THE ENVIRONMENTAL TECHNOLOGY VERIFICATION
PROGRAM

U.S. Environmental
Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**BIOLOGICAL WASTEWATER TREATMENT – NITRIFICATION AND DENITRIFICATION FOR NITROGEN REDUCTION**
APPLICATION:	**REDUCTION OF NITROGEN IN DOMESTIC WASTEWATER FROM INDIVIDUAL RESIDENTIAL HOMES**
TECHNOLOGY NAME:	**WATERLOO BIOFILTER® MODEL 4-BEDROOM**
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NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of a fixed film trickling filter biological treatment system for nitrogen removal for residential applications. This verification statement provides a summary of the test results for the Waterloo Biofilter Systems, Inc. Waterloo Biofilter® Model 4-Bedroom system. The Barnstable County (Massachusetts) Department of Health and the Environment (BCDHE) performed the verification testing.

The U.S. Environmental Protection Agency (EPA) created the Environmental Technology Verification (ETV) Program to facilitate 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, stakeholder groups consisting of buyers, vendor organizations, and permitters, and 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 verifiable quality are generated and that the results are defensible.

ABSTRACT

Verification testing of the Waterloo Biofilter Systems (WBS), Inc. Waterloo Biofilter® Model 4-Bedroom system was conducted over a thirteen month period at the Massachusetts Alternative Septic System Test Center (MASSTC) located at Otis Air National Guard Base in Bourne, Massachusetts. Sanitary sewerage from the base residential housing was used for the testing. An eight-week startup period preceded the verification test to provide time for the development of an acclimated biological growth in the Waterloo® system. The verification test included monthly sampling of the influent and effluent wastewater, and five test sequences designed to test the unit response to differing load conditions and power failure. The Waterloo® system proved capable of removing nitrogen from the wastewater. The influent total nitrogen (TN), as measured by TKN, averaged 37 mg/L with a median of 37 mg/L. The effluent TN (TKN plus nitrite/nitrate) concentration averaged 14 mg/L over the verification period, with a median concentration of 13 mg/L, which included an average TKN concentration of 3.7 mg/L and a median concentration of 1.6 mg/L. The system operating conditions (on-demand pump and float settings) remained constant during the test. Routine maintenance and system checks were performed for most of the test, except when media (foam cubes) was added after four months of operation. Adding media may be part of on-going maintenance, especially in the first few months according to the WBS Design, Installation, and Service Manual.

TECHNOLOGY DESCRIPTION

The Waterloo Biofilter® Model 4-Bedroom system is a two stage treatment technology, based on a fixed film trickling filter, using patented foam cubes to achieve treatment. The first stage of treatment occurs in the primary tank (normally a 1,500 gallon two compartment septic tank, a single compartment tank was used for the test) in which the solids are settled and partially digested. The second stage, the Biofilter® unit, is a separate system that provides secondary wastewater treatment. Microorganisms present in the wastewater attach to the Waterloo® patented foam media, and use the nutrients and organic materials provided by the constant supply of fresh wastewater to form new cell mass. The system does not have a fan, as passive aeration to support the microorganisms is provided by openings in the Biofilter® housing and the characteristics of the foam material, allowing air to freely pass through the media.

The Waterloo Biofilter® system is designed to remove total nitrogen from the wastewater by nitrification and denitrification. Nitrification occurs in the aerobic Biofilter® unit, where ammonia nitrogen is converted to nitrite and nitrate (predominately nitrate), while denitrification occurs in the anaerobic/anoxic primary tank, where the nitrite/nitrate is converted to nitrogen gas.

The verification testing was performed using a full scale, commercially available unit, which was received as a self-contained system ready for installation. Primary tank effluent flowed by gravity through an effluent screen (Zabel filter) to the pump/collection chamber. A pump in the chamber transferred the primary tank effluent to the Biofilter® spray nozzles located above the foam media, which was contained in baskets. The pump operated as an on-demand system, with a level control switch turning the pump on whenever the pump chamber accumulated six gallons of wastewater. The system had a gravity recycle line that recirculated approximately 50 percent of the treated effluent and any solids (if present) from the underflow of the Biofilter® back to the primary tank. The spray system and media were housed in an above grade, lined wooden enclosure.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site, initially funded by the State of Massachusetts and operated by BCDHE, is located at the Otis Air National Guard Base in Bourne, Massachusetts. The site uses domestic wastewater from the base residential housing and sanitary wastewater from other military buildings in testing. A chamber located in the main interceptor sewer to the base wastewater treatment facility provides a location to obtain untreated wastewater.

