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THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**COAGULATION AND MEDIA FILTRATION USED IN DRINKING WATER TREATMENT SYSTEMS**
APPLICATION:	**REMOVAL OF ARSENIC IN DRINKING WATER**
TECHNOLOGY NAME:	**KEMLOOP 1000 COAGUALTION AND FILTRATION WATER TREATMENT 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 coagulation and media filtration system for the removal of arsenic from drinking water. This verification statement provides a summary of the test results for the ORCA Technologies (ORCA) KemLoop 1000 Coagulation and Filtration Water Treatment System (KemLoop). The NSF Drinking Water Treatment Systems Laboratory (DWTS) performed the verification testing. The verification report contains a comprehensive description of the complete verification test.

ABSTRACT

Verification testing of the ORCA Water Technologies KemLoop 1000 Coagulation and Filtration Water Treatment System for arsenic removal was conducted at the St. Louis Center located in Washtenaw County, Michigan from March 23 through April 6, 2005. The source water was groundwater from 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 7.6, was treated with chlorine bleach to oxidize arsenic (III) to arsenic (V), as well as iron to coagulate the arsenic. When operated under the manufacturer's specified conditions at this site, at an average flow rate of 9.9 gallons per minute (gpm), the KemLoop System reduced the total arsenic concentration from an average of 22 micrograms per liter (µg/L) in the feed water (raw water after chemical addition) to 3 µg/L in the filtrate (treated) water.

TECHNOLOGY DESCRIPTION

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

The ORCA process is based on chemical addition with mixing in a proprietary mixing loop to optimize coagulation, and granular media filtration with no intermediate solids separation process. The KemLoop 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 natural occurring iron and optimize the iron dose. The chemically treated water (feed water) enters the mixing loop where coagulation of arsenic and iron occurs. The water exits the mixing loop and is applied directly to one of the two granular media filter modules. The water enters the top of the operating filter and flows through the granular media filter, exiting at the bottom of the module. The granular media filter removes the precipitate, including arsenic, iron, and any other precipitated constituents. The two-filter module system operates with the filters in parallel, one filter module is in active operation and one unit is in standby mode. When backwash of a filter module is required, the standby filter is brought online and the backwash cycle for the "dirty' filter module is initiated. Once the backwash cycle is complete, the clean filter module becomes the standby unit.

The KemLoop System is fully automated and programmed to control all aspects of the filter operation. The control system automatically initiates backwash cycles based on four criteria: differential pressure across the media filter, treated water turbidity compared to raw water turbidity, time, and volume, as set by the operator. The backwash frequency is dependent on the water quality conditions and the amount of solids generated in the coagulation process. The control system is a programmable logic control and personal computer (PLC/PC) based controller with data logging, trend display graphs, and a remote monitoring modem connection for off-site technical support. All the information is available to the on-site operator and to remote users

VERIFICATION TESTING DESCRIPTION

Test Site

The verification test site was the St. Louis Center, a residential community for people with developmental disabilities, located in Washtenaw County Michigan. The source water was groundwater from two wells located at this site, which pumped water to a common pressure tank that served as the raw water supply to the KemLoop System. Water quality data from historical information and the characterization test showed the wells had similar water quality. Total arsenic in the combined well water ranged from 14 to 32 ug/L and total iron ranged from 0.39 to 1.6 milligrams per liter (mg/L). The pH was in the 7.4 to 7.6 range with alkalinity of 250 to 260 mg/L as $CaCO_3$. Raw water turbidity was found to be <1 nephelometric turbidity unit (NTU) in 2004 and 1.2 NTU in the 2005 characterization test.

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 14-day verification test.

The verification test was performed from March 23, 2004 through April 6, 2005. The KemLoop System was operated continuously for the 14-day verification test, independent of the well operations, by using water supplied from the pressurized supply tank. Flow rate(s), production volume, water temperature, and system pressure(s) were monitored and recorded daily. Raw, feed (after 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 Drinking Water 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 daily, plus 14 samples were collected during a 48-hour intensive survey. In addition to the 25 sets of samples for total arsenic, a total of four 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 to characterize the backwash wastewater.

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

ORCA performed the system startup and shakedown testing, which included 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. The ferric chloride feed rate was set to deliver 1.5 to 2.5 mg/L (as Fe) of iron to augment the naturally occurring iron of 0.5 mg/L. The flow rate for filtrate was set at 10 gpm to give a targeted surface-loading rate of 2940 gallons per day per square foot (gfd). The backwash system was set to backwash once per day or if the pressure differential across the filter exceeded 8 pounds per square inch (psi) or if turbidity of the filtrate exceeded the raw water for ten minutes. The backwash cycle used treated water, which was pumped at 50 gpm through the filter in an up flow mode to flush out the accumulated solids.

