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:	**SEPTITECH® MODEL 400 SYSTEM**
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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 SeptiTech® Model 400 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 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 SeptiTech® Model 400 System was conducted over a twelve 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 SeptiTech® 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 SeptiTech® System proved capable of removing nitrogen from the wastewater. The influent total nitrogen (TN), as measured by TKN, averaged 39 mg/L, with a median of 39 mg/L. The effluent TN (TKN plus nitrite/nitrate) concentration averaged 14 mg/L over the verification period, with a median concentration of 14 mg/L, which included an average TKN concentration of 6.8 mg/L and a median concentration of 5.7 mg/L. The system operating conditions (pumps and float settings) were controlled by a programmable logic controller (PLC), which was adjusted at the end of the startup period and then remained constant during the test. All mechanical equipment, pumps, level switches, alarms, etc. operated properly throughout the test. There were two service calls during the test. During the first call, eight months into the test, the system was cleaned and the PLC reset. The second call for a high water alarm determined that the effluent pipe had collapsed due to an installation problem not related to the system itself. After a lightning strike at the test site, the modem for the PLC was replaced.

TECHNOLOGY DESCRIPTION

The following description of the SeptiTech System was provided by the vendor and does not represent verified information.

The SeptiTech® System is a two stage treatment technology, based on a fixed film trickling filter, using a patented highly permeable hydrophobic media. The first stage of treatment occurs in the primary tank (for this test a 1,500 gallon two compartment septic tank, standard unit uses a 1,000 gallon tank) in which the solids are settled and partially digested. The second stage of the SeptiTech® System, is a processor that provides secondary wastewater treatment. Microorganisms present in the wastewater grow within the media, using the nutrients and organic materials provided by the constant supply of fresh wastewater to form new cell mass. Air is drawn into the system via an air intake pipe at the top of the SeptiTech System. Venturis located in the sprinkler head distribution piping aerate the wastewater sprayed onto the media. The system does not have a fan or compressor.

The SeptiTech® System is designed to remove total nitrogen from the wastewater by nitrification and denitrification. Nitrification occurs in the second stage of the SeptiTech System, where ammonia nitrogen is converted to nitrite and nitrate (predominately nitrate), while denitrification occurs in the anaerobic/anoxic primary tank. According to SeptiTech, denitrification also occurs in the BioPack SF 30 Random Stack Media used in the system tested, which floats in the reservoir below the aerobic media.

The verification testing was performed using a full scale, commercially available unit, which was received as a self-contained system ready for installation. Wastewater from the septic (primary) tank flows by gravity to the Processor reservoir section, located below the filter media. There are four pumps located in the reservoir. One pump recirculates wastewater from the reservoir to the top of the Processor, where the wastewater is sprayed over the filter media. The second and third pumps are used to return wastewater and solids from the reservoir back to the septic tank. The fourth pump is for the discharge of treated wastewater to the disposal location. The SeptiTech® Model 400 System is supplied with a PLC, which controls the frequency and duration of pump operation, as well as all alarm functions, data collection, and communication packages.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site 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

The SeptiTech® System was installed by a contractor, with assistance from the BCDHE support team, in June 2001**.** The unit was installed according to installation instructions supplied by SeptiTech, Inc. On June 14, 2001, the primary tank was filled with wastewater and the dosing sequence began. An eight-week startup period allowed the biological community to become established and the operating conditions to be monitored. The standard dosing sequence was used for the entire startup period.

The system was monitored during the startup period, including visual observation of the system, routine calibration of the dosing system, and collection of influent and effluent samples. Three 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 twelve-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 performance. Operational characteristics, such as electric use, residuals generation, labor to perform maintenance, maintenance tasks, durability of the hardware, noise and odor production, were also monitored.

The SeptiTech® Model 400 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 twelve-month test, except during the low load and vacation stress tests. The SeptiTech® 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. Dosing volume was controlled by adjusting the pump run time for each cycle, based on twice weekly pump calibrations. Volume per dose and total daily volume varied only slightly during the test period. The daily volume, averaged on a monthly basis, ranged from 432 to 449 gallons per day. This was within the range allowed in the protocol for the 440 gallons per day design capacity.

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 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 performed according to *"Standard Methods for the Examination of Water and Wastewater,"* 19th Edition, 1998. Washington, D.C. or other EPA approved methods. An established quality assurance/quality control (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 SeptiTech® Model 400 System at MASSTC began on June 14, 2001, when the system pumps were activated, and the wastewater dosing started. Three samples of the influent and effluent were collected during the startup period, which continued until August 13, 2001. Verification testing began at that time and continued for twelve months, until August 12, 2002. During the verification test, 54 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 installation instructions were easy to follow and installation proceeded without difficulty. SeptiTech representatives setup the PLC, which controlled all recirculation, recycle, and discharge pump times. No changes were made to the unit during the startup period, and no special maintenance was required.

