THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**CHEMICAL COAGULATION/FILTRATION SYSTEM USED IN PACKAGED DRINKING WATER TREATMENT SYSTEMS**		
APPLICATION:	**REMOVAL OF ARSENIC**		
TECHNOLOGY NAME:	**eVOX® MODEL 5**		
COMPANY:	**WATERMARK TECHNOLOGIES, LLC**		
ADDRESS:	**12753 SOUTH 125 EAST** **DRAPER, UTAH 84020**	PHONE: FAX:	**(801) 816-1800** **(801) 816-0388**
EMAIL:	**info@watermarktechnologies.net**		

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 a Chemical Coagulation/Filtration system used in package drinking water treatment system applications. This verification statement provides a summary of the test results for the Watermark Technologies, LLC eVox® Model 5 Coagulation/Filtration System. Cartwright, Olsen & Associates, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of the Watermark Technologies, LLC eVox® Model 5 Coagulation/Filtration System (Watermark eVox® Model 5) was conducted at the Park City, Utah, Spiro Tunnel Water Filtration Plant from April 11 to April 26, 2000. The source water was groundwater from an abandoned silver mine, representing one of the sources of drinking water for the City of Park City, Utah. Verification testing was conducted at the operating conditions specified by the manufacturer. Ferric chloride ($FeCl_3$) and sodium hypochlorite (NaOCl) were metered into the feedwater supply at a rate of 0.094 gallons per hour (gph) of 0.7% $FeCl_3$ and 0.005 gph of 0.42% of NaOCl to effect coagulation. When operated under the designed conditions at this site, the Watermark eVox® Model 5, removed each arsenic (As) species [total As, dissolved As and As (V)], from the feedwater supply to an average concentration of less than 4.7 µg/L.

TECHNOLOGY DESCRIPTION

The Watermark eVox® Model 5 uses ferric hydroxide [$Fe(OH)_3$] (converted from $FeCl_3$) to react with the soluble As to produce an insoluble precipitate that can be removed with a backwashing media filter. The Watermark eVox® Model 5 consists of metering pumps to feed $FeCl_3$and NaOCl into the feedwater stream, a retention tank to facilitate coagulation, and a repressurization pump to feed coagulated water to a multi-media filter to continuously remove the precipitated As. The multi-media filter consisted of a 6" diameter column with a 6" depth of ¼" pea gravel, a 6" layer of 8 – 12 mesh course garnet, and a 24" layer of 60 mesh fine garnet. At four-hour intervals, a timer initiated a five-minute backwashing sequence utilizing raw water and consisting of a four-minute backwash at 20 gpm per square foot of surface area, followed by one minute for media settling.

The Watermark eVox® Model 5 is designed for small system applications; this sized unit would serve 15 – 20 people. The test unit is self-contained, skid-mounted and easily transportable by truck. The only connections required are an inlet line for pressurized feedwater, outlet line for filtrate, drain line for backwash water, and an electrical connection. The footprint of the unit is approximately 12 ft^2 (l.1 m^2).

VERIFICATION TESTING DESCRIPTION

Test Site

The verification testing site was the Park City Spiro Tunnel Water Filtration Plant in Park City, Utah. The source water was the Spiro Tunnel Bulkhead water, which is considered a groundwater source under the State of Utah source water protection program. Water is developed from water bearing fissures in an abandoned silver mine tunnel. A five-foot bulkhead built approximately two miles into the tunnel holds back the water and creates a reservoir. Water is piped from this reservoir to the treatment plant through a 12-inch diameter pipe. The water is considered stable with respect to quality and quantity, and is known to contain As.

Methods and Procedures

Temperature, pH, turbidity (both on-line and bench-top), and dissolved oxygen analyses were conducted on both the feedwater and filtrate streams at least once per day at the test site in accordance to *Standard Methods for the Examination of Water and Wastewater*, 18th edition (APHA, et. al., 1992). The State of Utah, Department of Health, Division of Laboratory Services performed analyses daily for alkalinity, antimony and speciated As [total, dissolved, As (III) and As (V)] on both the feedwater and filtrate streams. The As speciation procedure (see Appendix C of the Final Report) involved filling containers as follows: bottle A – as collected; bottle B – filtered through a 0.45µ filter; and bottle C – portion of the solution from bottle B run through an ion exchange resin for As (V) removal.

The Division of Laboratory Services also analyzed hardness, total organic carbon (TOC), UV254 absorbency, aluminum, iron (Fe), manganese, sulfate, and algae (chlorophyll A) on a weekly basis. These parameters were also measured on a more frequent basis during the verification performance where eleven sets of samples were collected over a 48-hour period.

VERIFICATION OF PERFORMANCE

System Operation

Verification testing was conducted under manufacturer's specified operating conditions. The flow rate of the system ranged between 1.0 and 1.1 gpm with a total backwash volume of 16 gallons produced every four hours during the backwashing operation.

The system initially operated for 24 hours without coagulation chemicals ($FeCl_3$ and NaOCl). At the end of this initial operation period, the metering pumps were activated and the coagulant chemicals of $FeCl_3$ and NaOCl were fed into the system. This coagulant addition continued, with only one brief interruption, for another 328.5 hours.

Evaluation of the required concentration of $FeCl_3$ necessary for optimum As removal was carried out by means of a simple series of jar tests conducted at the end of March prior to the initiation of the ETV testing period. Water from the Park City Bulkhead supply source was introduced into the Watermark eVox® Model 5 treatment equipment with increasing amounts of $FeCl_3$ added. The samples were then analyzed during the incremental addition of $FeCl_3$. The results were used to determine the $FeCl_3$ injection concentration for the ETV testing period at approximately 3 mg/L (as Fe).