The raw wastewater, after passing through a one-inch bar screen, is pumped to a dosing channel at the test site. This channel is equipped with four recirculation pumps that are spaced along the channel length to ensure mixing, such that the wastewater is of similar quality at all locations along the channel. Wastewater is dosed to the test unit using a pump submerged in the dosing channel. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle.

Methods and Procedures

All methods and procedures followed the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction,* dated November 2000. The Biofilter® was installed by a contractor, in conjunction with the BCDHE support team, in May 1999 as part of an earlier test program. The unit was installed in accordance with the Design, Installation, and Service Manual supplied by WBS. In order to prepare for ETV testing, the entire Waterloo® system was emptied of wastewater and cleaned. Solids were removed from the primary tank, and all pumps, lines, and associated equipment were cleaned. The foam filter media was replaced with new media.

In early January 2001, fresh water was added to the unit and the system was cycled for several days to make sure the unit was operating properly, the dosing pumps were calibrated, and the PLC was working properly. An eight-week startup period, following the startup procedures in the WBS Design, Installation, and Service Manual, allowed the biological community to become established and allowed the operating conditions to be monitored. Startup of the cleaned Biofilter® system began on January 15, 2001, when the primary tank was filled with wastewater from the dosing channel. The dosing sequence was then started, with the unit's pump and level switches set in accordance with the WBS Manual.

The system was monitored during the startup period, including visual observation, routine calibration of the dosing system, and collection of influent and effluent samples. Six sets of samples were collected for analysis. Influent samples were analyzed for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS. Effluent samples were analyzed for pH, alkalinity, temperature, $CBOD_5$, TKN, NH_3, TSS, dissolved oxygen, NO_2, and NO_3.

The verification test consisted of a thirteen-month test period, incorporating five sequences with varying stress conditions simulating real household conditions. The five stress sequences were performed at two-month intervals, and included Washday, Working Parent, Low Load, Power/Equipment Failure, and Vacation test sequences. Monitoring for nitrogen reduction was accomplished by measurement of nitrogen species (TKN, NH_3, NO_2, NO_3). Biochemical oxygen demand (BOD_5) and carbonaceous biochemical oxygen demand ($CBOD_5$) and other basic parameters (pH, alkalinity, TSS, temperature) were monitored to provide information on overall system treatment performance. Operational characteristics, such as electric use, residuals generation, labor to perform maintenance, maintenance tasks, durability of the hardware, and noise and odor production, were also monitored.

The Biofilter® system has a design capacity of 440 gallons per day. The verification test was designed to load the system at design capacity (± 10 percent) for the entire thirteen-month test, except during the Low Load and Vacation stress tests. The Biofilter® system was dosed 15 times per day with approximately 29-30 gallons of wastewater per dose. The unit received five doses in the morning, four doses mid-day, and six doses in the evening. The dosing volume was controlled by adjusting the pump run time for each cycle, based on twice weekly pump calibrations.

The sampling schedule included collection of twenty-four hour flow weighted composite samples of the influent and effluent wastewater once per month under normal operating conditions. Stress test periods were sampled on a more intense basis with six to eight composite samples being collected during and following each stress test period. Five consecutive days of sampling occurred in the twelfth month of the verification test. All composite samples were collected using automatic samplers located at the dosing channel (influent sample) and at the discharge of the Biofilter® unit. Grab samples were collected on each sampling day to monitor the system pH, dissolved oxygen, and temperature.

All samples were cooled during sample collection, preserved, if appropriate, and transported to the laboratory. All analyses were in accordance with EPA approved methods or Standard Methods. An established QA/QC program was used to monitor field sampling and laboratory analytical procedures. QA/QC requirements included field duplicates, laboratory duplicates and spiked samples, and appropriate equipment/instrumentation calibration procedures. Details on all analytical methods and QA/QC procedures are provided in the full Verification Report.

PERFORMANCE VERIFICATION

Overview

Evaluation of the Waterloo Biofilter® Model 4-Bedroom system at MASSTC began on January 15, 2001, when the Biofilter® pump was activated, and the initial dosing cycles activated. Flow was set at 440 gpd, resulting in 15 doses per day with a target of 29.33 gallons per dose. Six samples of the influent and effluent were collected during the startup period, which continued until March 13, 2001. Verification testing began at that time and continued for 13 months until April 17, 2002. The extra month of dosing and sampling (13 months versus the planned 12 months) was added to the test to obtain data on the system response as the temperatures began to rise in the spring. During the verification test, 53 sets of samples of the influent and effluent were collected to determine the system performance.

