2) molecules, which will initially react with water from the brine solution. At a pH of about 2, an equilibrium is reached where free Cl_2 gas is released to the air in the upper part of the enclosed anode compartment. Gas is drawn into a side stream of water by means of a venturi.

VERIFICATION TESTING DESCRIPTION

Test Site

The host site for this demonstration is the SJWD Water District Drinking Water Treatment Plant in Lyman, South Carolina, which draws water from the Middle Tyger River. The water is generally of good quality with a turbidity of less than 10 nephelometric turbidity units (NTU), hardness under 10 g/L and TOC of approximately 2.5 mg/L. During storm events, the turbidity may rise significantly. Furthermore, the water is known to have coliforms with counts generally varying between 100 to 1,000 colony forming units (CFU) per 100 ml. Raw water was drawn at a rate of 23 gallons per minute (gpm) from a sump directly in contact with the Middle Tyger River.

Methods and Procedures

The test was divided into three tasks: 1) Equipment Disinfection Production Capabilities and Operation, 2) Microbiological Contaminant Inactivation (Challenge Test), and 3) Treated Water Quality.

The objectives of Task 1 included the generation of data that describe the operation of the OXI-2B, i.e., the concentration of disinfectant (as chlorine) produced, the electrical power consumption per pound of available chlorine, the sodium chloride consumption per pound of available chlorine, and the amount of potable water used. The combined waste flow rate from anode and cathode, pH, and temperature were recorded once per day and the waste composition was determined once during the test. The electric power consumption of the system was also monitored. The sodium chloride consumption was determined based on a comparison of the mass of sodium chloride added to the OXI-2B and the total disinfectant production (as chlorine).

The objective of this task was to verify OXI-2B's efficacy for inactivation of *P. aeruginosa* when disinfectant (as chlorine) is dosed to achieve a concentration time (CT) of 70 in water with a pH between

6.0 and 8.0 and turbidity of 20 NTU or less, organic carbon concentrations between 1.0 and 3.0 and an alkalinity less than 20 mg/L as $CaCO_3$. This microbe was spiked into the raw water flow for a period of time equivalent to three hydraulic retention times. Subsequent analyses revealed an average *P. aeruginosa* effluent concentration of 1.5 x 10^4 CFUs/100 ml. *P. aeruginosa* enumeration of the samples was done using Standard Methods 9213 E. Membrane Filter Technique for *P. aeruginosa*. During the challenge testing, the total and free chlorine concentrations were verified. *P. aeruginosa* was selected as the bacterial challenge test organism because the *Pseudomonas* species background in the raw water was expected to be minimal and selective culture methods exist such that *P. aeruginosa* can be reproducibly cultured in the disinfected water.

The objective of the treated water quality task was to assess the impact that treatment with disinfectant generated by the OXI-2B has on treated water quality. Water quality parameters that were monitored during the test period include: pH, temperature, turbidity, chlorine residual (free and total), hydrogen sulfide, alkalinity, TDS, ammonia nitrogen, total organic carbon (TOC), ultraviolet absorbance (UVA) at 254 nanometer (nm), true color, iron, manganese, chloride, chlorite, chlorate, sodium, total coliforms, and heterotrophic plate count (HPC) bacteria. Simulated Distribution System testing for disinfection by-product (DBP) formation was conducted as a one-time event.

VERIFICATION OF PERFORMANCE

Operation and Maintenance

The OXI-2B system was fully automated and capable of normal operation without manual intervention. During the ETV test the float switch in the brine tank got stuck and had to be operated manually on occasion. Other than periodically adding salt, no maintenance was required during the test period. However, ARCADIS found the Operation & Maintenance manual limited and suggests that OXI provides a (ring-)bound operations and maintenance manual with the unit that makes ample use of illustrations and schematics and includes comprehensive operational instructions.

Disinfectant Production Capabilities

The OXI-2B system produced and dosed oxidant (measured as chlorine) constantly and effectively during the test. All chlorine analyses were done onsite in the SJWD laboratory. The average finished free and total chlorine concentrations were 3.07 and 3.54 mg/L respectively. During the test the raw water flow rate was maintained at the set rate of 23 gpm. The free and total chlorine content of the disinfectant stream was 38 mg/L with a standard deviation of 9 mg/L and 42 mg/L with a standard deviation of 8 mg/L respectively. Because the total volume of the disinfectant stream was 510,407 L, the total chlorine produced during the ETV-test was 21 kg (46 lb).

