THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ADSORBTIVE MEDIA**
APPLICATION:	**REMOVAL OF URANIUM IN DRINKING WATER**
PRODUCT NAME:	**BRIMAC HA 216 ADSORPTIVE MEDIA**
VENDOR:	**BRIMAC ENVIRONMENTAL SERVICES, INC.**
ADDRESS:	**318 GRALAKE AVE. ANN ARBOR, MI 48103**
PHONE:	**734-998-0763**
WEBSITE:	**HTTP://WWW.BRIMACSERVICES.COM**
EMAIL:	**INFO@BRIMACSERVICES.COM**

NSF International (NSF) manages the Drinking Water systems (DWS) Center under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The DWS Center recently evaluated the performance of the Brimac Environmental Services, Inc. (Brimac) HA 216 Adsorptive Media. The New Hampshire Department of Environmental Services (NHDES) monitored the operation of the pilot unit containing the media, collected water samples, and provided some laboratory services. NSF also analyzed samples and authored the verification report and this verification statement. The verification report contains a comprehensive description of the test.

EPA created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The ETV Program's goal is to further environmental protection by 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, stakeholder groups (consisting 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.

ABSTRACT

The Brimac HA 216 Adsorptive Media was tested for uranium (U) removal from a drinking water source (well water) at Grappone Toyota located in Bow, New Hampshire. The HA 216 media is a hydroxyapatite-based material. A pilot unit, consisting of a TIGG Corporation Cansorb® C-5 steel drum with 50 pounds (lb) (23 kilograms, 1.3 ft^3) of media, was used for this verification test. The pilot unit was operated at a flow rate of approximately two gallons per minute (gpm), resulting in a hydraulic loading rate of 1.04 gpm/ft^2, and an empty bed contact time (EBCT) of 4 minutes and 54 seconds. The integrity test phase included observation of the operation of the pilot unit. The pilot test unit was simple and easy to operate, particularly since there were no pumps required for this installation and no need for automated controls or backwash systems.

The source water contained a mean uranium concentration of 190 μg/L. The pilot unit produced treated water with uranium concentrations of <1 μg/L at the start of the test. The uranium concentration in the treated water began to increase after two days of operation and exceeded the EPA National Primary Drinking Water Regulation (NPDWR) maximum contaminant level (MCL) of 30 μg/L after approximately 21,400 gallons (gal) of water had been treated, representing 2,200 bed volumes (BV). The uranium concentration in the treated water exceeded the stop-test concentration of 60 μg/L at 33,700 gal (3,500 BV). The test was stopped two days later at 40,500 gal after the uranium results had been received showing that 60 μg/L had been passed. While the treated water uranium concentration increased more quickly than anticipated, the mean concentration for the 15-day monitoring period was 29.7 μg/L, which is below the MCL. Based on the mean source and treated water uranium concentrations (171 μg/L and 12.6 μg/L respectively) for the first ten days of operation before the treated water exceeded 30 μg/L of uranium, the 23 kilograms (kg) of media absorbed 13.1 g of uranium ($5.7x10^{-4}$ g U/g media). For the entire test period, the media adsorbed approximately 24.8 g of uranium (0.001 g U/g media).

TECHNOLOGY DESCRIPTION

The following technology description was provided by the manufacturer and has not been verified.

Brimac HA 216 Adsorptive Media is a hydroxyapatite-based media. The molecular formula for hydroxyapatite is $Ca_5(PO_4)_3(OH)$. Hydroxyapatite sequesters uranium by three processes: 1) incorporation within the hydroxyapatite lattice through ion-exchange with calcium, 2) physisorption and chemisorption with reactive phosphate and calcium oxide groups at the mineral surface, and 3) reaction with free phosphate to form solids that precipitate out of solution. The particles are highly porous and capable of adsorbing heavy metals, color forming compounds, trihalomethane (THM) precursor compounds, taste and odor producing compounds as well as other organic and inorganic compounds. The media performs over a wide range of pH and temperature. HA 216 has a Langmuir isotherm capacity of just over 1 g of uranium per g of media.

Uranium adsorption by hydroxyapatite occurs more slowly than contaminant adsorption by activated carbon. The rate-determining step is adsorption, not the rate of diffusion, as with activated carbon. For this reason, Brimac considers uranium adsorption by hydroxyapatite to be more like an ion exchange process. The bed of hydroxyapatite media has a mass transfer zone that moves through the bed in a plug flow manner until the media is exhausted.