Startup

Overall, the unit started up with no difficulty. The startup instructions in the Manual were easy to follow and provided the necessary instructions to get the unit up and operating. No changes were made to the unit during the startup period, and no special maintenance was required. Regular observation showed that biological growth was established on the media during the startup period.

The Biofilter® system performance for $CBOD_5$, TSS, and TN appeared good during the first three weeks of operation, but did not continue to improve over the next five weeks. Effluent $CBOD_5$ varied between 23 and 66 mg/L, with the higher value at the end of the startup period. There was some initial indication that TN removal was occurring, with effluent concentrations of 18 to 31 mg/L during the first three weeks, compared with influent concentrations of 34 to 41 mg/L. However, after eight weeks it did not appear that the nitrifying organisms had established themselves in the system, with low wastewater and ambient temperatures considered the primary reasons for the slow trend toward improved reduction in both $CBOD_5$ and TN. The temperature of the effluent wastewater was about 4 ^{o}C when the unit was started and remained in the 5 to 8 ^{o}C range through March 13. After startup, and early in the verification test in late April, it was discovered that the foam media had settled and short-circuiting was occurring in both media baskets. Foam media was added to the unit (a simple process) in accordance with the WBS instructions. The WBS maintenance recommendations and checklist include a regular check of the foam media and the addition of media, if needed.

Verification Test Results

The daily dosing schedule was designed for 15 doses to be applied every day, except during the Low Load (September 2001) and Vacation stress (February 2002) periods. In September, it was discovered that only 14 doses were being delivered because of a timing issue with the PLC. The issue was resolved and 15 doses were delivered for the last eight months of the test. Volume per dose and total daily volume varied only slightly during the test period. The daily volume, averaged on a monthly basis, ranged from 401 to 444 gallons per day. This was within the range allowed in the protocol for the 440 gallons per day design capacity.

The sampling program emphasizes sampling during and following the major stress periods. This results in a large number of samples being clustered during five periods, with the remaining samples spread over the remaining months (monthly sampling). Therefore, impacts of a stress test or an upset condition occurring during concentrated sampling periods can have an impact on the calculation of average values. Both average and median results are presented, as the median values compared to average values can help in analyzing these impacts. In the case of the Biofilter® results, the median concentrations are somewhat lower than the average concentrations due to an upset condition following the Vacation stress test.

The TSS and BOD_5/$CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1. The influent wastewater had an average BOD_5 of 210 mg/L and a median BOD_5 of 200 mg/L. The TSS in the influent averaged 150 mg/L and had a median concentration of 130 mg/L. The Biofilter® effluent showed an average $CBOD_5$ of 10 mg/L with a median $CBOD_5$ of 7.4 mg/L. The average TSS in the effluent was 7 mg/L and the median TSS was 5 mg/L. $CBOD_5$ concentrations in the effluent typically ranged from 1 to 10 mg/L, and TSS ranged from 1 to 20 mg/L.

Table 1. BOD_5/$CBOD_5$ and TSS Data Summary

	BOD_5 Influent (mg/L)	$CBOD_5$ Effluent (mg/L)	Percent Removal	TSS Influent (mg/L)	TSS Effluent (mg/L)	TSS Percent Removal
Average	210	10	95	150	7	95
Median	200	7.4	96	130	5	97
Maximum	370	43	99	340	55	>99
Minimum	67	1.0	71	61	<1	51
Std. Dev.	73	9.0	6.0	66	8	8

NOTE**:** The data in Table 1 are based on 53 samples.

The nitrogen results for the verification test, including all stress test periods, are shown in Table 2. The influent wastewater had an average TKN concentration of 37 mg/L, with a median value of 37 mg/L, and an average ammonia nitrogen concentration of 23 mg/L, with a median of 23 mg/L. Average TN concentration in the influent was 37 mg/L (median of 37 mg/L), based on the assumption that the nitrite and nitrate concentrations in the influent were negligible. The Biofilter® effluent had an average TKN concentration of 3.7 mg/L and a median concentration of 1.6 mg/L. The average NH_3-N concentration in the effluent was 2.4 mg/L and the median value was 0.7 mg/L. The nitrite concentration in the effluent was low, averaging 0.19 mg/L. Effluent nitrate concentrations averaged 10 mg/L with a median of 10 mg/L. Total nitrogen was determined by adding the daily concentrations of the TKN (organic plus ammonia nitrogen), nitrite, and nitrate. Average TN in the Biofilter® effluent was 14 mg/L (median 13 mg/L) for the thirteen month verification period. The Biofilter® system averaged a 62 percent reduction of TN for the entire test, with a median removal of 65 percent.