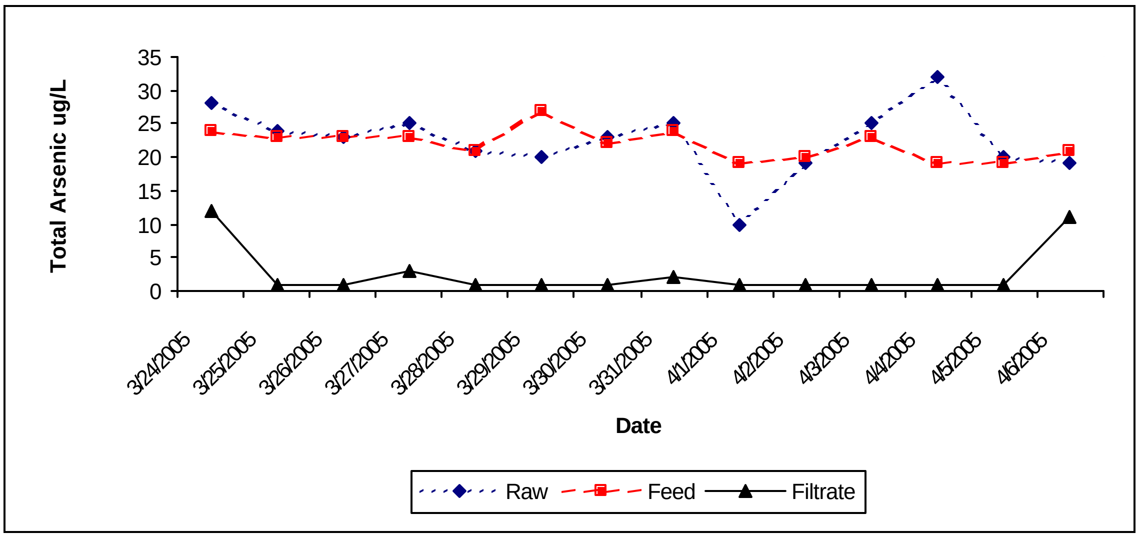
System pressure was monitored at three locations, raw water (from pressure tank), feed water (inlet to the filters), and filtrate (exit from the filters). There was very little change in head loss through the filter over each 24-hour operating period. The maximum pressure differential observed was 5.0 psi, with the filter inlet side averaging 5.8 psi and the filter outlet side averaging 2.0 psi. The automatic backwash cycle was not triggered due to pressure differential (head loss) or an increase in filtrate turbidity at any time during the verification test.

The filtrate flow rate remained steady for most days during the test yielding an average flow rate of 9.9 gpm over the 14 days. The total filtrate volume produced each day was also consistent, except for April 2 through 4 when volumes and flow rates were somewhat lower. It appears the pressure on the raw water supply tank at the St. Louis Center was periodically dropping below 40 psi (the setting on the pressure regulator). This caused periodic lower flow rates and lower volumes of filtrate to be produced over the

24-hour period. The average hydraulic loading through the filter was 2,890 gallons per square foot, based on the 24-hour filter run time between backwashes and the average daily filtrate production of 14,630 gallons.

Water Quality Results

The results of total arsenic analyses are shown in Figure VS-1. The raw water total arsenic averaged 23 µg/L with most of the arsenic as arsenic (III). Following chemical treatment, the feed water total arsenic concentration averaged 22 µg/L. While the soluble arsenic and arsenic speciation data showed some variability, the data indicate that pretreatment completely converted the raw water arsenic (III) to the arsenic (V). The filtrate water total arsenic concentration averaged 3 µg/L with the concentration being below the detection limit (1 µg/L) on six of 14 days. The filtrate exceeded 10 µg/L on the first and last day of the verification test. On the first day the total arsenic concentration was 12 µg/L with dissolved arsenic of <1 µg/L. It appears the high arsenic concentration was caused by an overdose of ferric chloride resulting in solids passing through the filter. After adjusting the iron feed rate, the turbidity in the filtrate dropped from 1.7 NTU to 0.10 NTU and the arsenic on Day 2 was 1 µg/L. The cause of the higher filtrate arsenic concentration (11 µg/L) on the last day is not known, as the iron feed rate, and iron concentration and turbidity level in the filtrate were low. The data collected during the 48-hour intensive survey were consistent with the data collected each day during the verification test. There was no indication of any transient or short time changes in the arsenic concentration or in any other monitored parameters.



