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THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**COAGULATION AND FILTRATION USED IN DRINKING WATER TREATMENT SYSTEMS**	
APPLICATION:	**PHYSICAL REMOVAL OF *GIARDIA* CYSTS AND *CRYPTOSPORIDIUM* OOCYSTS IN DRINKING WATER**	
TECHNOLOGY NAME:	**CPS100CPT COAGULATION AND FILTRATION SYSTEM**	
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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 a coagulation and filtration system used in drinking water treatment system applications. This verification statement provides a summary of the test results for the Kinetico Incorporated CPS100CPT Coagulation and Filtration System. Cartwright, Olsen and Associates, an NSF-qualified field testing organization (FTO), performed the verification testing.

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ABSTRACT

Verification testing of the Kinetico Incorporated CPS100CPT Coagulation and Filtration System was conducted for 12 days between March 24 and April 4, 2000, and three protozoan challenges were performed between April 24 to 26, 2000. Between March 24 and April 4, 2000, raw water characteristics were: average pH 8.3, temperature 12.3°C, and turbidity 3.4 Nephlometric Turbidity Units (NTU). The process flow rate through the pretreatment components was held at a constant 3.8 gpm while the flow rate through the filtration vessels was allowed to decrease against filter head resulting in an average filter flow rate of 2.8 gpm. The following coagulant doses were used: 266 mg/L of 2.64% Ferric Chloride (20.7 mg/L of 35% aqueous solution Ferric Chloride) and 351 mg/L of 3.47% AQM 100 (25.3 mg/L of 50% aqueous solution Aluminum Chlorhydrate), which were added into the influent water stream of the pretreatment components; and 182 mg/L of 0.10% C-1592 (0.54 mg/L of cationic, 34% aqueous solution Emulsion Polyacrylamide), which was introduced into the influent water stream of the filtration vessels. The average length per filter run was 56 hours and the average filtered water production was 1,024 gallons per run. The average effluent turbidity was 0.4 NTU. Source water conditions changed considerably during the 19-day period before the protozoan challenges. During the protozoan challenges the raw water characteristics were: average pH 8.7, temperature 15.9°C, and turbidity 14.7 NTU. The average effluent turbidity was 1.6 NTU. Results of the samples collected from the system effluent (i.e. combined pretreatment and filtration trains) indicate that *Giardia lamblia* (*G. lamblia*) $\log_{10}$ removals ranged from 2.6 to 3.6 and *Cryptosporidium parvum* (*C. parvum*) $\log_{10}$ removals ranged from 3.4 to 5.7 at filter train flow rates of 2.2 to 2.6 gpm over the challenge filter runs.

TECHNOLOGY DESCRIPTION

The Kinetico CPS100CPT has two distinct water treatment trains; a pretreatment train and a filtration train. The pretreatment train consists of an in-line static mixer, a settling tank and a clarifier. Within the pretreatment train, coagulants (2.64% Ferric Chloride and 3.47% AMQ 100) are introduced into the chlorinated raw water and mixed through an in-line static mixer. The coagulated raw water is allowed to floc and settle within a settling tank. Supernatant from the settling tank is further processed through a clarifier. An additional coagulant (0.10% C-1592) is added to the effluent from the clarifier prior to entry into the filtration train.

Within the filtration train, water is re-pressurized by a centrifugal pump and filtered through automatic backwashing, alternating filters. The alternating filters (designated A and B) contain Macrolite® media, a synthetic ceramic, filter media. The Macrolite® media meets the requirements of ANSI/NSF Standard 61 and is NSF listed as of the date of this report. Macrolite® of the 70/80 mesh size has a bulk density of 0.96 grams/cc. The specific gravity (as measured by ASTM D2840) is 2.23 g/cc. The collapse strength for the media of this size has not been measured, however, for a larger sphere (30/50 mesh) the collapse strength (as measured by ASTM D 3102) is a nominal 7,000 psi for 10% and nominal 8,000 psi for 20% collapse. The uniformity of the Macrolite® 70/80 mesh media was analyzed in accordance with AWWA Standard B100-96 by Bowser-Morner, Inc in December 1997. The results are summarized below.

Uniformity of the Macrolite® 70/80 Mesh Media (AWWA Standard B100-96)

Sieve Size, USA Std.	Nominal, mm	Effective, mm	Percent passing
#45	0.355	0.360	100.0
#50	0.300	0.307	99.9
#60	0.250	0.249	79.8
#70	0.212	0.212	28.9
#80	0.180	0.180	7.2
#100	0.150	0.150	0.4

Effective Size: 0.19 mm
Uniformity Coefficient: 1.2

Kinetico performed an analysis of the 70 mesh media (lot # 352) employing a mercury/penetrometer Micromeritics Autopore II 9220 instrument to estimate the uniformity of the media in June 1998. Results were as follows:

Uniformity of the Macrolite® 70/80 Mesh Media (Micromeritics Autopore)

Total intrusion volume	0.2098 mL/g
Total pore area	0.18 sq-m/g
Median pore diameter by volume	53.7990 µm
Median pore diameter by area	52.5351 µm
Median pore diameter by 4V/A	46.5685 µm

During verification testing, the process flow rate through the pretreatment train was held at a constant 3.8 gpm while the flow rate through the filtration train was allowed to decrease against filter head. Typically filter flow rates decreased from 3.3 gpm to approximately 2.7 gpm. To accommodate decreases in filter flow, the pretreatment train included an overflow weir, discharging to waste, at the outlet of the clarifier.

