THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Verification Statement

TECHNOLOGY TYPE:	**BIOLOGICAL TREATMENT**
APPLICATION:	**ARSENIC, AMMONIA, IRON AND MANGANESE REDUCTION**
PRODUCT NAME:	**CHEMILES NCL SERIES SYSTEM**
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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 Nagaoka International Corporation CHEMILES NCL Series system. NSF performed the laboratory analyses at its Ann Arbor, MI location, and the test site was located at the Clark Public Utilities Bridge Road Water Treatment Plant (also known as the Hayes Road Well)~~,~~ near Woodland, Washington in Clark County, USA. CH2MHill under contract with NSF and whose quality was overseen by NSF, performed all field monitoring and sample collection.

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 Nagaoka International Corporation CHEMILES NCL Series system was tested to verify its performance for the reduction of multiple contaminants including: arsenic, ammonia, iron, and manganese. The objectives of this verification, as operated under the conditions at the test site under real world conditions, were to evaluate:

- Impacts on performance of any variations in feed water quality or process variation;
- Logistical, human, and other resources necessary to operate the equipment;
- Reliability, ruggedness, ranges of usefulness, and ease of operation of the equipment.

Methods followed the approved test quality assurance project plan.

The CHEMILES NCL Series system pilot plant was easy to operate and maintain. The unit was completely automated and required only minimal maintenance. The programmable logic controller (PLC) monitored flow in the system, operated pumps and valves and conducted backwashing. The water produced was normalized to a 24-hour day and averaged 6,527 gallons (gal), with a range of 5,367 to 6,698 gal.

Results include arsenic, iron, manganese, and ammonia reduction for the raw and treated water. Also included with the ammonia results are the nitrate and nitrite results, since the system oxidizes ammonia to nitrate. Arsenic was detected below the reporting limit for all treated water samples, except for one sample during the intensive sampling period with arsenic reported at 0.002 mg/L. Nagaoka's target performance criterion for ammonia was 75% reduction. The treated water ammonia concentrations ranged from 0.03 to 0.19 mg/L, with a mean of 0.05 mg/L. The 75% reduction performance level was achieved for all weekly raw/treated sample pairs, except for three pairs. All weekly raw and treated water samples had nitrite below the laboratory reporting limit of 0.02 mg/L as N. Levels in treated water for nitrate were below the EPA MCL of 1 mg/L as N.

Iron and manganese are regulated secondary drinking water contaminants. The reduction of these contaminants is to improve the aesthetic quality of the finished produced water. All treated water iron measurements were below the EPA secondary maximum contaminant level (MCL) of 0.3 mg/L. The treated water iron concentrations ranged from 0.02 to 0.18 mg/L, with a mean of 0.05. The monitoring period for manganese removal was delayed to allow more time for the manganese oxidizing bacteria to cultivate on the filtration media. During the May 2013 intensive sampling, in the first period without pH adjustment, six of the seven treated water daily manganese samples results were below the MCL of 0.05 mg/L. Subsequently , the second period showed pH adjustment can be effective on higher raw water manganese contaminated levels. More detail is provided in the final ETV report.

A sample of the backwash was collected and analyzed following the EPA Toxicity Characteristic Leaching Procedure (TCLP) and the California Waste Extraction Test (CAWET) requirements. The backwash solids were not considered a hazardous waste based on the arsenic concentrations which were below the 5 mg/L limit under the Resource Conservation and Recovery Act (RCRA).

TECHNOLOGY DESCRIPTION

The vendor provided the following description, which was not verified: The CHEMILES NCL Series system is a self-contained, chemical-free system designed for treatment of groundwater. The system is a column design, intended for outdoor placement. The system does not include a chemical feed pump, but it does include a treated water pump and a backwash pump. The treatment column contains a sand filter

medium, with a support gravel layer at the base. The system must be allowed to ripen for three to six months, to allow autotrophic bacteria to colonize the sand filter medium.

Raw water is introduced into the top of the column through a proprietary oxidation nozzle of Nagaoka International Corporation (Nagaoka). The nozzle utilizes the "Venturi effect" to introduce air which reduces fluid pressure when the water flows through a constriction. Air is induced through a hole in the nozzle near the constriction and causes the air and water to be mixed.

The scientific theory of the CHEMILES system is that the oxidation nozzle increases the dissolved oxygen (DO) level of the raw water, causing soluble ferrous iron to oxidize to insoluble ferric iron, and arsenic (III) to oxidize to arsenic (V). The sand filter medium becomes coated with ferric oxi-hydroxide which acts as a catalyst to oxidize and retain a portion of the iron. The bacterium on the filter medium oxidizes any remaining ferrous iron to ferric iron, and also ammonia to nitrate and soluble manganese to insoluble manganese dioxide. The ferric iron and manganese dioxide are retained by the filter medium.

