THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**COAGUALTION AND MEMBRANE FILTRATION USED IN DRINKING WATER TREATMENT SYSTEMS**
APPLICATION:	**REMOVAL OF ARSENIC IN DRINKING WATER**
TECHNOLOGY NAME:	**MICROZA® MICROFILTRATION SYSTEM**
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The U.S. Environmental Protection Agency (EPA) supports 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 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.

NSF International (NSF) in cooperation with the EPA operates the Drinking Water Systems (DWS) Center, one of six technology areas under the ETV Program. The DWS Center recently evaluated the performance of a membrane filtration system for the reduction of arsenic in drinking water. This verification statement provides a summary of the test results for the Pall Corporation Microza® Microfiltration System. The NSF Drinking Water Systems Laboratory performed the verification testing. The verification report contains a comprehensive description of the complete verification test.

ABSTRACT

Verification testing of the Pall Corporation Microza® Microfiltration System for arsenic removal was conducted at the Oakland County Drain Commissioner (OCDC) Plum Creek Development well station located in Oakland County, Michigan from August 19 through October 8, 2004. The source water was groundwater from the two supply wells and the raw water for the verification test was withdrawn from the pressure tank at the site. Verification testing was conducted at the operating conditions specified by the manufacturer. The raw water, with a pH in the range of 7.0 to 7.4, was treated with sulfuric acid to lower the pH to a range of 6.6 to 7.0. Chlorine (bleach) was added to oxidize arsenic (III) to arsenic (V) and iron was added to coagulate the arsenic. When operated under the manufacturer's specified conditions at this site, with a flow rate of 6.3 gallons per minute (gpm), the Microza System reduced the total arsenic concentration from an average of 13 µg/L in the feed water (raw water after chemical addition) to below the detection limit of 2 µg/L in the filtrate (treated) water.

TECHNOLOGY DESCRIPTION

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

The Pall process is based on chemical coagulation, mixing, and microfiltration with no intermediate solids separation process. The Microza System includes pretreatment with sodium hypochlorite to oxidize any arsenic (III) to arsenic (V), and iron present in the water supply. Ferric chloride is added to augment any naturally occurring iron and optimize the iron dose. Sulfuric acid is added to adjust the pH to an optimal level, as determined during shakedown testing at the site. This chemically treated water (feed water) enters the feed tank supplied as part of the system. The coagulated water in the feed tank is mixed for five minutes and pumped directly to the microfiltration module. Flow enters the module on the outside of the membrane, passes through the membrane, and flows on the inside of the membrane to the outlet of the module. The microfiltration membrane filters the water, removing the precipitate, including arsenic, iron, and any other precipitated constituents. A portion of the filtrate is collected in a tank (reverse filtration tank) for use during the backwash process. The microfiltration system is designed to filter all of the water under normal operating conditions [i.e., there is no reject (concentrate) water from the system].

The Microza System uses a combination of air and water to backwash the microfiltration membrane. Water is supplied from the reverse filtration tank (30 gallon tank), which holds filtrate from the system. A compressor with a fully automated control system supplies air for the air scrub. When a backwash is initiated, the air system is activated and supplies air to the feed side of the module. The reverse filtration pump drives filtrate in a reverse flow through the membrane. The combination of air scrubbing and reverse water flow removes the particles that have been trapped by the microfiltration module. Occasionally, microfiltration membranes require chemical cleaning to remove materials that are not removed during the backwash process. Chemical clean in place (CIP) is typically required on a two or three month basis.

VERIFICATION TESTING DESCRIPTION

Test Site

The verification testing site was OCDC Plum Creek Subdivision well site in Oakland, Michigan. The source water was groundwater from two wells located at this site. The two wells pumped water to a common pressure tank that served as the raw water supply to the Microza System. Water quality data from historical information and from the characterization test showed the wells had similar water quality. Total arsenic ranged from 9 to 14 µg/L and total iron ranged from 0.9 to 1.0 mg/L. The pH was steady in the 7.0 to 7.6 range with alkalinity of 240 to 290 mg/L as $CaCO_3$. Raw water turbidity from the pressure tank was typically in the 3.3 to 8.4 Nephelometric turbidity units (NTU) range.

