THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**POINT-OF-ENTRY DRINKING WATER TREATMENT SYSTEM**
APPLICATION:	**REMOVAL OF SYNTHETIC ORGANIC CHEMICAL CONTAMINANTS IN DRINKING WATER**
PRODUCT NAME:	**ADVANCED SIMULTANEOUS OXIDATION PROCESS (ASOP™)**
VENDOR:	**RASCO, INC.**
ADDRESS:	**1635-2 WOODSIDE DRIVE WOODBRIDGE, VA 22191**
PHONE:	**703-643-2952**
FAX:	**703-497-2905**
EMAIL:	**ADMIN@RASCOENGINEERS.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 RASco, Inc. Advanced Simultaneous Oxidation Process (ASOP™) Drinking Water Treatment Module. 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 testing activities.

The 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

The RASco, Inc. ASOP Drinking Water Treatment Module was tested at NSF's Laboratory for the reduction of the following chemicals of concern: aldicarb, benzene, carbofuran, chloroform, dichlorvos, dicrotophos, methomyl, mevinphos, nicotine, oxamyl, paraquat, phorate, sodium fluoroacetate, and strychnine. The ASOP is a component of RASco's Hyd-RO-Secure™ Series 2 Anti-Terrorism/Force Protection Drinking Water Treatment System, which uses reverse osmosis (RO), the ASOP module, and a post-ASOP activated carbon filtration to treat drinking water. The ASOP module uses ultraviolet light (UV) and ozone to oxidize contaminants. An activated carbon filter was evaluated to demonstrate its capability to adsorb any oxidation byproducts and/or the amounts of challenge chemicals not oxidized by the ASOP module. The target chemical challenge concentration was 1,000 micrograms per liter (μg/L), and each challenge was 30 minutes in length. Both the ASOP module and activated carbon filter were tested at the same time, with the carbon filter plumbed downstream of the ASOP module. Treated water samples were collected from both the ASOP and carbon filter effluents, so that the ASOP module's performance could be evaluated alone, and also combined with activated carbon treatment. The percent reductions for the ASOP module alone ranged from zero for carbofuran, chloroform, and mevinphos, to 98% for strychnine. The combination of the ASOP and activated carbon filter removed all challenge chemicals, except paraquat, by 94% or more.

TECHNOLOGY DESCRIPTION

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

The patent-pending RASco, Inc. ASOP module is marketed as a component of the point-of-entry Hyd-RO-Secure Series 2 Anti-Terrorism/Force Protection Drinking Water Treatment System. A complete Hyd-RO-Secure system consists of an RO module, the ASOP module, and an optional post-ASOP activated carbon filter. The Hyd-RO-Secure is a modular system, with the RO and ASOP components on individual platforms. The RO and activated carbon components are not standard, but rather are selected based on the site-specific application. The main components of the ASOP module are an Aquafine model CSL-4R-UV UV unit, an Ozotech model OZ2BTUSL ozone generator, an Ozotech model PP Phoenix oxygen generator to supply oxygen to the ozone generator, and an ozone contact tank. A Pentek model RFC20-BB activated carbon filter supplied by RASco was tested to demonstrate the ability of an activated carbon filter to adsorb any oxidation by-products and/or the amounts of challenge chemicals not oxidized by the ASOP module. The carbon filter was plumbed downstream of the ASOP module. A sampling valve was installed between the ASOP module contact tank and carbon filter to allow sampling of both the ASOP effluent and carbon filter effluent.

The ASOP module offers simultaneous treatment with both UV light and ozone, plus a contact tank (volume varies depending on installation) to complete the ozone oxidation treatment. The ozone is injected into the UV reactor vessel to oxidize contaminants synergistically with the UV light. The UV light has an output of 30,000 microwatt-seconds/cm^2. Delivery of ozone into the reaction chamber is controlled by adjusting the flow of oxygen into the ozone generator. The ASOP module as tested did not include any sensors for UV intensity, but it did include an oxidation reduction potential (ORP) meter immediately downstream of the contact tank to indirectly measure the ozone residual. The contact tank volume for the test module was 3 gallons (gal). The system is programmed so that the ozone generator turns on when the ORP meter reaches a preset value, in this case 450 millivolts (mV) or less, and turns off when the ORP rises to another preset value, in this case 550 mV. The preset ORP values can be changed depending on the concentration of contaminants being treated. A green light on the system cabinet door indicates when the ozone generator is functioning. The UV unit inside the ASOP module cabinet has four lights to indicate whether each UV lamp is functioning.

VERIFICATION TESTING DESCRIPTION

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 challenge tests followed the procedures described in the *Test/QA Plan for Verification Testing of the RASco Engineering, Inc. Hyd-RO-Secure™ Series 2 Anti-Terrorism/Force Protection Point-of-Entry Water Treatment System for Removal of Chemical Contaminants*. The chemical challenge protocol was adapted from the *ETV Protocol for Equipment Verification Testing for Removal of Synthetic Organic Chemical Contaminants*. Production of drinking water from an untreated source water was not evaluated; this verification only evaluated the system's ability to remove chemical contaminants from an otherwise potable drinking water. The challenge chemicals are listed in Table VS-1. Separate challenges were conducted for each chemical in the table. The target challenge concentration for each chemical was 1,000 ± 500 μg/L.