The Watermark eVox® Model 5 was set to automatically backwash every four hours (based on a timer setting). The on-line turbidimeter alarm was set to initiate when the filtrate turbidity reached 0.5 NTU. Based on data gathered during initial operations, it was determined that the backwashing frequency should be every four hours. Backwash cycles were automatically initiated and controlled with a timer/controller. This frequency was maintained throughout the duration of the test.

Arsenic Removal

During initial operations, without coagulation chemicals, the media filter removed approximately 49% of the total As in the feedwater stream and approximately 11.5% of dissolved As was removed. Because Fe is present in the tunnel water, and this supply is exposed to the air, it is suspected that the resulting [$Fe(OH)_3$] reacted with a portion of the total As in the feedwater stream forming the insoluble [$Fe(OH)_3$] / As complex, which was almost 93% removed by the media filter.

During the test period, while coagulant chemicals were being fed to the feedwater stream, approximately 95% of the average total As concentration was removed by this system, with all but two of the filtrate concentration readings at 2 µg/L or less. The Watermark eVox® Model 5 removed approximately 89% of the average dissolved As in the feed water and all of the filtrate samples were at or below 4 µg/L, except for two instances. Almost all of the dissolved As was found as the As (V) species and this species was removed to an average of 4 µg/L in the filtrate. The As (III) species was detected near the detection limit (quantitative at 2 µg/L) in the feed water and at the qualitative detection limit (0.5 µg/L) in the filtrate. A summary of the concentrations of As species in both the feedwater and filtrate streams is presented in the following table.

Arsenic Data Summary (April 12 – April 26, 2000) based on 22 samples

	Feedwater (µg/L)	Filtrate (µg/L)
Total Arsenic		
Average	77.6	4.1
Minimum	60.9	1.2
Maximum	146.0	34.5
Standard Deviation	16.8	8.5
95% Confidence	70.6, 84.6	0.6, 7.6
Dissolved Arsenic		
Average	42.0	4.7
Minimum	37.4	1.4
Maximum	45.9	32.6
Standard Deviation	2.5	7.5
95% Confidence	41.0, 43.1	1.5, 7.8
Arsenic (III)		
Average	2.5	0.7
Minimum	2.1	<0.5*
Maximum	3.6	1.0
Standard Deviation	0.4	0.2
Confidence Interval	2.4, 2.7	0.6*, 0.8
Arsenic (V)		
Average	39.5	4.0
Minimum	35.2	0.9
Maximum	43.8	31.6
Standard Deviation	2.6	7.4
95% Confidence	38.4, 40.6	0.9, 7.1

*All readings at the MDL for As (III) (<0.5 µg/L) were used as that number in calculations.

Note: the reliability of the low-level data (MDL of 0.1 µg/L to approximately 2 µg/L) should be considered only qualitative (not quantitative).

Iron Removal

Fe in the feedwater stream was at an average concentration of 0.268 mg/L and was consistently removed to below detection limits (<0.02 mg/L) in all samples collected.

Turbidity

Turbidity measurements made both with on-line turbidimeters and the bench-top instrument showed significant turbidity reduction by the Watermark eVox® Model 5 (in excess of 90%). On-line feedwater turbidity readings during the testing period averaged 1.51 NTU, compared to the bench-top turbidity average of 1.66 NTU. The on-line filtrate turbidity readings for the testing period averaged 0.060 NTU, compared to the bench-top average of 0.13 NTU. Although there was a lack of complete agreement between the instruments in the measurement of filtrate turbidity, the trend was consistent.

Operation and Maintenance Results

Testing was initiated at 16:30 hours on April 11, 2000, and except for approximately one hour on April 14 (when a new feed pump was installed), the system ran continuously until 09:00 hours on April 26, 2000. On April 20, 2000, a pinhole leak occurred in the $FeCl_3$ discharge tubing line from the metering pump, which was quickly repaired. On six occasions, the on-line turbidimeter alarm was initiated, signaling a filtrate turbidity reading exceeding 0.5 NTU. This always occurred during or immediately following the automatic backwashing activity, and the alarm shut off automatically within five minutes. It was concluded that this was due to the generation of turbidity during backwashing with incomplete settling and no rinse prior to the system returning to operation. By adjusting the backwashing sequence to allow for complete settling, this problem can be eliminated.

The electrical power used was 110VAC, single phase, 20A service. The power was recorded on an Amprobe Kilowatt/Hour (kWh) Meter (non-demand). The total power consumed was 359 kWh. The total quantity of filtrate produced was 23,265 gallons. Total quantity of NaOCl consumed was 0.13 gallons of 5.25% bleach. Total quantity of $FeCl_3$ consumed was 0.67 gallons of a 32.5% $FeCl_3$ solution.

All of the sludge from the backwashing operations was collected in a drum, and over the 352.5 hours of the test, a total of 18.9 liters of a 1% solids concentration was obtained. This is equivalent to 2.1×10^{-6} gallons of sludge produced (100% basis) per gallon of filtrate produced.

Original Signed by	*Original Signed by*
E. Timothy Oppelt *04/18/01*	*Gordon Bellen* *04/27/01*
E. Timothy Oppelt Date	Gordon Bellen Date
Director	Vice President
National Risk Management Research Laboratory	Federal Programs
Office of Research and Development	NSF International
United States Environmental Protection Agency	

Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Arsenic Removal* dated March 30, 2000, the Verification Statement, and the Verification Report (NSF Report #01/26/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