THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**BAG AND CARTRIDGE FILTER USED IN DRINKING WATER TREATMENT SYSTEMS**
APPLICATION:	**PHYSICAL REMOVAL OF *GIARDIA*- AND *CRYPTOSPORIDIUM*-SIZED PARTICLES IN DRINKING WATER**
TECHNOLOGY NAME:	**MODEL GFS-302P2-150S-ESBB BAG AND RIGID CARTRIDGE FILTER SYSTEM**
COMPANY:	**ROSEDALE PRODUCTS, INC.**
ADDRESS:	**3730 WEST LIBERTY STREET ANN ARBOR, MICHIGAN 48106** PHONE: **(734) 665-8201** FAX: **(734) 665-2214**
WEB SITE:	**www.rosedaleproducts.com**
EMAIL:	**jima@rosedaleproducts.com**

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 bag and cartridge system used in drinking water treatment system applications. This verification statement provides a summary of the test results for the Rosedale Products, Inc. (RPI) Model GFS-302P2-150S-ESBB Bag and Rigid Cartridge Filter System. Cartwright, Olsen and Associates, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

The verification testing of the RPI Model GFS-302P2-150S-ESBB Bag and Rigid Cartridge Filter System occurred at the Minneapolis Municipal Water Works (MWW) facility during a 32-day verification test period conducted between March and April 2000. The system employed a Model GD-PO-523-2 bag filter element and a Model PL-520-PPP-141 rigid cartridge filter element. The source water was a blend of untreated river water and finished water. The system was operated for 23 hours per day with a one-hour stoppage. There were a total of 22 filter runs with an average flow rate of 9.7 gpm. The manufacturer specified 15 pounds per square inch (psi) as terminal headloss. Following a brief ripening period during each filter run, on-line turbidity on average over twenty-two filter runs was 1.08 NTU influent and 0.21 NTU effluent. Three fluorescent microsphere challenges were performed during three filter runs, for a total of nine challenges. The challenges occurred at the beginning of the run, at roughly the mid-point as determined by headloss, and then again at a point between 90% headloss and terminal headloss. The number of microspheres added to the feed water during the nine challenges was approximately 11,746 particles/mL. Fifty percent of the microspheres used were from a 3.4 µm microsphere stock solution (further evaluation of the 3.4 µm stock solution indicated that the stock solution actually contained microspheres with a mean size of approximately 3 µm) and the remaining 50% were 5 µm and 6 µm in size. Particle counters were used to measure the number of particles in the feed and finished water, and samples were collected of the feed and finished water and analyzed by microscopic enumeration. The RPI bag and cartridge system demonstrated 1.1 to 2.1 $\log_{10}$ removal of seeded microspheres (2.5-7.0 µm) based on the microscopic enumeration results, and 1.9 to 2.7 $\log_{10}$ removal of microspheres and indigenous particles sized 2.0 to 7.0 µm based on the on-line particle counter data that was adjusted for the number of fluorescent microspheres added (as described later).

TECHNOLOGY DESCRIPTION

The system consists of two connected stainless steel filter housings. The first housing contained a Model GD-PO-523-2 bag filter element. The second housing contained a Model PL-520-PPP-141 rigid cartridge filter element (which replaced the Model GLR-PO-825-2 filter element used during Phase I initial operations). Valves and other components are also made of stainless steel or of materials that will not degrade in water. The flow through both the bag and cartridge filter is from inside to outside. The filter housings are designed to accommodate a flow rate of 20 gpm, but were operated at 10 gpm during the verification testing to limit possible filter loadings by high turbidity levels. The system is designed to operate with surface waters that have turbidity levels of 1 NTU or less and with pressures of less than 60 psi. This testing used 15 psi as a terminal pressure loss value. Liquid chlorine bleach (sodium hypochlorite) was added during the verification testing to limit any microbial growth within the filters. The bleach-metering pump was stopped during microsphere challenge events.

The system is designed to act as a final barrier and to capture/contain particles in the size range of *C. parvum* (approximately 3-7 µm). Since *G. lamblia* cysts are larger than *C. parvum* oocysts, it is assumed that if the smaller oocysts are contained, the larger cysts will be contained at least the same level[1]. Accordingly, while this system is applicable to *G. lamblia* removal as well as *C. parvum* removal, focus was placed on *C. parvum* sized particles.