The SeptiTech® System removed $CBOD_5$ and TSS after the first three weeks of operation, and continued to improve over the next five weeks. At the end of the eight week startup, effluent $CBOD_5$ was <2.0 mg/L and TSS was 2 mg/L. The effluent TN concentration dropped from 24 mg/L after three weeks of operation to 8.5 mg/L at the end of the startup period. Influent TN concentration ranged from 30 to 42 mg/L during this time. Both the nitrification and denitrification processes were established as shown by the effluent TKN and nitrate concentrations of 2.3 mg/L and 6.0 mg/L, respectively. During the startup period, ten percent of the treated wastewater was being recycled to the septic tank. Shortly after the end of the startup, SeptiTech changed this recycle ratio to twenty percent by adjusting the pump rates in the PLC. The discharge pump rate was also adjusted to account for daily dosing of the system at full design flow. No other changes were made to the system.

Verification Test Results

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). Both average (mean) and median results are presented, as the median values compared to average values can help in analyzing the impacts of the stress periods. In the case of the SeptiTech® System results, the median concentrations for ammonia nitrogen are somewhat lower than the average concentrations due to reduced nitrification efficiency from February through May, which impacted the twelve month average concentration.

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 250 mg/L and a median BOD_5 of 240 mg/L. The TSS in the influent averaged 150 mg/L and had a median concentration of 140 mg/L. The effluent showed an average $CBOD_5$ of 5.4 mg/L with a median $CBOD_5$ of 4.7 mg/L. The average TSS in the effluent was 3 mg/L and the median TSS was 2 mg/L. $CBOD_5$ concentrations in the effluent typically ranged from 1 to 10 mg/L, and TSS ranged from 1 to 10 mg/L, except for two sampling days during the twelve month verification test.

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)	Percent Removal
Average	250	5.4	98	150	3	98
Median	240	4.7	98	140	2	98
Maximum	380	22	>99	280	13	>99
Minimum	140	1.3	93	73	1	90
Std. Dev.	66	4.0	1.3	46	3	2.1

Note: Data in Table 1 are based on 54 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 39 mg/L, with a median value of 39 mg/L, and an average ammonia nitrogen concentration of 24 mg/L, with a median of 24 mg/L. The average TN concentration in the influent was 39 mg/L (median of 39 mg/L), based on the assumption that the nitrite and nitrate concentrations in the influent were negligible. The effluent had an average TKN concentration of 6.8 mg/L and a median concentration of 5.7 mg/L. The average NH_3-N concentration in the effluent was 5.1 mg/L and the median value was 2.4 mg/L. The nitrite concentration in the effluent averaged 0.32 mg/L. Effluent nitrate concentrations averaged 6.7 mg/L with a median of 7.0 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 effluent was 14 mg/L (median 14 mg/L) for the twelve month verification period. The SeptiTech® System averaged a 64 percent reduction of TN for the entire test, with a median removal of 64 percent.

Table 2. Nitrogen Data Summary

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Effluent
Average	39	6.8	24	5.1	39	14	6.7	0.32	16
Median	39	5.7	24	2.4	39	14	7.0	0.31	15
Maximum	69	27	29	20	69	27	15	0.70	28
Minimum	18	0.7	19	0.6	18	7.5	0.3	0.04	5.8
Std. Dev.	6.6	6.3	2.3	5.2	6.6	4.6	4.5	0.10	6.4

Note: The data in Table 2 are based on 54 samples, except for Temperature, which is based on 48 samples.

Verification Test Discussion

By the end of the eight-week startup period and start of the verification test, the system was operating with an acclimated biomass for both nitrification and denitrification. From August to December, the TN reduction was typically in the 61 to 78 percent range with TN effluent concentrations of 8 to 11 mg/L. The washday stress test performed in October 2001 did not appear to have an impact on nitrogen reduction. Likewise, in December 2001, the working parent stress test was performed and the performance of the unit remained steady during and following the stress period. In January and early February, the normal monthly samples showed a decrease in nitrification efficiency as measured by increases in TKN and ammonia in the effluent, to 18 mg/L and 14 mg/L respectively. TN in the effluent increased to 20 mg/L in early February, during a period that corresponded to lower wastewater temperatures and outside air temperatures.

The low load stress test was started on February 18 and was completed on March 10, 2002. During the months of February and March, which included the stress test, the TN concentration varied from 7.5 to 17 mg/L. Nitrification was still occurring, but at lower efficiency than during the previous five months. This also corresponded with the time frame with low effluent temperatures. At the end of the stress test, the system was still reducing TN concentrations. It does not appear that the low load stress test had a direct impact on the system, as the reduced nitrification efficiency started in the four weeks prior to the stress test. The post stress test period from mid-March through May showed consistent results with TN concentrations in the 15 to 18 mg/L range, except for one day at 27 mg/L. The power/equipment stress test was performed from May 6 to 8, 2002, with no apparent change in the effluent quality in the post stress test monitoring period.