Accessories and instrumentation included with the system included flow rate and pressure sensors and monitors, on-line turbidimeters, pressure gauges, and an electrical enclosure containing a programmable logic controller. The equipment also contained data transfer connections available for remote monitoring. Electrical power was required for operation of the re-pressurization pump, analytical instruments and system instrumentation.

The filtration train itself is skid mounted and is shipped absent of media. The total weight of the filtration train, without media, is approximately 300 pounds. The physical dimensions of the filtration train were 26¼" wide x 53½ long x 76" high. Physical dimensions of the settling tank were 36" diameter x 78" high. Physical dimensions of the clarifier were 22½ wide x 51¼" long x 51" high. The pretreatment and filtration trains together had a footprint of approximately 24.8 ft^2.

VERIFICATION TESTING DESCRIPTION

Test Site

The host site for this demonstration was the University of Minnesota St. Anthony Falls Hydraulic Laboratory (SAFHL), which has direct access to untreated and treated Mississippi river water. SAFHL is located on the Mississippi River at Third Avenue S.E., Minneapolis, Minnesota, 55414. Chlorinated river water was supplied to the system.

Methods and Procedures

The verification test was divided into tasks that evaluated the system's treatment performance, specifically its ability to physically remove *G. lamblia* cysts and *C. parvum* oocysts from the feed water, and documented the system's operational parameters.

Water quality parameters that were monitored during the verification test included: pH, temperature, turbidity, particle counts, free chlorine residual, alkalinity, total hardness, total organic carbon (TOC), ultraviolet absorbance (UVA) at 254 nanometer (nm), true color, aluminum, iron, manganese, algae, total coliforms, and *E. coli.* Laboratory analyses were performed in accordance with the procedures and protocols established in *Standard Methods for the Examination of Water and Wastewater,* 19th Edition *(SM*) or EPA approved methods as listed in the report.

Three seeding challenges employing *G. lamblia* cysts and *C. parvum* oocysts occurred between April 24 and 26, 2000. The protozoan analyses (identification and enumeration) were conducted using EPA Method 1623. The mixed cocktail of cysts and oocysts was added to the raw water upstream of the

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pretreatment train. The analyses of the influent samples indicated that the cocktail contained 150, 260, and 363 *G. lamblia* cysts per liter, and 8,000, 21,000, and 45,000 *C. parvum* oocysts per liter, respectively, for each of the three seeding challenges. Samples for protozoa analyses were collected on a side-stream and filtered through Gelman capsule filters. Post clarifier and filter effluent samples were collected at time zero (based on tracer test data), and at times 1/2 hour, 1.0 hour, and 2.0 hour (if filter runs allowed) after time zero. Seeded influent source water was collected and filtered through a Gelman capsule filter throughout the duration of the microbial injection.

Operating conditions were documented during each day of verification testing, including: filter flow rate, coagulants used, chemical feed volumes and dose rates, filter headloss, occurrence and volume of backwashes, hours of operation, power use, filtered water production, and waste production.

VERIFICATION OF PERFORMANCE

Source Water

Between March 24 and April 4, 2000, average raw water characteristics were: pH 8.3, temperature 12.3°C, and turbidity 3.4 NTU. Source water conditions changed considerably during the 19-day period before the protozoan challenges. During the protozoan challenges, average raw water characteristics were: pH 8.7, temperature 15.9°C, and turbidity 14.7 NTU.

Operation and Maintenance

During the verification period of March 24 through April 4, 2000, there were 42 filter runs; 21 filter runs for each filter "A" and "B". Coagulants used included solutions of 2.64% Ferric Chloride and 3.47% AQM 100, which were added into the influent water stream of the pretreatment components, and a solution of 0.10 % C-1592, which was introduced into the influent water stream of the filtration vessels. The average length per filter run was 5.6 hours and the average filtered water production was 1,024 gallons per run. The average filtration flow rate was 2.8 gpm with an average minimum flow rate of 2.5 gpm and an average maximum flow rate of 3.1 gpm. The average effluent turbidity was 0.4 NTU. The following table summarizes the averages per filter run for several operating parameters.