The filter system is suited to small public water systems where water treatment plant operators typically have minimal technical training. The system itself requires no additional chemicals beyond normal disinfection and relatively limited on-site supervision, for tasks such as reading pressure gauges and changing filters. No special licensing is required for the use of the filters. Training in bag/element

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[1] Niemiinski, Eva C. *Removal of Cryptosporidium and Giardia through Conventional Water Treatment and Direct Filtration*. EPA/600/SR-97/025, 1997.

replacement is minimal and is explained in the Operations and Maintenance (O&M) Manual, as supplied by the manufacturer (see Verification Report).

VERIFICATION TESTING DESCRIPTION

Test Site

The host site for this demonstration was the Minneapolis Municipal Water Works (MWW) located in Fridley, Minnesota, a suburb adjacent to and directly north of the City of Minneapolis. The testing equipment was located in Pump House #5. Pump House #5 is the intake point from the Mississippi river.

Source Water

The source water for the verification testing was a blend of raw water from the Mississippi River and finished water from the MWW treatment plant. Water at the MWW is softened with lime and treated with alum for removal of color and turbidity. Powdered activated carbon and occasionally potassium permanganate are also added to remove taste and odor. The water is then treated with carbon dioxide to lower the pH and stabilize the remaining hardness prior to being pumped to one of two filtration plants. At the filtration plant, chlorine and ammonia are added for initial disinfection, fluoride is added for tooth decay prevention and ferric chloride is added as a coagulant to remove remaining color and turbidity. The water then enters a series of coagulation/sedimentation basins after which the water is filtered with single, dual or mixed media filters. Blended poly/ortho phosphate is later added as a corrosion control/inhibitor. The water is post-chlorinated for final adjustment of the disinfectant residual before being fed into the reservoirs and pumped into the distribution system. Finished water was blended with raw river water to obtain a turbidity level between 1-3 NTU.

Methods and Procedures

The verification test was divided into tasks that evaluated the system's treatment performance, specifically its ability to physically remove polystyrene microspheres in the size range of 3 to 6 μm from the feed water, and documented the system's operational parameters.

Prior to the 32-day verification test, cartridge filter elements underwent filter variability testing to evaluate the variations between and within filter production lots. Phase I was designed to determine variations *within* a production lot number of Model GLR-PO-825-2 cartridge filter elements. Based on the results of the first phase of variability testing, Rosedale chose to change the cartridge filter to the Model PL-520-PPP-141 cartridge filter for the remainder of the testing. Phase II variability testing was designed to show variations *between* production lots. Each phase included 10 days of system operation with 23 hours of operation and one hour off line (no flow).

The 32-day verification test was performed to evaluate the total number of gallons treated per filter system (bag and cartridge) and the finished water characteristics. The bags and cartridges were replaced if terminal headloss (15 psi) or turbidity breakthrough, as established by the manufacturer, was reached. Water quality parameters 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 nanometers (nm), true color, aluminum, iron, manganese, algae, and total coliforms. 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.

During the testing, microspheres in the size range of 3 to 6 μm were injected into the pilot installation feed water via a metering pump to demonstrate 3+ $\log_{10}$ removal. Fifty percent of the microspheres used were from a 3.4 µm microsphere stock solution (further evaluation of the 3.4 µm stock solution indicated that the stock solution actually contained microspheres with a mean size of approximately 3 µm) and the remaining 50% were 5 µm and 6 µm in size. Three microsphere challenges were performed during three filter runs, for a total of nine challenges. The challenges occurred at the beginning of the run, at roughly the mid-point as determined by headloss, and then again at a point between 90% headloss and terminal headloss. The feed and finished water were evaluated for the presence of microspheres by using on-line particle counters and enumeration of samples collected with hemacytometer techniques and/or membrane filtration.

Operating conditions were documented during each day of verification testing, including: filter flow rate, filter headloss, hours of operation, filtered water production, and frequency of filter replacement.