Methods and Procedures

Operations, sampling, and analyses were performed in accordance with the Product Specific Test Plan (PSTP) developed and approved for this verification test. The PSTP included a Quality Assurance Project Plan (QAPP) designed to assure the quality of the data collected and to provide an accurate evaluation of the treatment system under the field conditions. Testing included characterization of the raw water, an arsenic loss test (no chemical fed to the system), and a 30-day verification test.

The verification test was performed from September 9, 2004 through October 8, 2004. The Microza System was operated continuously for the 30-day verification test, independent of the well operations, by using water supplied from the well station's pressurized supply tank. Flow rate(s), production volume, water temperature, and system pressure(s) were monitored and recorded daily. These data provided the basis for calculating transmembrane pressure and flux through the membrane system. Raw, feed (after sulfuric acid, chlorine, and iron addition), and filtrate (treated) water samples were analyzed on-site for pH, temperature, turbidity, free and total residual chlorine, color, and dissolved oxygen by the field operator. Grab samples were collected and delivered to the NSF Chemistry Laboratory to be analyzed for alkalinity, calcium, magnesium, iron, manganese, sulfate, chloride, total organic carbon (TOC), total suspended solids (TSS), and fluoride. Samples for total arsenic were collected three times per week, plus 11 samples were collected during a 58-hour intensive sampling period. In addition to the 23 sets of samples for total arsenic, a total of eight sets of arsenic samples were speciated during the test to determine the soluble arsenic concentration and the concentrations of arsenic (III) and the arsenic (V) present in the soluble fraction. Samples of backwash water were collected and analyzed in addition to monitoring backwash and chemical cleaning operating parameters.

Complete descriptions of the verification testing results and quality assurance/quality control (QA/QC) procedures are included in the verification report.

VERIFICATION OF PERFORMANCE

System Operation

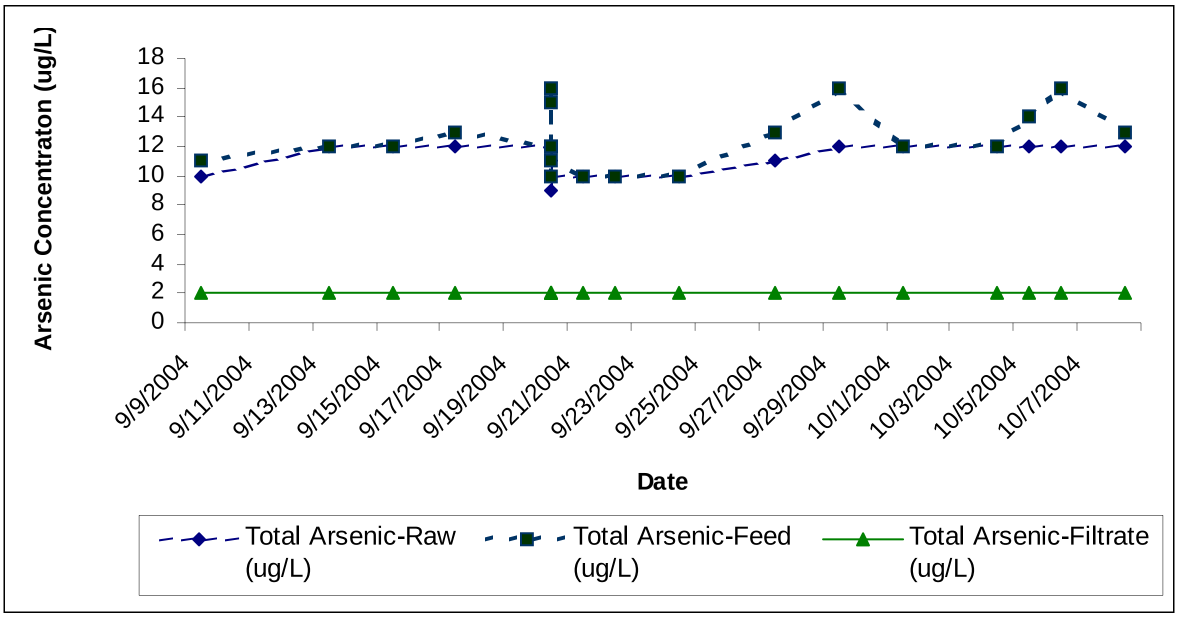
Pall performed the system startup and shakedown testing, which included a system integrity test, optimization of the chemical feed rates, and determination of backwash frequency. The verification test was conducted under the manufacturer's specified operating conditions. Chemical feeds were established to feed 1.0 mg/L of total chlorine to maintain total residual chlorine in the feed water of 0.5 to 1.0 mg/L. The ferric chloride feed rate was set to deliver 3 mg/l of ferric chloride (1 mg/L as Fe) and the sulfuric acid feed system was set to maintain a pH of 6.8 in the feed water. The flow rate for filtrate was set at 6.3 gpm to give a targeted flux rate of 120 gallons per day per square foot (gfd). The backwash system was set to backwash the membrane every 30 minutes. The backwash cycle time was about two minutes, including a one-minute air scrub period, followed by a 30-second forward flush period. All operating conditions remained steady throughout the verification test.

