THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**MULTI-COMPONENT SYSTEM THAT INCLUDES AERATION/PRE-FILTRATION, DISINFECTION, AND POST-TREATMENT CARBON FILTRATION**	
APPLICATION:	**WATER PURIFICATION AND MICROBIAL CONTAMINANT INACTIVATION IN DRINKING WATER**	
TECHNOLOGY NAME:	**PENTAPURE H-3000-I**	
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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 stand-alone drinking water purification and disinfection system. This verification statement provides a summary of the test results for PentaPure's H-3000-I System. ARCADIS G & M, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

The PentaPure H-3000 – I Water Purification Station is a complete on-site package treatment plant that treated an average flow rate of 45 gallons per minute (gpm). The verification test began on July 31, 2000 and ran, with several periods of downtime, until October 5, 2000. The cornerstone of PentaPure is the filtration unit that uses pentaiodide for microbial inactivation. The PentaPure H-300 consisted of a filtration component to remove solids in advance of a pentaiodide resin component for the inactivation of microorganisms. More operational difficulties were found with the filtration component than with the pentaiodide component which performed well throughout the study.

Average log removals of *Escherichia coli* with one pentaiodide resin tank in operation, and with two pentaiodide resin tanks in operation in parallel, were 6.9 and 6.3, respectively. For *MS-2* bacteriophage average log removal were 3.6 for one tank and 3.2 for the two-tank test. The difference in log removal results can be attributed to variability in influent and effluent microbe concentrations. The PentaPure unit was particularly effective in the removal of total coliforms with all treated water samples being below the detection limit of 20 CFU/100 mL.

Although the disinfected (semi-treated) water stream showed significant iodine concentrations, most of this iodine was removed again in the post disinfection carbon filters. The carbon filters were not as successful at removing iodide ions and the concentration of iodide ions in the treated water averaged 0.911 mg/L. Trace amounts of silver were detected in the treated water at an average level of 0.3 µg/L.

TECHNOLOGY DESCRIPTION

The PentaPure H-3000 – I Water Purification Station is a full on-site package treatment plant designed to treat an average flow rate of 50 gpm. The main components of the H-3000 – I that was provided for the test were: 1) diaphragm pump and coagulant dosage system, 2) Iron Curtain™ Pre-Filter System, 3) two Harmsco Hurricane™ centrifugal separators with 1 micron filter elements in parallel, 4) two fiberglass tanks in parallel with PentaPure® Formula 53 pentaiodide resin, supported on an underbedding of pea gravel, 5) two fiberglass tanks in parallel filled with coconut carbon and HyGene® brand Mark 4.3 silver-impregnated carbon. The key component of the station is the pentaiodide disinfection unit.

PentaPure disinfection resin is manufactured through a complex proprietary process. In short, polyiodide ions are bound to an anion exchange resin, creating a positively charged structure. According to the manufacturer, many waterborne pathogenic bacteria and viruses are associated with negatively charged particles. The filtering of particles through the disinfection resin prompts the release of iodine, which disinfects the water by deactivating microorganisms; when a contaminant comes into contact with the PentaPure resin bead, sufficient iodine is released to penetrate and kill associated microorganisms.

VERIFICATION TESTING DESCRIPTION

Test Site

The host site for this demonstration was the SJWD Water District Drinking Water Treatment Plant in Lyman, South Carolina, which draws water from the Middle Tyger River. The water is generally of good quality with a turbidity of less than 10 nephelometric turbidity units (NTU), hardness under 10 mg/l and TOC of approximately 2.5 mg/l. During storm events, the turbidity may rise significantly. Furthermore, the water is known to have coliforms with counts generally varying between 100 to 1,000 colony forming units (CFU) per 100 ml. Raw water was drawn at a rate of 50 gpm from a sump directly in contact with the Middle Tyger River.