VERIFICATION OF PERFORMANCE

Filter Element Variability

Phase I filter element variability testing began on June 24, 1999, with three Model GLR-PO-825-2 cartridge filters from the same production lot (No. 88-4546). The bag filters, used as pre-filters within the filter train, all were from the same manufacturing lot. The flowrate was 20 gpm per filter and the target turbidity level was achieved by blending raw river water with finished water to approximately 3.0 NTU. By the second day of Phase I, the bags and cartridge filters had been replaced once and the filters were again approaching terminal headloss. Accordingly, the system was shut down on June 25 to reevaluate the operating parameters. After discussions with the manufacturer, it was decided to reduce influent turbidity to 1 NTU and decrease the flow rate to 10 gpm to reduce rate of filter loading. It was also decided that only finished drinking water would serve as the feed water when the equipment was not attended by an operator to avoid reaching terminal headloss during unmanned periods. Due to concerns expressed by the manufacturer regarding the cartridges from production lot No. 88-4546, the manufacturer provided replacement cartridges from a different production lot, No. 6-2-99. Phase I testing recommenced on June 29 and ended July 7, 1999. Bag and cartridge filters were replaced twice during the remaining portion of Phase I. Based on the results of Phase I, the manufacturer elected to address concerns pertaining to the manufacturing process of the Model GLR-PO-825-2 cartridge filter element. Subsequently, for Phase II of filter element variability testing, the manufacturer provided cartridge filter elements with a different model number (PL-520-PPP-141) and internal seals within the filter housing.

Phase II of the filter element variability testing occurred between January 10 through 20, 2000 with Model PL-520-PPP141 cartridge filters from 3 different production lots (Numbers 990541-5, 990541-4, 990541-3). Again, the bag filters used as pre-filters within the filter train were from the same manufacturing lot. Bag and cartridge filters were replaced twice during Phase II. Headlosses at time of filter replacement on January 13 were 12 psi, 8 psi, and 15 psi respectively for filter trains #1, #2, and #3. Corresponding $\log_{10}$ reductions of indigenous particles sized 2 to 15 µm as measured by particle counters were 1.4, 1.2, and 1.6. Head losses at time of filter replacement on January 17 were 12 psi, 8 psi, and 9 psi respectively for filter trains #1, #2, and #3 and corresponding 2-15 µm particle count $\log_{10}$ reductions were 1.5, 1.5, and 1.6. Head losses at time of shut-down on January 20 were 6 psi, 6 psi, and 5.5 psi respectively for filter trains #1, #2, and #3. Corresponding 2-15 µm particle count $\log_{10}$ reductions were 1.4, 0.81, and 1.4. Filter train #2 demonstrated comparatively poor particle reduction performances during Phase II. This was attributed to a faulty pressure differential gauge that bypassed feed water into the filtered water stream. Due to the limited number of filters evaluated within each production lot, conclusions regarding variation in filter performance between production lots cannot be offered with any degree of certainty.

Operation and Maintenance

The verification testing for the system began on March 7, 2000, and ended its 32-day period on April 20, 2000. The system was operated for 23 hours per day with a one-hour stoppage. There were a total of 22 filter runs (bag and cartridges replaced at the start of each filter run unless otherwise noted). The average flow rate over the 22 filter runs was 9.7 gpm. The average terminal headloss, volume of water produced, and duration of the 22 filter runs are summarized in the following table:

Operating Data – 22 Filter Runs (March 7 – April 20, 2000)

Filter Run Number	Terminal Headloss (psi)	Water Produced (Gallons)	Filter Run Duration (hours)
Average	16.3	22,789	38.04
Minimum	11.0	10,980	19.25
Maximum	25.5	74,173	135.25
Std Dev.	3.6	15,434	27.76
95% Confidence Interval	14.8, 17.9	16,340, 29,239	25.88, 50.18

The manufacturer supplied O&M Manual illustrates the equipment and shows the proper configuration of the housings. The system start up and element replacement procedures are instructive and thorough. A parts list is included.

Microsphere Removal

The fluorescent microsphere challenge was performed between April 16 and 20, 2000. Particle counters were used to measure the number of particles in the feed and finished water, and samples were collected of the feed and finished water and analyzed by microscopic enumeration and a laboratory optical particle counter. The system demonstrated 1.1 to 2.1 $\log_{10}$ removal of the seeded microspheres based on the microscopic evaluations by Huffman Environmental Consulting; however, it was noted by the laboratory that, upon visual inspection, a considerable number of microspheres were smaller than 3 µm. The 3.4 µm microsphere stock solution obtained from Bangs Laboratories was reanalyzed by Bangs and the results indicated that the true particle median size was not 3.4 µm as specified, but was actually 2.98 µm with a standard deviation of 0.66 µm or 21.2%. Further evaluation of the particle count data indicated that 1.9 to 2.7 $\log_{10}$ removals of particles sized 2 to 7 µm were achieved during the fluorescent microsphere challenge testing based on normalized on-line particle counter data which involved adding the number of seeding microspheres (approximately 11,746 particles/mL) to the source water's indigenous material particle counter value and comparing with the effluent particle counter value (details regarding the normalized particle count data are described in the Verification Report). The duplicate set of samples collected during the microsphere challenge were sent to Micro Measurement Laboratories, Inc. for analysis by a laboratory optical particle counter called an Accusizer. Log_{10} reductions calculated with the use data as analyzed with the Accusizer were not performed because an analysis of the control sample container demonstrated a suspected level of contamination (approximately 315 particles/mL). However, influent particle count data as provided from these analyses were helpful in validating influent particle/microsphere concentrations used to calculate $\log_{10}$ reductions of particles/microspheres sized between 2µm and 7µm. Results are summarized in the following table:

