THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ON-SITE SODIUM HYPOCHLORITE GENERATION USED IN DRINKING WATER TREATMENT SYSTEMS**	
APPLICATION:	**ON-SITE GENERATION OF SODIUM HYPOCHLORITE AND INACTIVATION OF PSEUDOMONAS**	
TECHNOLOGY NAME:	**CLORTEC T-12**	
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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 an on-site hypochlorite generation system used in drinking water treatment system applications. This verification statement provides a summary of the test results for Exceltec's ClorTec T-12 System. ARCADIS Geraghty & Miller, an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

Verification testing of ExcelTec's on-site hypochlorite generation system ClorTec T-12 system was conducted for 30 days between March 6 and May 4, 2000. The system is capable of producing at least one pound of chlorine in the form of sodium hypochlorite solution containing 0.8 percent (± 0.1 percent) chlorine equivalent using 4.11 pounds of salt, 3.5 AC kilowatt hours and 15 gallons of water. In addition, the 0.8 percent sodium hypochlorite solution that the ClorTec T-12 produces on site produced a 4-log kill of *Pseudomonas aeruginosa* when dosed to achieve a concentration-time product (CT) of 50 based on actual hydraulic retention time or a CT of 26 based on a T_{10} value.

TECHNOLOGY DESCRIPTION

Sodium hypochlorite disinfection is generally used to kill bacterial contaminants in water, as well as to provide residual chlorination to drinking water. The sodium hypochlorite generation unit supplied by Exceltec for the verification project is the ClorTec T-12, which is a wall-mounted, tubular electrolytic cell. Ancillary equipment consists of a water softener that uses a small amount of potable water, salt mix tank, dual head bellows type water and brine pump, stainless steel control panel, direct current (DC) power supply, product storage tank, and a peristaltic product dosing pump with manual dose rate adjustment. A parallel system to the existing water treatment operation was established for the purposes of this verification project, consisting of the ClorTec unit and four baffled, 200-gallon tanks in series to achieve the required concentration time.

The basic principle of onsite sodium hypochlorite generation is the use of a direct current electrical field on a brine solution that results in the oxidation of the chloride found in brine, with the simultaneous and physically separated reduction of water to gaseous hydrogen, which needs to be vented to the atmosphere. While still in the electrolytic cell, all chlorine immediately reacts to form hypochlorous acid, which in turn reacts with the sodium ions to form sodium hypochlorite.

VERIFICATION TESTING DESCRIPTION

Test Site

The host site for this demonstration is 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 23 gallons per minute (gpm) from a sump directly in contact with the Middle Tyger River.

Methods and Procedures

The test was divided into three tasks: 1) Equipment Disinfection Production Capabilities and Operation, 2) Microbiological Contaminant Inactivation (Challenge test), and 3) Treated Water Quality.

Under Task 1, the operation of the ClorTec T-12 was verified in terms of the concentration of sodium hypochlorite produced, the electrical power consumption per pound of available chlorine, the sodium chloride consumption per pound of available chlorine, and the volume of potable make-up water consumed per pound of available chlorine. Chlorine samples were taken twice daily and analyzed according to Standard Methods. Under this task, an assessment of the waste stream from the water softener was also performed. Parameters that were quantified in the waste stream include flow, chlorine, chloride, alkalinity, total dissolved solids (TDS), and pH, as well as heavy metals.

The objective of the microbial task was to characterize the ClorTec T-12's efficacy for inactivation of *Pseudomonas aeruginosa*. This microbe was spiked into the raw water flow for a period of time equivalent to three hydraulic retention times at a concentration of 1.9×10^6 CFUs/100 ml. *P. aeruginosa* enumeration of the samples was done using Standard Methods 9213 E. Membrane Filter Technique for *P. aeruginosa*. During the challenge testing, the total and free chlorine concentrations were verified.

The objective of the third task was to assess the impact that treatment with sodium hypochlorite generated by the ClorTec T-12 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, chlorine residual (free and total), hydrogen sulfide, alkalinity, total dissolved solids (TDS), ammonia nitrogen, total organic carbon (TOC), ultraviolet absorbance (UVA) at 254 nanometer (nm), true color, iron, manganese, chloride, chlorite, chlorate, sodium, total coliforms, and heterotrophic plate count (HPC) bacteria. Analytical samples were collected from various locations within the overall treatment system. Simulated Distribution System testing for disinfection by-product (DBP) formation was conducted as a one-time event.

VERIFICATION OF PERFORMANCE

Operation and Maintenance

The ClorTec system was fully automated and capable of normal operation without manual intervention. Early in the test, the system stopped producing hypochlorite, although it continued to run. After trouble shooting with the ExcelTec technician, it was determined that the most probable cause was a failure in the programmable logic controller (PLC). A new PLC was shipped to the plant and installed by a licensed electrician. When the system was brought on-line again it operated briefly and then shut down again with a "high voltage" alarm. After about five minutes the system reset itself and started up again and ran without down-time.