There are two types of backwashes for the CHEMILES system – "P" backwashes and "W" backwashes. The P backwashes are partial backwashes, and W backwashes are whole-system backwashes. The P backwashes occur several times per day, while the W backwash usually occurs once per day or less frequently.

The P backwash just backwashes the upper filtration zone where most of the arsenic and iron precipitate is retained. The P backwash utilizes Nagaoka's proprietary rotating surface washing nozzles to assist in the backwash process. This approach minimizes disturbances of the biological active lower treatment zone.

VERIFICATION TESTING DESCRIPTION

Test Site and Equipment

The test site is the Clark Public Utilities Bridge Road Water Treatment Plant (also known as the Hayes Road Well), located near Woodland, Washington in Clark County, USA. The site is only about 200 feet away from the Lewis River, but it is not classified as ground water under the influence of surface water. The site has an 8-inch diameter well with a submersible pump rated at 50 gallons per minute (gpm). The plant is not continuously manned and is only operated periodically, depending on the level in the finished water reservoir. The treatment plant includes manganese greensand filtration to remove iron, manganese, and arsenic. For the verification test, a separate five gallon per minute (5 gpm) pump was installed in the well casing to provide a dedicated supply to the pilot unit.

Methods and Procedures

An ETV Test Quality Assurance Plan (TQAP) was prepared for the CHEMILES NCL Series system verification test in accordance with the ETV *EPA/NSF Protocol for Equipment Verification Testing for Arsenic Removal* (September 2003). This protocol was used for the aspects of testing related to removal of arsenic, iron, and manganese. There is no ETV Protocol for ammonia reduction so best available professional judgment was used for the testing aspects related to this contaminant. More detail is described in the final report and TQAP.

VERIFICATION OF PERFORMANCE

System Operation

The operational data included production of treated water, headloss, and backwash flow rates. The pilot unit produced treated water for approximately 23 hours per day. The water production, normalized to a 24-hour day, averaged 6,527 gal, with a range of 5,637 to 6,698 gal. For 47 days of headloss

measurements, the average headloss recovery was 257 mm of water, with a range of 52 to 904 mm. The mean backwash flow was 5.19 gpm, with a range of 4.92 to 10.67 gpm.

A review of the ability and ease of operation was evaluated by CH2MHill. The unit was completely automated and required only minimal maintenance. Initially, the unit required some process modifications, but once they were adjusted, very little adjustment was required thereafter. Because the pilot filter was quite tall, an enclosed structure with ladder steps and access platforms was provided.

The pilot system is controlled by a PLC. The PLC monitored flow in the system, operated pumps and valves and conducted backwashing. The Operation and Maintenance manual provided by Nagaoka accurately described the PLC set points, and operators were able to change the set-points when requested by Nagaoka. The pilot system could be improved by adding a differential pressure recording device across the filter and incorporating all of the flow data into the PLC. A data logger would also be useful to allow evaluation of data on a more frequent basis.

Infrequent maintenance included cleaning the aeration nozzles. Spare aeration nozzles were provided. Over the testing period, the aeration nozzle only required replacement and cleaning one time. The CHEMILES system uses three pumps for operation: a raw water pump, a treated water pump, and a backwash pump. Based on an estimated pump efficiency of 90%, these three pumps consume approximately 29.5 kW/day.