Table 2. Nitrogen Data Summary

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L)	Nitrite (mg/L)	Temperature (ºC)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Influent
Average	37	3.7	23	2.4	37	14	10	0.19	15
Median	37	1.6	23	0.7	37	13	10	0.14	15
Maximum	45	31	29	24	45	45	33	0.84	24
Minimum	24	<0.5	18	<0.2	24	6.8	0.6	<0.05	5.2
Std. Dev.	4.1	5.5	2.4	4.0	4.2	6.0	5.0	0.20	5.9

NOTE: The data in Table 2 are based on 53 samples, except for Temperature, which is based on 51 samples.

Verification Test Discussion

In late March and early April 2001, when temperatures began to increase, there was evidence of a more established biological population on the foam media. In late April, when it was discovered that the foam media had settled and wastewater was short-circuiting through the media, media was added to the unit. With the increasing temperatures and the elimination of the short-circuiting, the nitrifying population clearly became established, as indicated by the decrease in the TKN and ammonia concentrations in the effluent, and an increase in effluent nitrate concentration. TN concentration in the effluent began to decrease indicating that the denitrification population was becoming established in the primary tank. During May and June, the TN reduction was typically in 65 to 80 percent range. The Washday stress test performed in May 2001 did not appear to have a negative impact on nitrogen reduction. Likewise, in July 2001, the Working Parent stress test was performed and the performance of the unit remained steady during and following the stress period. The Biofilter® system continued to reduce the total nitrogen concentration on a steady basis (60-80 percent reduction) until February 2002. During this period, which included the Low Load and Power/Equipment Failure stress sequences, nitrification was very effective, with ammonia nitrogen and TKN being reduced to less than 1 mg/L. The denitrification process during this period was effective in removing nitrate produced during the nitrification step, but not as efficient or complete as the nitrifying step. The total nitrogen in the effluent ranged from 6.2 to 13 mg/L during the August to January period.

The Vacation stress test was started on February 4 and was completed on February 13, 2002. The sample taken before the stress test showed some signs that the denitrification process was slowing, while the nitrification process, as measured by TKN (1.6 mg/L) and ammonia (1.5 mg/L), was still consistent. Effluent $CBOD_5$ and TSS concentrations continued to be low, with values of 4.4 and 8 mg/L, respectively. On the first day after the Vacation stress test ended, the effluent nitrate value jumped to 33 mg/L, the ammonia level increased to 10 mg/L, total nitrogen went to 45 mg/L, and $CBOD_5$ and TSS increased. It would appear that both the nitrification and denitrification processes were impacted during this time by the lack of wastewater application to the media (no flow for eight days). The use of the "on-demand" pumping approach results in no application of wastewater to support the biological population on the Biofilter® when there is no flow to the system. The timing of the Vacation stress test also coincided with the coldest time of the year, with the temperature of the effluent dropping to 5 ^{o}C from 7 ^{o}C on first day after the stress period ended.

Performance began to improve almost immediately after the flow returned to normal conditions. In general, the effluent nitrogen concentrations were nearly back to pre-stress levels within one to two weeks of the resumption of dosing. Likewise, $CBOD_5$ and TSS concentrations returned to levels close to those prior to the stress. The overall performance of the system was slightly lower during the weeks following the Vacation stress test, as compared to the October to December 2001 period, showing effluent TN concentrations of 15 to 17 mg/L versus 9 to 11 mg/L.

The last sample collected in April 2002 indicated that the both the nitrifying and denitrifying processes had recovered, and the TN concentration in the effluent was 11 mg/L. TKN and ammonia concentrations were 3.5 mg/L and 1.1 mg/L, respectively, only slightly higher than the less than 1 mg/L levels achieved in previous summer and fall periods. The nitrate concentration was 7.1 mg/L, which was actually on the low side of the levels found in the summer and fall. The verification test provided a sufficiently long test period to collect data that included both a long run of steady performance by the Biofilter® system and a period of an apparent upset following the Vacation stress test. While the system was apparently impacted by the Vacation stress test and probably by the low temperatures, recovery was rapid with TN removal on the order of 60 percent (55-70 percent measured) being established within two to four weeks.