Average Operating Conditions for 42 Filter Runs (March 24 through April 4, 2000)

	Filter Run Length (Hrs)	Ave. Pre-Treatment Train Flow Rate (gpm)	Ave. Filter-Train Flow Rate (gpm)	ΔPSI End Run (psig)	Total Volume (gal)	Backwash Volume (gal)
Average	5.61	3.8	2.8	19	1,024	80
Minimum	1.72	3.8	2.6	9	363	53
Maximum	8.57	3.9	3.1	20	1,657	98
Std. Dev	1.57	0.0	0.1	2	259	11
95% Conf. Int.	5.15, 6.07	NA	2.8, 2.9	18, 20	945, 1,103	77, 84

The failure of a pressure differential switch, which caused the operation of the filtration system to become non-automatic, combined with continuous monitoring required for the operation of the pretreatment train made the operation of the Kinetico CPS100CPT labor intensive. The system was staffed 24 hours per day during testing. Manual tasks included stabilization and monitoring of the coagulant chemistry, manual backwashing, and data recording. If coagulation chemistry is stabilized, such as what was experienced for an extended period during verification testing, and the filtration train is operating on an automatic basis, the Kinetico CPS100CPT could be operated with less technician interface. Minimal changes in source water characteristics may negatively influence performance of coagulation chemistry and continuous monitoring would be necessary to be aware when such changes occur so corrective action can be taken on a timely basis.

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The O&M manual provided by the manufacturer primarily defined installation, operation and maintenance requirements for the filtration train of the Kinetico CPS100CPT. The O&M manual was reviewed for completeness and used during equipment installation, start-up, system operation, and trouble-shooting. The manual provided adequate instruction to perform these functions. In cases where system components failed, such was concluded based upon a review of the information in the O&M manual. Specific component failures included an on-line turbidimeter manufactured by Great Lakes International and a pressure differential switch manufactured by Orange Research. In both cases, Kinetico was responsive to remedy component failures. The Kinetico O&M manual did not contain information on the pretreatment train (settling tank and clarifier).

Coagulant Usage

Coagulant doses used between March 24 and April 4, 2000 included 266 mg/L of 2.64% Ferric Chloride (20.7 mg/L of 35% aqueous solution Ferric Chloride) and 351 mg/L of 3.47% AQM 100 (25.3 mg/L of 50% aqueous solution Aluminum Chlorhydrate), which were added into the influent water stream of the pretreatment components, and 182 mg/L of 0.10% C-1592 (0.54 mg/L of cationic, 34% aqueous solution Emulsion Polyacrylamide), which was introduced into the influent water stream of the filtration vessels. A total of 83.25 liters of 3.60% AQM 100, 62.80 liters of 2.72% Ferric Chloride, and 27.49 liters of 0.10% C1592 were used during the verification testing period between March 24 and April 4, 2000. These volumes, converted to undiluted solutions as provided by the chemical supplier, are equivalent to 3.00 liters of AQM 100, 1.71 liters of Ferric Chloride, and 0.03 liters of C1592.

Protozoan Contaminant Removal

The system (i.e. combined pretreatment and filtration trains) demonstrated 2.6 to 3.6 $\log_{10}$ reductions of *G. lamblia* cysts and 3.4 to 5.7 $\log_{10}$ reductions of *C. parvum* oocysts. These results were obtained at an average pretreatment train flow rate of 3.7 gpm and at a filter train flow rates of 2.2 to 2.6 gpm over the challenge filter runs. Filter runs during challenge testing were considerably short (4.4 hours) due to changes in the water quality of the Mississippi River. During the first challenge, effluent samples were only collected during the first hour after time zero before terminal head loss occurred across the filter. On the two subsequent challenges, effluent samples were collected during a two-hour period after time zero.

Finished Water Quality

The average effluent turbidity during the twelve days between March 24 and April 4, 2000 was 0.4 NTU. The average effluent turbidity during the protozoan challenges was 1.6 NTU. A summary of the influent and effluent water quality information for the verification period of March 24 through April 4, 2000 is presented in the following table.

Influent/Effluent Water Quality (March 24-April 4, 2000)

Parameter	# of Samples	Average	Minimum	Maximum
Total Alkalinity (mg/L)	11/11	150/140	140/140	150/140
Total Coliform (cfu/100mL)	2/2	NA/NA	<1/<1.2	>200/>200
E. coli (CFU/100mL)	2/2	NA/NA	<1/<1	1/7
Total Hardness (mg/L)	2/2	NA/NA	160/160	160/160
TOC (mg/L)	2/2	NA/NA	11/8.9	12/9.0
UVA_{254} (cm-l)	2/2	NA/NA	0.151/0.125	0.185/0.240
Turbidity (NTU)*	494/7,061	3.3/0.4	2.6/0.03	4.0/5.0

Note: All calculations involving results with below PQL values used 1/2 the PQL in the calculation.
NA = Average was not performed for data sets with two samples (i.e. n=2).
*Influent turbidity measurements involved a bench-top turbidimeter. Effluent turbidity measurements were made with an on-line turbidimeter.

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Power Consumption

During the verification testing period of March 24 through April 4, 2000, the system used 196 kWh for 39,812 gallons through the filtration train. This equates to 203 gallons of filtered water per kWh.

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* dated May 14, 1999, the Verification Statement, and the Verification Report (NSF Report # 01/12/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 Treatment 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)

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