System pressure was monitored at three locations, feed water (inlet to the membranes), filtrate (exit of the membranes), and on the concentrate side of the membrane unit. The pressure on the feed water line slowly, steadily increased over the 30-day period, while the filtrate pressure remained steady, as expected. The transmembrane pressure (TMP) steadily increased indicating the membranes were accumulating materials in the pores that were not removed by the backwash. Pall recommends that the Microza System be cleaned using the CIP procedure when TMP exceeds 35 pounds per square inch (psi). After 30 days of operation, the TMP was 15.5 psi, indicating that cleaning was not yet required. However, in accordance with PSTP, the membranes were chemically cleaned and checked for performance after cleaning at the end of the test period.

The hydraulic flow conditions for membrane systems, such as the Microza System, are typically described by calculating the flux, the temperature corrected flux (20°C), and the specific flux at 20°C. The flux remained constant throughout the test. Specific flux started at 17.2 gfd/psi and decreased to a low of 9.1 gfd/psi near the end of the 30-day test. TMP increased from 8.1 psi to 15.7 psi over the same period. The steady rise in TMP can be used to project when the TMP would reach 35 psi, the Pall-recommended TMP when chemical cleaning is required. It is projected that the TMP would approach 35 psi at between 90 and 120 days. Thus, it could be expected that the membranes would require chemical cleaning in this site application about once every 90 and 120 days, as well.

Water Quality Results

The results of total arsenic analyses are shown in Figure VS-1. The raw water total arsenic averaged 11 µg/L with dissolved arsenic of 11 µg/L. Arsenic (III) was the dominant species in the raw water, averaging 10 µg/L. The feed water (after chemical treatment) total arsenic concentration averaged 13 µg/L, with <2 µg/L in the soluble state. Pretreatment completely converted the raw water arsenic (III) to the arsenic (V) species. The filtrate water total arsenic concentration was below the detection limit of 2 µg/L in all samples collected during the verification test.



Note: Arsenic Intensive Sampling Test occurred on 9/20/04.

Figure VS-1. Total Arsenic Results

The addition of sulfuric acid to the raw water reduced the pH from 7.0 to 7.6 to a range of 6.6 to 7.0 in the feed water. The acid addition reduced the alkalinity of the water from an average of 250 mg/L as $CaCO_3$ in the raw water to 230 mg/L as $CaCO_3$ in the feed water. The filtrate alkalinity averaged 230 mg/L as $CaCO_3$, indicating that the membrane had no impact on the alkalinity concentration. The average raw water iron concentration was 0.99 mg/L, and the feed water averaged 2.3 mg/L of iron after the addition of ferric chloride. The filtrate water iron concentration was <0.02 mg/L in all but two samples. One day the iron concentration was 0.10 mg/L and the other sample showed 3.6 mg/L, which appear to be outliers. Turbidity was also reduced through the Microza System from an average bench-top turbidity of 4.9 NTU in the raw water to an average in-line turbidity of <0.05 NTU in the filtrate water.

The backwash water was sampled on five occasions and found to have an average total arsenic concentration of 580 µg/L, an average iron concentration of 114 mg/L, and an average TSS concentration of 290 mg/L. The backwash cycle occurred every 30 minutes and yielded an average of two gallons of backwash water per cycle or 96 gallons per day. This represented 1.2% of the average daily treated water production. The backwash water was enriched in arsenic, iron, and TSS, as would be expected given the removal of arsenic and iron as measured in the filtrate. Local disposal requirements determine whether this water is acceptable for discharge to a sanitary sewer system, some other discharge location, or if it will require further treatment prior to discharge. The backwash water is not considered a hazardous waste based on the arsenic concentration, which is below the 5,000 µg/L (5.0 mg/L) limit under the Resource Conservation and Recovery Act (RCRA).