ClorTec-specific maintenance consisted of periodically adding salt, as well as regenerating the water softener. Because this regeneration was not necessary during the test, the water softener was regenerated separately after the test to study the procedure and to take a sample of the waste stream from the water softener. This procedure was simple and is expected to last about 20 minutes when conducted by an experienced operator. It was noted that the ClorTec T-12 Operations Manual was well organized and clear. Routine maintenance and start-up procedures are well documented, but the description on routine operation should be expanded.

Disinfectant Production Capabilities

The ClorTec T-12 system produced and dosed chlorine constantly and effectively during the test, with the exception of the one PLC stoppage described above. The raw water was typically below the total chlorine analytical detection limit of 0.05 mg/L; six instances of raw water total chlorine concentrations above 0.05 mg/L were observed during the verification period. The average treated free and total chlorine concentrations were 1.57 and 1.68 mg/l respectively. The average finished free and total chlorine concentrations were 1.45 and 1.61 mg/l respectively. (Treated water samples are taken from contact tank 1, whereas finished water samples are taken after contact tank 4.) Generally, the bulk of measured chlorine was free chlorine. The average total chlorine concentration for the concentrated hypochlorite (ClorTec out) stream was 8.0 ± a standard deviation of 1.5 g/l, which is equal to the target production of 0.8 percent.

Potable Water, Salt, and Power Consumption

The ClorTec T-12 unit used 4.11 lb of salt and 15 gallons of potable water to produce 1 lb of chlorine. The power consumption was 3.5 kWh per lb of chlorine.

Microbiological Contaminant Inactivation

Prior to the bacterial challenge test, a tracer test was conducted on March 18 to establish the precise hydraulic retention time (HRT). According to this study, the volumetric capacity of the system was 850 gallons (3,218 liters) at a flow rate of 23 gpm or 5,223 liters per hour (l/h). The actual experimentally measured HRT was 34.1 minutes, whereas the theoretical HRT was 37 minutes.

Two challenge tests were conducted to assess the disinfection capabilities of the ClorTec T-12 system on *P. aeruginosa*. The first challenge test was performed on March 21. Due to unexpected high turbidity of the water, the test did not result in representative bacterial enumeration data. The test was repeated on May 3. Enumerations for the five positive control samples demonstrate that *P. aeruginosa* was recovered at an average concentration of 2.3×10^5 CFUs/100 ml. Enumeration for the eight valid treated samples indicated a survival of 12 CFUs/100 ml using worst-case approximations. The log reduction in bacteria acquired by inputting eight data points was 4.3.

Finished Water Quality

The average raw water pH was 7.06 ± 0.13. The ClorTec T-12 unit had a slight increasing effect on pH, which was to be expected because the hypochlorite is a base. On average, the pH of the raw water was raised by 0.33 due to hypochlorite addition. The alkalinity for the raw water was 14 ± 2.3 mg/l, whereas the alkalinity for the finished water was 17 ± 3.8 mg/l, which is what would be expected as a result of the hypochlorite dosage. The average turbidity of the raw and finished water was 9.26 and 10.76 NTU respectively.

The hypochlorite system had no apparent effect on UVA, color, iron, manganese, or TOC, because raw and finished water values are of the same magnitude. TDS values increased as a result of chlorine dosage, which was to be expected. The raw water TDS was 37.7 ± 3.2 mg/l and the finished water TDS was 47.0 ± 5.3 mg/l, thus there was an increase of approximately 9 mg/l. As far as chlorine compounds[1], the ClorTec T-12 system increases the average chloride concentration by approximately 4 mg/l (equal to 113 millimol/l). The increase in average sodium concentration was approximately 3.8 mg/l (equal to 165 millimol/l). Chlorite samples were below the detection limit for both raw water and finished water. The finished water did contain chlorate in a concentration of approximately 0.012 mg/l.

The ClorTec system performed well in eliminating coliforms. For all test days, total microfiltered coliforms were reduced from an average of 400 colony forming units (cfu)/ml to below 20 cfu/ml and the calculated log inactivation varied between 0.8 and 1.9. On March 10, no chlorine was dosed and the coliform spike in the finished water reflects this. Also on March 20, coliforms were detected in the finished water. This was the day of the storm that caused a spike in the turbidity and it may be that the debris in the raw water had a diminishing effect on the residual chlorine. The ClorTec system was effective in reducing HPC, although the value of zero was only reached on one day. The system did not perform well on March 10 and 20, due to a storm that adversely affected raw water parameters.

Halogenated byproducts were also analyzed as part of the ETV test project. In the finished water, dichloroacetic acid was 14-17 µg/l and trichloroacetic acid was 10-13 µg/l. Also approximately 7 µg/l chloroform was found in the finished water.

[1] Chloride = Cl^-; chlorate = ClO_3^-; chlorite = ClO_2^-; hypochlorite = ClO^-.

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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 # 01/21/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)