HA 216 is certified by NSF to NSF/ANSI Standard 61 for water treatment plant applications and received European Pharmacopeoia and UK Drinking Water Inspectorate approvals. Hydroxyapatite is also listed 'Generally Recognized as Safe' by the U.S. Food and Drug Administration.

VERIFICATION TESTING DESCRIPTION

Test Site and Equipment

The verification test was conducted using a pilot unit installed at Grappone Toyota at 514 Route 3A in Bow, New Hampshire. Groundwater was drawn from an 11 gpm capacity well, serving 82 employees. Brimac provided a pilot unit containing HA 216 media installed in a TIGG Corporation Cansorb® C-5 steel drum. The drum contains internal schedule 40 PVC plumbing to ensure proper distribution of the feed water onto the media bed. The C-5 is 30 inches (in) high, with a diameter of 19 in. For the verification test, the pilot unit contained 50 lb (23 kg) of media, which equals approximately 1.3 ft^3 of media at a depth of 8.2 in. in the C-5 drum. The unit was set up to operate at approximately 2.0 gpm.

The inlet water line was connected to the pressure (bladder) tank that was used to maintain water pressure in the building water supply system. This provided sufficient water pressure to operate the pilot unit, and no additional pumping was required to maintain flow to the test system. Treated water was discharged to the sanitary sewer.

The verification test included two main tasks: system integrity verification and adsorptive capacity verification. System integrity verification was a two-week test of the pilot unit with daily monitoring to ensure the media and pilot unit were functioning properly and to identify any major systemic problems such as channeling, insufficient media, excessive headloss buildup, etc. Adsorption capacity verification evaluated the capability of the media at a set contact time to remove uranium to below the EPA NPDWR MCL of 30 μg/L. As requested by Brimac, the test was continued until at least 60 μg/L of uranium was detected in the treated water.

Methods and Procedures

The testing methods and procedures are detailed in the *Product-Specific Test Plan Removal of Uranium in Drinking Water Brimac HA 216 Adsorptive Media*. The EPA/NSF *ETV Protocol for Equipment Verification Testing for Removal of Radioactive Chemical Contaminants* (April 2002, Chapter 1) and the EPA/NSF ETV *Equipment Verification Testing Plan for Adsorptive Media Processes for the Removal of Arsenic* (September 2003, Chapter 6) provided the basis for the procedures used to develop the test plan and to ensure the accurate documentation of pilot unit performance and treated water quality. NSF and NHDES co-managed verification responsibilities and analytical laboratory efforts. The pilot unit was operated 24 hours a day, seven days a week during the testing period.

For the first 14 days of the integrity test, operational data were collected once per day, Monday through Saturday. These data included cumulative feed water volume, feed water flow rate, treated water pressure, and time on site. Grab samples for on-site and laboratory water quality analyses were collected daily for temperature, pH, turbidity, and uranium. Grab samples were collected weekly for TSS, TOC, TDS, calcium magnesium, sodium, iron, hardness, chloride, sulfate, fluoride alkalinity, phosphorus, nitrate, arsenic aluminum silica, radon 222, alpha radioactivity, and UV_{254}. Prior to collecting samples, the sample tap was flushed for at least five seconds. All samples were collected into clean containers.

The analytical laboratories performed the water quality analyses using EPA or Standard Methods procedures. Samples for off-site laboratory analysis were collected and preserved according to *Standard Methods* 3010 B.

VERIFICATION OF PERFORMANCE

System Operation

Brimac coordinated with NHDES and NSF to install the equipment and ready the system for operation. Once ready for operation, Brimac ran initial startup and shakedown tests to determine operating conditions for water treatment. The system started up quickly and without any difficulties. Verification testing was started on July 10. The two-week integrity test was completed on July 24 and the capacity test phase ended on July 25 after 15 days of operation. The capacity test was stopped because the uranium data showed that the concentration in the treated water had exceeded the stop-test level of 60 μg/L on the 13th day. The pilot unit continued in operation until July 30, while the analyses were being completed.