A major change in performance occurred in late May or early June. The June 5 sampling showed TN concentrations reduced to 10 mg/L, and both TKN and ammonia concentration in the effluent decreased as well (6.0 mg/L and 3.7 mg/L, respectively). The nitrification process had improved and was reducing the ammonia concentrations to levels similar to the first five months of the test. As the TKN and ammonia levels decreased, the nitrate levels began to increase in the effluent, indicating that while the denitrification process was removing some nitrate, it was not removing the increased concentration produced by the improvement in nitrification.

The vacation stress test started on July 8 and continued through July 16, 2002. During this stress test, there was no wastewater dosed to the system. The TKN and ammonia levels remained low in the post stress monitoring period but the nitrate levels increased from 9 to 15 mg/L. During this period nitrate was the main contributor to the effluent TN concentration, which ranged from 16 to 24 mg/L. It is not clear if the vacation stress test had a direct impact on the denitrification process, as the increasing nitrate levels began to occur when the nitrification process improved prior to the start of the vacation test. It is possible that the nitrate levels would have been higher, even if the stress test was not performed. However, the lack of flow during the vacation stress test reduced the amount of recycle flow from the SeptiTech reservoir to the septic tank. Therefore, there was less nitrified wastewater being recycled, which may have impacted the response time for the denitrifying organisms.

The system performance remained consistent for the duration of the verification test. The TKN and ammonia nitrogen effluent concentrations were consistently low and similar to the first five months of the verification test. The nitrate levels remained in the 13 to 15 mg/L range and the TN concentration in the effluent ranged from 14 to 20 mg/L. Alkalinity concentration in the effluent remained lower at 50 mg/L. It is not clear why the denitrification efficiency was lower throughout the July and August period as compared to the previous August through December period.

Over the twelve-month test, the system did exhibit some instability in the individual nitrogen removal mechanisms, i.e. the nitrification and denitrification processes, particularly during December 2001 to July 2002. These changes could be due to stressors not apparent from the data. Despite these changes, the process continued to remove TN, providing an overall stable effluent quality for TN. The verification test provided a sufficiently long test period to collect data that included both a long run of steady performance by the SeptiTech® System and a period of reduced nitrification and denitrification efficiencies. During the five months following startup, the TN removal was in the 60 to 80 percent range, with effluent concentrations typically in the 8 to 11 mg/L range. The SeptiTech System continued to remove TN in the later periods, even though the nitrification or denitrification processes were not operating as efficiently. During the last six months of the verification test, the TN removal was in the 32 to 82 percent range, with most results in the 50 to 60 percent range. Effluent TN concentrations ranged from 10 to 27 mg/L, with most concentrations in the 15 to 20 mg/L range. The net effect of the lower performance in these later periods increases the average effluent TN concentration for the verification test to 14 mg/L.

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 60.0, with a minimum of 58.9 and maximum of 61.5. 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.

Electrical use was monitored by a dedicated electric meter serving the SeptiTech® System. The average electrical use was 8.4 kW/day. The electrical use included a heater for the PLC, which was located outside at the test site. In normal applications, the PLC is placed in the home and an auxiliary heater is not needed. The SeptiTech® System does not require or use any chemical addition as part of the normal operation of the unit.

During the test, no mechanical problems were encountered with the operation of the system. The system was cleaned after eight months by spraying water over the nozzles and media. This cleaning was performed when a service call was placed to SeptiTech in April 2002, based on site operators observing a lack of sound coming from the unit. During the service call, no problems were found with the unit. The PLC was reset and the system continued in operation. In June 2002, a high water alarm sounded and a call was placed for service. SeptiTech responded the next day and found the discharge pipe had collapsed. In addition, lightning had struck the test site, damaging the modem and causing the PLC to enter a "safe" mode. The discharge pipe was repaired, a new modem installed, and the PLC reset. The discharge pipe failure was apparently due to improper soil preparation and was not related to the system itself. No changes or adjustments were needed to the float switches or pumps after the initial changes following the startup period.

The treatment unit appeared to be of durable design and also proved to be durable during the test. The polyethylene piping used in the system meets the needs of the application. Pump and level switch life is always difficult to estimate, but the equipment used is made for wastewater applications. The only trouble with the PLC was when lightning hit the site, at which time the modem was replaced to reestablish remote communications.

Quality Assurance/Quality Control

NSF International completed QA audits of the MASSTC and BCDHE laboratory 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.

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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