A total of 240 lb of salt was used during the test. Most salt was added during the first part of the test: during the first 10 days, 120 lbs was added and during the last 10 days, only 40 lbs was added. The OXI-2B system was required to have a brine overflow, which was considerable during the first part of the test resulting in 5.2 lbs of salt expended for each pound of total chlorine produced. During the later part of testing, the brine overflow was significantly reduced. In the last 10 days of the test, 40 lbs of salt was needed to produce approximately 7 kg (15 lbs) of chlorine, resulting in a ratio of only 2.7 lbs salt/lb chlorine. OXI states that the newer models of the OXI disinfectant systems do not include a brine overflow, which they indicate was a cause of the higher salt consumption during verification testing.

Microbiological Contaminant Inactivation

Based on the results of an earlier tracer test, the hydraulic retention time was calculated to be 19 minutes. ARCADIS performed a challenge test to assess the disinfection capabilities of the OXI-2B system on *P. aeruginosa*. The concentration for *P. aeruginosa* in the broth culture was 1.6 x 10^{10} CFUs/100 ml. The results of the *P. aeruginosa* challenge test show that the OXI-2B system is capable of a 4.2-log kill of *P. aeruginosa* at a CT value of 56 based on actual hydraulic retention time or a CT of 30 based on a T_{10} value.

Finished Water Quality

In-line turbidity readings were taken twice daily for finished water and were verified by taking grab samples. The OXI-2B system has no apparent effect on turbidity: the average raw water turbidity was 11.45 NTU and the average finished water turbidity was 11.67 NTU for grab samples and 10.92 NTU for in-line samples.

The OXI-2B has no apparent effect on UVA, true color, TOC, manganese, and iron. Readings for chlorite and chlorate were always below the detection limit of 20 µg/L. The OXI-2B system produced some chloride (6.0 mg/L), which can probably be attributed to the use of brine. Ammonia nitrogen was not detected in raw nor finished water.

The OXI-2B system performed well in eliminating total coliforms. For all test days, total coliforms were reduced to zero cfu/100 ml. The OXI –2B system was very effective in reducing HPC during the first 20 days of the test, but for the remaining 10 days of the test, the HPC kill capacity diminished. Although ARCADIS has no complete explanation for this phenomenon, the concentration of heterotrophic bacteria in the raw water samples generally increased by an order of magnitude during this same interval.

Total trihalomethanes (TTHMs) and haloacetic acids (HAAs) were also analyzed as part of the ETV test. None of these analytes were detected in the raw water. The OXI-2B system generated some chloroform (10 µg/L) and small amounts of bromodichloromethane (2.8 µg/L) and dibromochloromethane (0.3 µg/L), whereas none of the other TTHMs were detected. Average dichloroacetic acid and trichloroacetic acid concentrations were 18 µg/L and 21 µg/L respectively. Small amounts of bromochloroacetic acid, monochloroacetic acid, and bromodichloroacetic acid were detected. No other HAAs were detected.

Simulated distribution system (SDS) testing was conducted to determine the extent to which disinfection byproducts would be formed when the OXI-2B was used as source for both primary and residual disinfection. Testing included analyses for TTHMs and HAAs. Significant amounts of chloroform (~ 85 µg/L), dicholoracetic acid (46-50 µg/L), trichloroacetic acid (78-91 µg/L) and relatively low levels of bromodichloromethane (9.9-11 µg/L), dibromochloromethane (0.7-0.8 µg/L), bromochloroacetic acid (4.1-4.2 µg/L), monochloroacetic acid (5.3-6.3 µg/L), and bromodichloroacetic acid (4.3-4.6 µg/L) were found. The support system for the verification of the OXI-2B during this project was not designed to remove dissolved organics from the raw water prior to chlorination. Thus, the formation of substantial quantities of DBPs during the verification interval is not a surprising result.

Waste Production

The OXI-2B produced a small continuous waste stream of 13.7 ml/min (5.2 gal. or 19.8 L per day). The waste stream had a high alkalinity, pH, and a high TDS content. The average alkalinity of the waste was 30,960 mg/L, the pH was 12.91, and the TDS was 13,800 mg/L. According to OXI documentation, the OXI-2B cathode generates 11.2 L of hydrogen for each 35.5 gram of total chlorine. Because 21 kg total chlorine were generated, 6,625 L of hydrogen were produced over the duration of the verification test which was vented to the atmosphere.

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E. Timothy Oppelt	Date	Gordon Bellen	Date
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United States Environmental Protection Agency			

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Inactivation of Microbiological Contaminant* dated August 1999, the Verification Statement, and the Verification Report (NSF Report #01/28/EPADW395) are available from the following sources:

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

1. Drinking Water Systems ETV Pilot 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)