The average daily flow rate reported for the 19 total days of operation (Days 0-20) was 1.97 gpm and the average flow rate calculated using the total volume treated was 2.03 gpm (54,728 gal over 19 days, as recorded from the flow meter totalizer). The flow rate to the unit cycled between a high to low flow rate, as the pressure in the well system cycled from high to low. The field technician observed several flow rates over several minutes and recorded a range of flow rates on the bench sheet. These flow rate ranges were then used to report an average flow rate for the unit. While the flow rate did change over a range of readings, the average flow rate was close to the target of 2.0 gpm and was consistent during the test. Overall, the frequent change in flow rate did not impact the volume of water treated each day, as shown by comparing the data for the average flow rate and daily volume treated.

The hydraulic loading rate during the test, based on a mean flow rate of 1.97 gpm and a pilot unit surface area of 1.90 ft^2, averaged 1.04 gpm/ft^2. The EBCT during the verification test was approximately 4.9 minutes (4 minutes, 54 seconds).

Test Results

The source water had a mean uranium concentration of 190 μg/L. All turbidity measurements were <1 NTU and all TSS concentrations were <2 mg/L. A sediment/particulate pre-filter was not used ahead of the test unit. There was no indication during the test of any problems with particulate accumulation in the media bed. The pH of the source water and treated water was steady throughout the test, with a range of 6.52-6.93 SU and 6.63-7.29 SU, respectively.

Figure VS-1 presents the uranium removal results plotted as a function of the bed volumes treated during the integrity and capacity tests. At the beginning of the verification, the uranium concentration observed in the treated water was near or below 1 μg/L. The uranium concentration observed in the treated water began to increase as the cumulative bed volumes of treated water increased. The concentration exceeded the water quality standard of 30 μg/L after approximately 21,400 gal of water were treated, or 2,200 BV. The capacity test was stopped two days later at 40,500 gal after the uranium results had been received showing that the treated water concentration had exceeded 60 μg/L. While the treated water uranium concentration increased more quickly than anticipated, the mean concentration for the 15-day monitoring period was 29.7 μg/L, which is below the MCL. However, the treated water was below the water quality standard for only the first 10 days of the test.

Considering the mean source and treated water uranium concentrations (171 μg/L and 12.6 μg/L) for the first ten days of data (until breakthrough had occurred at 30 μg/L), the 50 lbs (23 kg) of media adsorbed 13.1 g of uranium ($5.7x10^{-4}$ g U/g media). Over the entire test period, the 23 kg of media adsorbed approximately 24.8 g of uranium (0.001 g U/g media). These data indicate that while the HA 216 media had capacity to adsorb uranium beyond the first 10 days, movement of the mass transfer zone thru the media and the adsorption kinetics were not well predicted for the contactor configuration used in the test, and the media would need to be changed frequently using the current contactor configuration.

Uranium adsorption kinetics of HA 216 media are slow compared to activated carbon, and design EBCT has a significant impact on the final treated water concentration, as the media is loaded with uranium. The size of the mass transfer zone moving through the bed and the equilibrium between the media and the treated water concentrations will vary as a function of EBCT. Particle size can also affect the kinetics of the adsorption process with smaller particle sizes providing more surface area for adsorption in a given media volume.