The ozone generator's oxygen delivery rate for the challenges was approximately 8 cubic feet per minute, as set by RASco personnel. The flow rate was controlled at 5.0 ± 0.5 gallons per minute (gpm). According to Aquafine, at this flow rate the 85% theoretical hydraulic residence time for the UV chamber is 33 seconds. Dividing the contact tank volume (3 gal) by the flow rate, the theoretical hydraulic residence time for that component is 36 seconds.

The ASOP ozone generator was set to turn on when the ORP meter read 450 mV or less, and turn off when the ORP rose past 550 mV. The ORP can continue to rise for a period of time if the water has minimal ozone demand. To ensure that the ozone generator was on at the beginning of each chemical challenge, and each challenge was conducted under similar ORP conditions, each challenge, except for sodium fluoroacetate, officially began when the ORP meter read 450 mV. Prior to the start of each challenge, the ASOP module was turned on and deionized water was run through the unit for approximately one minute until the ORP rose to above 550 mV. Then the water supply was switched over to the chemical challenge water, and the ASOP module was operated using this water until the ORP dropped back down to 450 mV and the ozone generator turned on. The point where the ozone generator turned on was considered "time zero" for each challenge. The ASOP module was operated continuously for 30 minutes from time zero for each challenge. For the sodium fluoroacetate challenge, the lab technician started the challenge when the ORP was 854 mV. The technician attempted to lower the ORP to 450 mV, but it dropped very slowly, and there was concern that the tank of challenge water would be exhausted prior to 30 minutes of operation. The ORP only dropped to 483 mV after 30 minutes, so the ozone generator did not operate at all during the sodium fluoroacetate challenge.

Influent and effluent samples were collected for challenge chemical analysis after 15 and 30 minutes of operation. The ASOP effluent samples were collected downstream of the contact tank. At 30 minutes, samples were also collected for oxidation byproducts analysis. To accomplish this, two scans were conducted: base/neutrals and acids (BNA) according to EPA Method 625, and volatile organic compounds (VOC's) according to EPA Method 524.2. BNA scans were performed on both the ASOP and carbon filter effluent samples, but the VOC scan was only performed on the carbon filter effluent samples.

VERIFICATION OF PERFORMANCE

The chemical challenges data are presented in Table VS-1. The mean challenge chemical concentrations for the influents, ASOP effluents, and activated carbon filter effluents are presented, as well as the percent reductions calculated for the ASOP module alone and the ASOP and activated carbon filter treatment combined.

Table VS-1. Chemical Challenge Results

Challenge Chemical	Mean Influent (μg/L)	Mean ASOP Effluent (μg/L)	ASOP % Reduction	Mean Carbon Effluent (μg/L)	ASOP + Carbon % Reduction
Aldicarb	930	160	83	4	>99
Benzene	440	330	25	3.0	>99
Carbofuran	1100	1100	0	22	98
Chloroform	740	790	0	43	94
Dichlorvos	850	430	49	13	99
Dicrotophos	750	250	67	23	97
Methomyl	1200	830	31	8	>99
Mevinphos	940	1200	0	11	99
Nicotine	1200	80	93	4	>99
Oxamyl	1200	210	83	3	>99
Paraquat	700	600	14	340	51
Phorate	630	170	74	6	>99
Sodium Fluoroacetate	760	740	2.6	21	97
Strychnine	910	20	98	5	>99

The percent reductions for the ASOP module ranged from zero for carbofuran, chloroform, and mevinphos, to 98% for strychnine. The combination of the ASOP module and activated carbon filter removed all challenge chemicals, except paraquat, by 94% or more. However, as previously discussed, a complete Hyd-RO-Secure system employs an RO system in addition to the ASOP module and activated carbon filter, but there is no standard RO make and model employed. A previous ETV verification for the Watts Premier M-2400 POE RO system (EPA/600/R-06/101) demonstrated that the selected RO membrane reduced by more than 95%, 1 mg/L concentrations of various chemicals, including Paraquat and most of the chemicals used in this study. Therefore, it is feasible that a complete Hyd-RO-Secure configuration employing a high quality RO module may also be able to achieve significant chemical reductions.

As discussed in the Methods and Procedures section, 30-minute influent and effluent samples were analyzed for oxidation byproducts in addition to the challenge chemicals themselves. The BNA scans did qualitatively detect “tentatively identified” compounds (TIC) in the contact tank effluent samples, which may have been oxidation byproducts. However, many of the TICs were detected in both the influents and contact tank effluents, indicating that perhaps they were impurities in the challenge chemical solutions. The only compound detected above 10 μg/L in the contact tank effluent, but not in the influent, was methyl dimethylcarbamate for the oxamyl challenge. The activated carbon filter effluent samples did not yield any BNA scan TICs that could have been oxidation byproducts. However, the activated carbon filter effluent VOC scans found chloroform, chloromethane, methylene chloride, and total trihalomethanes, all at less than 10 μg/L.

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 conducted a technical systems audit at the start of 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 S. Gutierrez *08/14/07*

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

Original signed by R.Ferguson *08/10/07*

Robert Ferguson Date
Vice President
Water Systems
NSF International

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Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 06/25/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