Log_{10} Reduction Analyses for Fluorescent Microsphere Seeding Challenges

Seeding	Microscopic Enumeration (2-7 µm microspheres)	Normalized On-Line Particle Counters (2-7 µm indigenous particles and microspheres)
First Challenge Run		
No headloss	1.1	1.9
Midpoint	2.1	2.3
90% headloss	1.8	2.0
Second Challenge Run.		
No headloss	1.5	1.9
Midpoint	2.1	2.7
90% headloss	1.9	2.6
Third Challenge Run.		
No headloss	1.5	2.0
Midpoint	1.8	2.7
90% headloss	1.6	2.7

Following the 50% headloss seeding challenges, the flow through the system was interrupted for a brief interval and then restarted to determine the level of particle sloughing following resumption of flow. Particles were sloughed for less than three recording cycles of the particle counter, or less than three minutes. The results are discussed more fully in the Verification Report but point to the necessity for a brief filter to waste cycle following an interruption in flow.

Water Quality

The following table summarizes the results of the influent and effluent samples collected during the verification testing period.

Feed/Filtered Water Quality (March 7-April 20, 2000)

Parameter	# of Samples	Average	Minimum	Maximum	Standard Deviation	95% Confidence Interval
Temperature (°C)	38/0	7.3/-	3.9/-	11.0/-	2.2/-	6.7, 8.0/-
pH	37/0	8.5/-	8.0/-	8.9/-	0.2/-	8.4, 8.5/-
Total Alkalinity (mg/L)	7/7	70/66	55/54	110/100	18/16	57, 84/55,78
Total Coliform (cfu/100mL)	7/7	24/2	<1/<1	110/6	40/3	<1, 54/ <1, 4
Total Hardness (mg/L)	7/7	94/95	82/82	130/130	16/16	82, 107/ 83, 107
TOC (mg/L)	7/7	7.8/7.5	6.8/6.4	11/8.8	1.4/0.8	6.7, 8.9/ 6.9, 8.1
True Color (TCU)	7/7	14/10	10/5	25/15	6/4	10, 18/ 7, 13
UVA_{254} (cm^{-1})	7/7	0.140/0.130	0.180/0.109	0.229/0.156	0.042/0.017	0.109, 0.171/ 0.117, 0.143
On-line Turbidity (NTU)*	continuous	1.08/0.21	0.68/0.17	1.46/0.26	0.20/0.02	0.98, 1.16/ 0.20, 0.22
On-line Total Particle Counts (#/mL)*	continuous	7,329/91	3,784/39	10,056/300	1,737/59	6567, 8090/ 65, 117
Iron (mg/L)	7/7	0.1/0.1	<0.1/<0.1	0.4/0.6	0.1/0.2	<0.1, 0.2/ <0.1, 0.3
Manganese (mg/L)	7/7	0.02/0.1	<0.01<0.01	0.04/0.04	0.01/0.01	0.01, 0.03/ <0.01, 0.02
Total Chlorine (mg/L)	27/0	1.4/-	0.7/-	3.5/-	0.82/-	1.1, 1.7/-
Free Chlorine (mg/L)	27/0	0.6/-	0.1/-	2.5/-	0.6/-	0.4, 0.8/-

Note: All calculations involving results with below detection limit values used half the detection limit in the calculation.
*Measurements are the average of the filter run averages.

Turbidity removals were consistent and generally good throughout the verification period. Following a brief ripening period, the average on-line turbidity over the 22 filter runs was 1.08 NTU for the feed and 0.21 NTU in the filtered water. No algae were detected in the filtered water samples.

Original Signed by
E. Timothy Oppelt *9/20/01*

E. Timothy Oppelt Date
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original Signed by
Gordon Bellen *9/22/01*

Gordon Bellen Date
Vice President
Federal Programs
NSF International

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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 # 01/08/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)