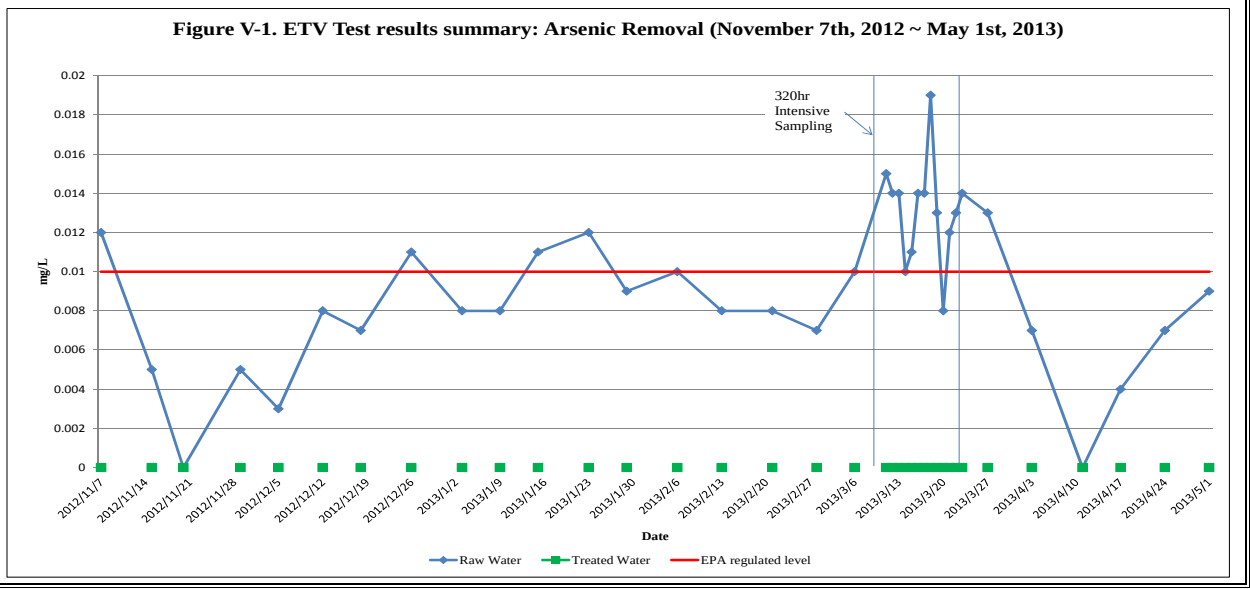
Test Results

Results include arsenic, iron, manganese, ammonia, nitrite and nitrate reduction for the raw and treated water.

Arsenic

The historical water quality data suggested that the arsenic concentration in the raw water ranged from 15 to 36 ug/L. However, this was not the case at any time during the verification test. The arsenic level reached as high as 0.020 mg/L during the March 48-hour intensive sampling period, but most of the time it was below the EPA MCL of 0.010 mg/L. The statistical analysis of the weekly samples shows a mean raw water arsenic concentration of 0.008 mg/L for the test, with a range of <0.002 to 0.014 mg/L. There were two weeks when the raw water arsenic level was below the laboratory reporting limit of 0.002 mg/L. Arsenic was below the reporting limit for all treated water samples, including all of those for the March 320-hour daily and 48-hour intensive sampling periods, except for one sample during the intensive sampling period with arsenic reported at 0.002 mg/L.

Figure V-1. ETV Test results summary: Arsenic Removal (November 7th, 2012 ~ May 1st, 2013)



Ammonia, Nitrite and Nitrate

Ammonia in the raw water for the weekly samples ranged from 0.07 to 0.71 mg/L as N, with a mean of 0.40 mg/L. Ammonia in the treated water ranged from 0.03 to 0.19 mg/L as N, with a mean of 0.05 mg/L. Nagaoka's target performance criterion for ammonia was 75% reduction. The 75% reduction performance level was achieved for all weekly raw/treated sample pairs, except three. The first pair was that for November 21 and, in this instance, 75% reduction was not achieved because the raw concentration was at the minimum of 0.07 mg/L measured for the entire test. The treated water level was less than the laboratory reporting limit of 0.03 mg/L, so the low percent reduction was simply a function of the low raw water concentration and the analytical method reporting limit. The other two sample pairs with less than 75% reduction corresponded to spikes in the raw water ammonia concentration on January 23 and March 12. All weekly raw and treated water samples had nitrite below the laboratory reporting limit of 0.02 mg/L as N. Levels in treated water for nitrate were below the EPA MCL of 1 mg/L as N.

Iron and Manganese

Iron and manganese are regulated secondary drinking water contaminants. The reduction of these contaminants is to improve the aesthetic quality of the finished produced water. The raw water iron concentrations varied widely during the test, just as the ammonia levels did, ranging from 2.0 to 15 mg/L, with a mean of 9.4 mg/L. All treated water iron measurements were below the EPA secondary MCL of 0.3 mg/L. The treated water iron concentrations ranged from 0.02 to 0.18 mg/L, with a mean of 0.05. On March 27, the raw water pH was raised with NaOH to try to improve the biologically mediated manganese treatment. During this period, the treated water iron level rose to 0.40 mg/L on March 27, and 0.62 mg/L on April 3. The pH adjustment was stopped on April 8, and the treated water iron level was measured at 0.03 mg/L on April 11.

The monitoring period for manganese removal was delayed until January 2013 to allow more time for the manganese oxidizing bacteria to grow on the filtration media. The verification testing period was extended into May of 2013 to allow for a second 320-hour daily sampling and 48-hour intensive sampling periods focusing only on manganese reduction.

