

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:	MACROLITE® COAGULATION AND FILTRATION SYSTEM, MODEL CPS100CPT	
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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 permittees; 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 Kinetico, Inc. Macrolite® Coagulant and Filtration System (KIMCFS), Model CPS100CPT, Cartwright, Olsen & Associates, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of the KIMCFS, Model CPS100CPT, was conducted at the Park City, Utah, Spiro Tunnel Water Filtration Plant from April 7 to April 22, 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. Starting on April 8, 2000, ferric chloride (FeCl₃) and sodium hypochlorite (NaOCl) were metered into the feedwater supply at a rate of 0.074 gallons per hour (gph) of 3.5% FeCl₃ and 0.82 gph of 578 mg/L NaOCl to effect coagulation. When operated under the designed conditions at this site, the KIMCFS removed each arsenic (As) species [total As, dissolved As and As (V)], from the feedwater supply to an average concentration of less than 3.0 µg/L.

TECHNOLOGY DESCRIPTION

The KIMCFS utilizes NaOCl and FeCl₃ to convert the arsenate to an insoluble precipitate that is removed by the media filter. The KIMCFS consists of metering pumps to feed FeCl₃ and NaOCl into the feedwater stream, two retention tanks to facilitate coagulation, and a repressurization pump to feed coagulated water to a Macrolite[®] media filter to continuously remove the precipitated As. The Macrolite[®] media is a proprietary ceramic material specifically designed for filtration of water supplies. The system initiates backwashing based on filter headloss or turbidity breakthrough.

The KIMCFS 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 23 ft² (2.1 m²), including retention tanks.

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 abandoned silver mine tunnel. A five-foot high 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 arsenic.

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, and 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 D of the Final Report) involved filling containers as follows: bottle A – as collected; bottle B – filtered through a 0.45µ filter; and bottle C – a 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 absorbance, aluminum, total 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 period 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 3.4 and 5.0 gpm with a total backwash volume of 84 gallons produced after processing approximately 1,600 gallons of water (approximately 95% recovery).

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 342.5 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 tested 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 optimum FeCl_3 injection concentration for the ETV testing period at approximately 1.4 mg/L (as Fe).

The KIMCFS was set to automatically backwash based on a terminal headloss (pressure drop) of 20 psig or a turbidity breakthrough of 0.15 NTU, whichever came first. These settings were maintained throughout the duration of the test.

Arsenic Removal

During initial operations, without coagulation chemicals, the media filter removed approximately 50% of the total As in the feedwater stream and approximately 11% 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 $[\text{Fe}(\text{OH})_3]$ reacted with a portion of the total As in the feedwater stream forming the insoluble $[\text{Fe}(\text{OH})_3]/\text{As}$ complex, which was removed by the media filter.

During the test period, while coagulant chemicals were being fed to the feedwater stream, the total As concentration in the feedwater stream was removed to an average of 2.9 $\mu\text{g}/\text{L}$ in the filtrate. The dissolved As in the feedwater stream was removed to an average level of 1.5 $\mu\text{g}/\text{L}$ in the filtrate. The As (V) species constituted 93% of the dissolved As concentration in the feedwater stream, and was removed to an average of 0.8 $\mu\text{g}/\text{L}$ in the filtrate. The As (III) species was detected near the detection limit (quantitative at 2 $\mu\text{g}/\text{L}$) in the feed water and at an average concentration of 0.7 $\mu\text{g}/\text{L}$ in the filtrate. A summary of the concentrations of As species in both the feedwater and filtrate stream is presented in the following table.

Arsenic Data Summary (April 8 – April 22, 2000) based on 23 samples

	Feedwater (µg/L)	Filtrate (µg/L)
<u>Total Arsenic</u>		
Average	71.4	2.9
Minimum	59.9	0.9
Maximum	75.8	11.6
Standard Deviation	4.43	2.4
95% Confidence Interval	69.3, 73.4	1.9, 3.9
<u>Dissolved Arsenic</u>		
Average	41.1	1.5
Minimum	37.6	1
Maximum	42.7	2.6
Standard Deviation	1.16	0.35
95% Confidence Interval	40.6, 41.7	1.3, 1.6
<u>Arsenic (III)</u>		
Average	2.7	0.7
Minimum	1.4	<0.5
Maximum	3.4	1.1
Standard Deviation	0.46	0.2
Confidence Interval	2.5, 2.9	0.6, 0.8
<u>Arsenic (V)</u>		
Average	38.4	0.8
Minimum	35.1	<0.5
Maximum	40.4	1.5
Standard Deviation	1.22	0.3
95% Confidence Interval	37.8, 39.0	0.7, 0.9

*All readings at the MDL for Arsenic 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

Total iron in the feedwater stream was at an average concentration of 0.299 mg/L and an average of 0.063 mg/L in the filtrate.

Turbidity

Turbidity measurements made both with on-line turbidimeters and the bench-top instrument showed significant turbidity reduction by the KIMCFS. On-line feedwater turbidity readings during the testing period averaged 1.75 NTU, compared to the bench-top turbidity average of 1.54 NTU. The on-line filtrate turbidity readings for the testing period averaged 0.097 NTU, compared to the bench-top average of 0.25 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 1400 hours on April 7, 2000, and the system ran continuously until 2045 hours on April 22, 2000. It is estimated that 51 backwashing episodes occurred during the test period.

The coagulant chemical metering pumps required no adjustments during the test. The concentration of ferric chloride in the feedwater stream was approximately 8.6 mg/L; the concentration of hypochlorite was approximately 1.6 mg/L in the feedwater.

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 516 kWh. The total quantity of filtrate produced was 82,200 gallons. Total quantity of NaOCl consumed was 280.9 gallons of 5.25% bleach. Total quantity of FeCl₃ consumed was 25.3 gallons of a 32.5% FeCl₃ solution.

The backwash water was collected (while the test system was staffed) with an average quantity of 84 gallons per backwash episode. Samples were analyzed for TSS. This revealed an average concentration of 333 mg/L.

<i>Original Signed by</i> <i>E. Timothy Oppelt</i>	<i>9/26/01</i>	<i>Original Signed by</i> <i>Gordon Bellen</i>	<i>10/02/01</i>
_____ E. Timothy Oppelt Director National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency	_____ Date	_____ Gordon Bellen Vice President Federal Programs NSF International	_____ Date

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report is not a NSF Certification of the specific product mentioned herein.

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 #01/23/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)