Operation and Maintenance Results

The Microza System was found to be easy to operate and required little time for daily maintenance. The field staff was on-site for two to three hours per day. Most of the time on-site was spent performing field activities, including daily chemical analyses, flow checks, calibrations, etc. In a normal operation, the inline pH meters and turbidimeters would be used for system checks. The Microza System has a PLC/PC that records data for all key operating parameters, including flow data, pressure information, backwash cycles, etc. The system also has manual readouts on the feed and filtrate flow rate, the pressures for feed, filtrate and concentrate, and on the inline pH meters and turbidimeters. It is estimated that the time to check the system on-site would be minimal, possibly less than 30 minutes, except when chemical feedstocks needed to be replenished or inline instruments calibrated. The PLC can be setup for remote access so that main system parameters can be monitored without a site visit.

The chemical feed system maintained steady chemical feed rates over the duration of the test. The only maintenance performed on the Microza System was the replacement of one pH meter cable that failed on September 25. The cable was shipped to the site and the field personnel were able to install the cable and recalibrate the pH meter.

The Pall operation and maintenance (O&M) manual provides a detailed description of the system, appropriate safety precautions, and detailed descriptions of operating procedures, capability and operation of the computer control system, and specific instructions for utility operators. The maintenance section of the manual includes descriptions of components that require maintenance. Maintenance checklists, including example forms for daily and periodic maintenance activities, are included along with a troubleshooting section in a tabular format. The review of the O&M manual shows that the manual is well organized and easy to read.

Consumables and Membrane Chemical Cleaning

The Microza System used a 6% sodium hypochlorite (bleach) as the stock chemical for adding chlorine to the system. A total of 3.9 gallons of 6% bleach solution was used to treat 252,600 gallons of raw water. This equates to an average concentration added to the raw water of 0.92 mg/L. Iron was added to the raw water using a 40% ferric chloride solution. A total of 1.3 gallons (15.2 pounds) of ferric chloride solution was used to treat 252,600 gallons of raw water. Sulfuric acid addition was based on the need to lower pH to an operating range of 6.6 to 7.0. Approximately 5.4 gallons of sulfuric acid was used over the 30-day test to treat 252,600 gallons of raw water.

The chemical CIP procedure used by Pall to clean membranes uses a sodium hydroxide and bleach solution that is recirculated through the system for two hours. After a rinse, a citric acid solution is used to further clean the membranes with low pH water, followed by a rinse. Pall performed a CIP before the start of the verification test and again at the end of the test. Field staff observed both cleaning procedures and recorded the chemical use and TMPs before and after the final cleaning. The CIP procedure took around five hours to complete. This time includes the time to drain the feed water tank, make the chemicals used for cleaning, perform the entire procedure, and reset the unit for operation. The chemicals used for the post verification test CIP included: 1.25 lbs. of sodium hydroxide (NaOH), 942 mL of bleach (6% solution), and 1.688 lbs of citric acid. The cleaning solutions were made by diluting the sodium hydroxide and bleach into 15 gallons of water, and the citric acid was diluted into 10 gallons of water. At the end of the CIP, the TMP had returned to the original TMP at the beginning of the verification test. These data indicated that the unit was cleaned and restored to original operating condition. The final check was an integrity test, which demonstrated that the membranes were still in good condition.

Electrical power consumption was estimated based on pump, mixer, and air compressor horsepower of 2.75 hp-hr. With miscellaneous electrical use by chemical feed pumps and the PLC/PC, power consumption is estimated to be 2.55 kilowatt-hr.

Quality Assurance/Quality Control

NSF provided technical and QA oversight of the verification testing as described in the verification report, including an audit of nearly 100% of the data. The NSF QA department conducted a technical systems audit during testing to ensure the testing was in compliance with the test plan and performed a QA review of the analytical data. A complete description of the QA/QC procedures is provided in the verification report.

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Arsenic Removal* dated April 2002, the verification statement, and the verification report (NSF Report #04/10/EPADWCTR) are available from the following sources:
(NOTE: Appendices are not included in the verification report. Appendices are available from NSF upon request.)

1. ETV Drinking Water Systems Center 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)