Methods and Procedures

The test was divided into three tasks: 1) equipment operation and disinfection production capabilities, 2) microbiological contaminant inactivation (challenge test), and 3) treated water quality.

Task 1 included the generation of data that describe the operation of the PentaPure H-3000 – I, including power consumption, potable water generation, the rate of water usage for backwashing, the rate of replacement of filter elements, the rate of coagulant usage and the required operations staff time. Also, a disinfection resin backwash sample was collected for analysis (including heavy metals) during the test period. Operation and maintenance issues were also evaluated during the testing period.

The objective of task 2 was to characterize the PentaPure H-3000 – I for its efficacy for inactivation of *Escherichia coli (E. coli)* bacterium and the Bacteriophage *MS-2* viral surrogate with two pentaiodide resin columns in operation in parallel, as well as with one pentaiodide resin column in operation. The task was split into bacterial and viral challenge sections. The initial part of Task 2 consisted of a tracer test with rhodamine dye to determine the hydraulic residence time.

The bacterial challenge tests were carried out using *E.coli, Migula* strain. The target concentration for *E. coli* in broth culture was 5×10^{10} colony forming units (CFU)/100 mL. During each challenge test, a peristaltic pump and autoclaved tubing was used to feed *E. coli* into the 50 gpm water stream leaving the prefiltration components of the H-3000-I and entering the pentaiodide resin beds, at a rate calculated to produce an *E. coli* concentration in the contact tanks of 1×10^{6} cells/mL. Samples were collected at 5-minute intervals. These samples were submitted to Environmental Health Laboratories for *E. coli* enumeration by Standard Methods 9213 D *E. coli* membrane filtration procedure.

The viral challenge tests were carried out using the MS-2 bacteriophage. The target MS-2 concentration for the bacteriophage growth broth was 1×10^{11} plaque forming units (PFU)/mL. The samples were collected at 5-minute increments and submitted to BioVir Laboratories for phage enumeration by USEPA Method 1601 (modified for MS-2).

The objective of the third task was to assess the impact that treatment using the PentaPure H-3000 – I has on treated water quality. Samples were preserved, stored, shipped and analyzed in accordance with appropriate procedures and hold times, as specified by the analytical methods. Water quality parameters that were monitored during the test period include: pH, temperature, turbidity, hydrogen sulfide, alkalinity, total dissolved solids (TDS), ammonia nitrogen, total organic carbon (TOC), ultraviolet absorbance (UVA) at 254 nanometer (nm), true color, iron, manganese, bromide, chloride, sodium, silver, iodide, and iodine. In addition, total coliforms, and heterotrophic plate count (HPC) bacteria were enumerated five times per week. A metals scan as a one-time event was performed on the waste stream. Also, feed and treated total trihalomethane (TTHMs) and haloacetic acid (HAAs) sampling was conducted. Analytical samples were collected from various locations within the overall treatment system.

VERIFICATION OF PERFORMANCE

Operation and Maintenance

The PentaPure H-3000 - I system was initially installed on March 16 and 17, 2000. The system commenced verification testing two times. The first test run commenced in late April 2000 and was terminated on May 26, 2000 after it was determined that the pentaiodide resin beds had been prematurely fouled due to high turbidity levels caused by insufficient pretreatment. For the second test, the unit was modified with the addition of a coagulation unit. The second test began on July 31, 2000 and ran, with several periods of downtime, until October 5, 2000.

The cornerstone of PentaPure is the pentaiodide technology. The pentaiodide component operated well from an O&M standpoint and most operational difficulties were found in the pretreatment filtration system that consisted of non-PentaPure components. ARCADIS and site operations staff found the separate instructions provided by PentaPure adequate in addressing routine operation and maintenance issues pertaining to system components.