Note: 48-hour intensive survey began on 3/30/05.

Figure VS-1. Total Arsenic Results

The raw water and filtrate alkalinity averaged 260 mg/L as $CaCO_3$, indicating that the chemical addition and filtration process had no impact on the alkalinity concentration. The pH of the raw water was steady in the range of 7.20 to 7.48 with a mean value of 7.30. The filtrate pH ranged from 7.22 to 7.46 with a median value of 7.30 showing that the addition of chlorine and ferric chloride had very little impact on pH. The average raw water iron concentration was 0.47 mg/L, and the feed water averaged 1.9 mg/L of iron after the addition of ferric chloride. The filtrate water iron concentration was 0.03 mg/L or less on ten out of fourteen days. On March 25 and 31, the iron concentration was 0.08 and 0.07 mg/L, respectively. The first day of the test, when the iron concentration in the feed was measured at a maximum concentration of 4.5 mg/L (chemical feed pump subsequently adjusted downward), the filtrate concentration was 1.7 mg/L. On March 27 the iron was 0.31 mg/L. These data show that the KemLoop System can produce a filtrate with <0.30 mg/L of iron. The KemLoop System lowered the turbidity levels with the filtrate turbidity averaging 0.30 NTU based on the bench-top turbidimeter and 0.20 NTU based on the inline turbidimeter. The bench top turbidity meter always gave higher turbidity readings compared to the inline units. The raw water turbidity based on the bench top unit averaged 2.4 NTU, whereas the average turbidity based on the inline unit was 0.60 NTU. It is believed that the bench top unit data may have been biased high due to temperature and fogging issues that can be problematic when collecting cold samples and transferring them to the bench top vials. Based on the bench-top meter measurements, the filtrate was below 0.5 NTU in 93% of samples, had no values between 0.5 and 1 NTU, and 7% of the readings (1 reading) were between 1 and 2 NTU. There were no turbidity levels above 2 NTU. The inline turbidimeter gave the same distribution of turbidity readings in the filtrate. During the 48-hour intensive survey the turbidity levels in the filtrate did tend to increase slightly near the end of each filter run, and then were lower again when the standby filter was brought on line. All inline turbidity measurements for the filtrate during the 48-hour intensive survey were below 0.2 NTU, even at the end of a 24-hour run.

The backwash water was sampled on four occasions and found to have an average total arsenic concentration of 760 µg/L, an average iron concentration of 120 mg/L, and an average TSS concentration of 250 mg/L. The backwash cycle occurred once every 24 hours and yielded an average of 220 gallons per day of backwash water. This represented 1.5% 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 solids are not considered a hazardous waste based on Toxicity Characteristic Leaching Procedure (TCLP) arsenic results of 0.32 mg/L, which is below the 5.0 mg/L limit under the Resource Conservation and Recovery Act (RCRA).

Operation and Maintenance Results

The KemLoop 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 KemLoop System has a PLC/PC that records data for all key operating parameters, including flow data, pressure information, backwash cycles, etc. 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 main system parameters can be monitored without a site visit.

The ORCA 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 some descriptions of required maintenance, but refers the reader to the individual equipment literature supplied by the various pump and instrument manufacturers. These manuals were provided in a notebook. The draft O&M manual did not contain specific checklists for routine site visits. The review of the O&M manual shows that the manual is well organized and easy to read.

Consumables and Membrane Chemical Cleaning

The KemLoop System used a 6% sodium hypochlorite (bleach) solution, made on site from a 12% stock solution. A total of 28 liters of 6% bleach solution was used to treat 204,870 gallons of raw water. This equates to an average concentration added to the raw water of 2.2 mg/L. The average total residual chlorine in the feed water after chlorine addition was 1.0 mg/L, indicating a chlorine demand in the water of 1.2 mg/L. Iron was added to the raw water using a 4.8% as iron (Fe) ferric chloride solution. A total of

23.9 L (6.3 gallons) was used to treat 204,870 gallons of raw water, yielding an average concentration of iron added to the water of 1.5 mg/L. The feed water concentration averaged 1.9 mg/L and the raw water concentration averaged 0.47 mg/L, indicating 1.43 mg/L of iron addition, which was close to the calculated 1.5 mg/L fed based on chemical use.

Electrical power consumption was estimated based on the raw water pump (not used at this site) and backwash pump horsepower. With miscellaneous electrical use by chemical feed pumps and the PLC/PC, power consumption is estimated to be 0.5 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)