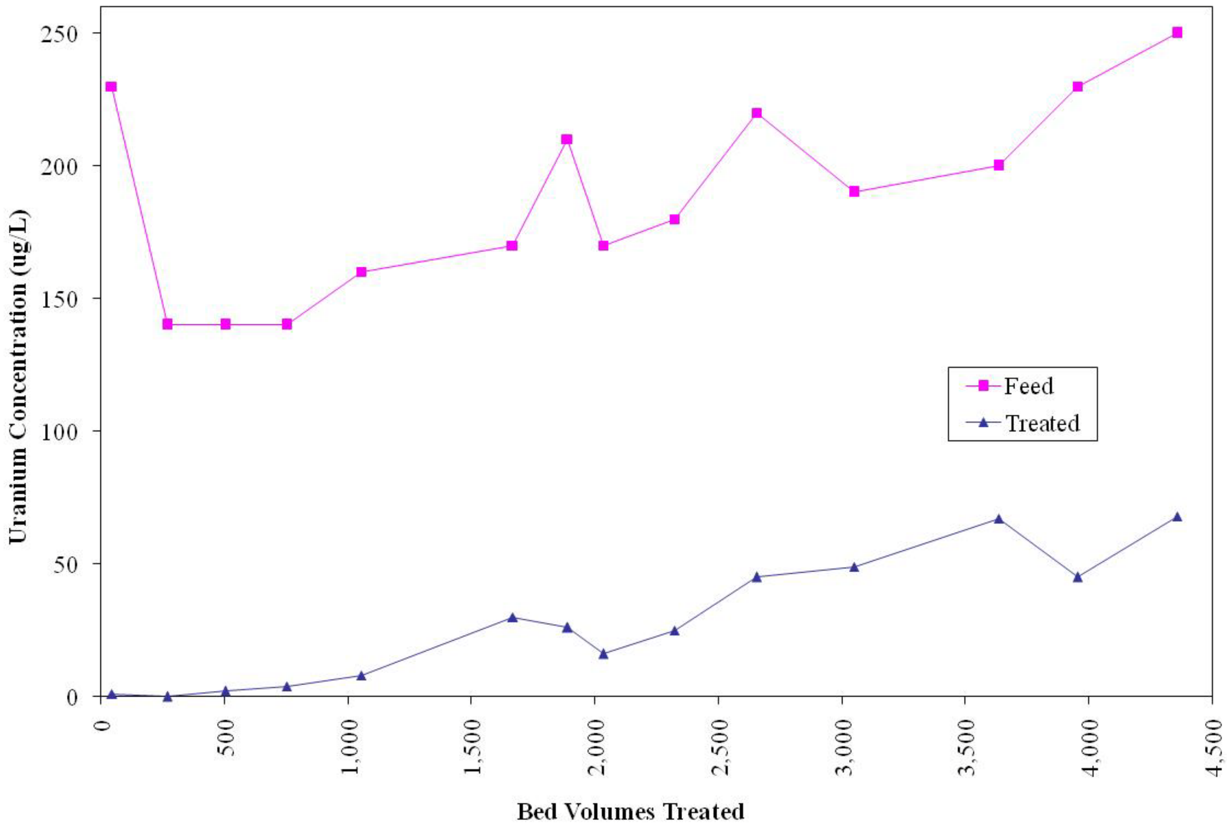

Figure VS-1. Uranium Concentration versus Bed Volumes Treated

Supplemental data provided by Brimac is presented in the report concerning adsorption rates and capacity of the HA 216 media. Their documentation indicates that reducing the particle size of the media increases the adsorption rate. Brimac is currently developing an approach to manufacture a smaller particle size media. Brimac has indicated the need for additional verification testing in the future with a redesigned treatment contactor and media.

Feed and treated water concentrations of cations and anions (calcium, magnesium, sodium, iron, silica, chloride, sulfate, alkalinity, fluoride, nitrate, phosphorus) were about the same, with the exception of phosphorus. The phosphorus levels increased from <0.05 mg/L in the source water to a concentration range of 0.08 to 0.19 mg/L in the treated water. The HA 216 adsorptive media contains calcium, phosphorus, and hydroxide. The slight increase in phosphorus could be due to a small amount of dissolution of the phosphorus from the media. The contribution appears small. There was minimal or no increase in calcium or hydroxide (alkalinity) concentrations in the treated water.

System Operation

The test unit was simple and easy to operate, particularly since there were no pumps required for this installation and no need for automated controls or backwash systems. Flow control was maintained by one manual control valve and the source water was fed to the unit using well system pressure. In this application with the treated water discharging by gravity to the sewer system, there was no concern with operating the unit in-line with the water supply system. Time to operate and monitor the system was minimal with most time being spent for sample collection. Over the testing period, the average time on site was about 40 minutes each day (90 minutes, the first two days).

The feed water contained low turbidity and low TSS concentrations, and pressure buildup due to solids entering the media bed was not observed. Other source waters may require pre-filtration and continuous monitoring of inlet and outlet pressures to address possible media fouling conditions.

QUALITY ASSURANCE/QUALITY CONTROL

NSF provided technical and QA oversight of the verification testing, including an on-site audit of operating and sampling procedures. The NSF QA Department performed a QA review of the analytical data. A complete description of the QA/QC procedures is provided in the verification report.

Original signed by Sally Gutierrez 10/06/10

Sally Gutierrez Date
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original signed by Robert Ferguson 09/17/10

Robert Ferguson Date
Vice President
Water Systems
NSF International

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Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 10/33/EPADWCTR) are available from the following sources:

1. ETV Drinking Water Systems Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. Electronic PDF copy
   NSF web site: http://www.nsf.org/info/etv
   EPA web site: http://www.epa.gov/etv