The weekly sample raw water manganese levels ranged from 0.13 to 0.32 mg/L, with a mean of 0.21 mg/L. The treated water levels ranged from 0.02 to 0.28 mg/L, with a mean of 0.11 mg/L. Of the fifteen treated water weekly manganese sample results, only two samples were below the EPA secondary MCL of 0.05 mg/L. Consequently, more time was allowed for the adjustment of the bacteria associated with manganese treatment.

The May 320-hour daily sampling period for manganese is divided into several periods where pH adjustment was used to enhance reduction. During May 10 to May 16, the pH of the raw water was not raised, with a range of 6.62 to 6.69. From May 17 to May 23, the mean feed water pH after NaOH addition was 7.03, with a range of 6.85 to 7.28. From May 10 to May 16, the raw water manganese concentration ranged from 0.09 to 0.19 mg/L, with a mean of 0.14 mg/L. For the second week, from May 17 to May 23, the raw water manganese concentration was higher, ranging from 0.21 to 0.32 mg/L, with a mean of 0.25 mg/L. Likewise, the treated water manganese concentrations were lower the first week than the second week. From May 10 to May 16 the treated water manganese ranged from 0.03 to 0.07 mg/L, with a mean of 0.04 mg/L. From May 18 to May 23, the treated water manganese ranged from 0.02 to 0.12 mg/L, with a mean of 0.06 mg/L. For this second week, the two lowest manganese measurements were on the 22nd and 23rd, at 0.02 and 0.04 mg/L, respectively, indicating that perhaps pH adjustment takes a few days to affect the treated water levels of manganese.

Other Water Quality Parameters

The pH of the raw water averaged 6.39 over the verification testing period, with a minimum of 6.17 and a maximum of 6.57. Aeration of the raw water for treatment raised the pH to a mean of 6.68, with a range

of 6.55 to 6.80. The pH of the treated water was slightly lower, with a mean of 6.46 and a range of 6.36 to 6.54. The raw water temperature was steady throughout the verification test, ranging from 11.9 to 14.2 °C.

The DO of the raw water ranged from 2.97 to 4.16 mg/L, with a mean of 3.49 mg/L. Aeration of the water raised the DO level to an average of 9.77 mg/L (range 7.61 to 11.31). Passage of the water through the media column consumed oxygen, as would be expected for a biological treatment process. The DO of the treated water averaged 6.51 mg/L (range 3.62 to 8.85).

The turbidity of the raw water was low, at 0.09 to 0.88 NTU, with a mean of 0.33 NTU. The treatment process raised the turbidity somewhat, to a range of 0.17 to 3.23 NTU (mean of 0.80).

The CHEMILES system treated water HPC counts were below 10 CFU/mL, except for one count of 149. For most raw/treated sample pairs, the raw water count was 1, or <1 CFU/mL, so the treatment process did contribute a small amount of HPC to the water but not to a degree warranting any concern about hitting the EPA MCL of 500 CFU/mL

Backwash Waste

The backwash waste was sampled and analyzed. Immediately following a backwash event, samples were collected from the backwash collection vessel. The backwash waste was enriched in arsenic, iron, manganese, and TSS, as would be expected, given the removal of contaminants as measured in the treated water. The CHEMILES System produced an average daily volume of 6,527 gal, and generated an average backwash volume of 150 gpd. Analysis of the filter media by Nagaoka after the test ended revealed that the filter media particle sizes had increased, indicating the backwashes did not fully remove the accumulated contaminants from the filter media particles.

If solid separation were required before the backwash waste could be discharged, the solids would need to be sent to a landfill for disposal. A sample of the backwash was collected and analyzed following the EPA TCLP and the CAWET requirements. The backwash solids were not considered a hazardous waste based on the arsenic concentrations, which were below the 5 mg/L limit under the Resource Conservation and Recovery Act (RCRA).

QUALITY ASSURANCE/QUALITY CONTROL

The NSF QA Department performed a QA review of the analytical data. An audit was performed on December 5, 2013. As a result of the audit, certain biological samples and on-site measurements were deemed not to have met data quality criteria and thus were excluded from the analysis of results. However, the audit found that samples of critical parameters like arsenic and ammonia were deemed acceptable. A complete description of the QA/QC procedures is provided in the verification report.

Original signed by Cynthia Sonich-Mullin on 04/09/2014

Cynthia Sonich-Mullin Date
Director

National Risk Management Research Laboratory
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Original signed by David Purkiss on 04/07/2014

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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