Operation and Maintenance Results

Noise levels associated with mechanical equipment were measured once during the verification period using a decibel meter. Measurements were made one meter from the unit, and one and a half meters above the ground, at 90° intervals in four (4) directions. The average decibel level was 47.6, with a minimum of 44.8 and maximum of 50.5. The background level was 37.7 decibels.

Odor observations were made monthly for the last eight months of the verification test. The observations were qualitative based on odor strength (intensity) and type (attribute). Observations were made during periods of low wind velocity (<10 knots), at a distance of three feet from the treatment unit, and recorded at 90° intervals in four directions. There were no discernible odors during any of the observation periods. The unit has two charcoal filters to help control odors. No maintenance was required on these units during the test.

Electrical use was monitored by a dedicated electric meter serving the Biofilter® system. The average electrical use was 1.3 kW/day with a maximum of 2.5 kW/day. The Biofilter® system does not require or use any chemical addition as part of the normal operation of the unit.

During the test, no problems were encountered with the operation of the system. The screen on the outlet from the septic tank (influent to the pump chamber) required periodic cleaning. During the test, the filter was cleaned after eight months (two months of startup and six months of testing) in accordance with the WBS recommendation. The distribution plates near the nozzles were cleaned when the outlet screen was cleaned to help maintain a uniform spray pattern over the media. No changes or adjustments were needed to the float switches or the pump. Media was added one time after four months of operation. No additional media was added for the duration of the test.

The treatment unit itself proved durable for the duration of the test and appears to generally be a durable design. The piping is standard PVC that is appropriate for the applications. Pump and level switch life is always difficult to estimate, but the equipment used is made for wastewater applications by a reputable and known manufacturer. The lined wooden box used as housing did attract ants that bore through the wood. This was solved by liberal application of borax in the area of the unit.

WBS recommends a minimum of once per year maintenance checks, and the sample maintenance contract is designed for twice per year maintenance of the unit. Based on fifteen months of observation, BCHDE staff believes that quarterly maintenance checks would seem appropriate to ensure the system is in good operating condition. It is possible that a knowledgeable homeowner could perform certain routine quarterly checks, after the system has been in operation for several months, and routinely checked by a trained operator. Homeowner involvement in routine cleaning and system checks might be able to reduce the scheduled contractor maintenance to a semi-annual frequency. Maintenance activities should include checking the filter media for subsidence, adding media if needed, checking the nozzles and distribution plates for clogging and cleaning if needed, and checking the pump, alarms, and floats for proper operation. The primary tank should be checked for sludge depth and the primary tank effluent screen should be cleaned. Replacement of the activated carbon located on the air openings should be part of routine maintenance, but the carbon life may be long, and replacement only needed if odor becomes a problem.

Quality Assurance/Quality Control

QA audits of the MASSTC and BCDHE laboratory were completed by NSF International during testing. NSF personnel completed a technical systems audit to assure the testing was in compliance with the test plan, a performance evaluation audit to assure that the measurement systems employed by MASSTC and the BCDHE laboratory were adequate to produce reliable data, and a data quality audit of at least 10 percent of the test data to assure that the reported data represented the data generated during the testing. In addition to quality assurance audits performed by NSF International, EPA QA personnel conducted a quality systems audit of NSF International's QA Management Program, and accompanied NSF during audits of the MASSTC and BCDHE facilities.

Original signed by *Hugh W. McKinnon*	*5/30/03*	*Original signed by* *Gordon E. Bellen*	*6/3/03*
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Availability of Supporting Documents

Copies of the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction*, dated November 2000, the Verification Statement, and the Verification Report are available from the following sources:

1. ETV Water Quality Protection 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)

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

EPA's Office of Wastewater Management has published a number of documents to assist purchasers, community planners and regulators in the proper selection, operation and management of onsite wastewater treatment systems. Two relevant documents and their sources are:

1. *Handbook for Management of Onsite and Clustered Decentralized Wastewater Treatment Systems* http://www.epa.gov/owm/onsite
2. *Onsite Wastewater Treatment Systems Manual* http://www.epa/gov/owm/mtb/decent/toolbox.htm