Consumables expended by the PentaPure H-3000 – I system during the 31 days of verification testing included electrical power, coagulant and Harmsco filter elements. Ten filter elements were used over the 31-day verification test. Initially, the coagulant dosing system was set up to deliver about 70 mL of solution per minute, but the coagulant delivery rate was lowered incrementally to about 40 mL/min toward the latter stages of the verification test interval. Optimization of coagulant dose will minimize the filter element replacement frequency and result in lower operating and maintenance costs. Operator staff time required for routine monitoring of the system was estimated at about 1 hour per day. Per gallon of treated water, the power consumption was approximately 1.31 Watthour.

Microbiological Contaminant Inactivation

ARCADIS performed both bacterial and viral challenge tests on the PentaPure H-3000-I to assess its disinfection capabilities. *E. coli* served as the bacterial challenge test microorganism and the *MS-2* bacteriophage was used as the viral challenge test microorganism. Bacterial and viral challenge test microorganisms were used to assess the disinfection capabilities of the PentaPure H-3000-I with both one and two pentaiodide resin tanks in operation. For all challenge testing, treated samples were collected at five minute intervals.

Prior to the inactivation tests, the hydrodynamic tracer test was conducted. Since the PentaPure H-3000 – I does not rely on a concentration-contact time (CT) relationship for facilitating microbial deactivation, the results of this tracer test were primarily to determine whether the proposed challenge testing sampling schedule was appropriate.

The average log removal of *E.coli* with one pentaiodide resin tank, and with two pentaiodide resin beds in operation was 6.9 and 6.3, respectively. The *MS-2* enumeration of the treated samples from the one-tank test ranged from 1.5×10^2 PFU/mL to 4.4×10^7 PFU/mL, whereas the average concentration of the feed water was 1.6×10^8 PFU/mL. The average of this range is 4.3×10^4 PFU/mL and resulted in a log removal of 3.6. Log removal for the two tank test was 3.2. Considerable variability in the *MS-2* concentrations in the disinfected water was seen in both the one and two pentaiodide resin tank viral challenge tests. The one pentaiodide resin tank test resulted in *MS-2* enumerations spanning seven orders of magnitude. The two pentaiodide resin tank test resulted in *MS-2* enumerations spanning six orders of magnitude.

Treated Water Quality

In the PentaPure H-3000-I system, the iodine concentration in the disinfected (before carbon filtration) water increased from 0.019 mg/L to 1.549 mg/L. However, nearly all of this iodine was removed again in the post disinfection carbon filters. The final iodine concentration in the treated water was 0.020 mg/L. The carbon filters were not as successful at removing iodide ions and the concentration the iodide ions in the treated water was 0.911 mg/L compared to an influent iodide concentration of 0.019 mg/L.

Turbidity of the raw river water was effectively reduced by the coagulation/filtration steps. Average raw water turbidity was 13.93 NTU with a maximum value of 78.3 NTU. Average pre-filtered (post-coagulation) turbidity was 1.19 NTU.

As part of daily routine analysis, total coliforms were monitored and heterotrophic plate counts (HPC) were conducted for raw and treated water. The PentaPure unit was particularly effective in the removal of total coliforms with all treated water samples being below the detection limit of 20 CFU/100 mL. Using the value of 20, the log removal rate for total coliforms was at least 1.6. The log removal rate for HPC organisms was 1.5.

The PentaPure H-3000-I performed well in removing aluminum and performance was fair for removal of manganese. All measured aluminum and manganese concentrations in the treated water were below 11 and 100 µg/L respectively. Also, iron was removed effectively by the unit, from an average of 1.5 mg/L in the raw water down to an average of 0.3 mg/L in treated water. Trace amounts of silver were detected in the treated water at an average level of 0.3 µg/L. In addition, single samples were taken to analyze metals concentration in the disinfection column backwash. Barium and copper were detected in the backwash stream at concentrations of 13 and 6.3 µg/L respectively as well as trace amounts of arsenic, chromium, nickel, thallium, and zinc.

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Inactivation of Microbiological Contaminant* dated August 1999, the Verification Statement, and the Verification Report (NSF Report # 01/27/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)