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Environmental Technology Verification Report

Nutrient Reduction in Domestic Wastewater From Individual Residential Homes

SeptiTech, Inc.
SeptiTech® Model 400 System

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

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	**$CBOD_5$**		**TSS**		
	Influent (mg/L)	**Effluent (mg/L)**	**Percent Removal**	**Influent (mg/L)**	**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

The accompanying notice is an integral part of this verification statement.

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.

Original signed by *High W. McKinnon*	*7/23/03*	*Original signed by* *Gordon E. Bellen*	*7/23/03*
Hugh W. McKinnon Director National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency	Date	Gordon E. Bellen Vice President Research NSF International	Date

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report in no way constitutes an NSF Certification of the specific product mentioned herein.

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

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SeptiTech, Inc.
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Prepared for

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Prepared by

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Under a cooperative agreement with the U.S. Environmental Protection Agency

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Notice

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development has financially supported and collaborated with NSF International (NSF) under a Cooperative Agreement. The Water Quality Protection Center, Source Water Protection area, operating under the Environmental Technology Verification (ETV) Program, supported this verification effort. This document has been peer reviewed and reviewed by NSF and EPA and recommended for public release.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Hugh W. McKinnon, Director
National Risk Management Research Laboratory

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Glossary of Terms

Accuracy - a measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction.

Commissioning – the installation of the nutrient reduction technology and start-up of the technology using test site wastewater.

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a qualitative and quantitative term that expresses confidence that all necessary data have been included.

Precision - a measure of the agreement between replicate measurements of the same property made under similar conditions.

Protocol – a written document that clearly states the objectives, goals, scope and procedures for the study. A protocol shall be used for reference during Vendor participation in the verification testing program.

Quality Assurance Project Plan – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project.

Residuals – the waste streams, excluding final effluent, which are retained by or discharged from the technology.

Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point, a process condition, or environmental condition.

Standard Operating Procedure – a written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained.

Technology Panel - a group of individuals established by the Verification Organization with expertise and knowledge in nutrient removal technologies.

Testing Organization – an independent organization qualified by the Verification Organization to conduct studies and testing of nutrient removal technologies in accordance with protocols and test plans.

Vendor – a business that assembles or sells nutrient reduction equipment.

Verification – to establish evidence on the performance of nutrient reduction technologies under specific conditions, following a predetermined study protocol(s) and test plan(s).

Verification Organization – an organization qualified by USEPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

Verification Report – a written document containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results. The Verification Test Plan(s) shall be included as part of this document.

Verification Statement – a document that summarizes the Verification Report and is reviewed and approved by EPA.

Verification Test Plan – A written document prepared to describe the procedures for conducting a test or study according to the verification protocol requirements for the application of nutrient reduction technology at a particular test site. At a minimum, the Verification Test Plan includes detailed instructions for sample and data collection, sample handling and preservation, and quality assurance and quality control requirements relevant to the particular test site.

Abbreviations and Acronyms

ANSI	American National Standards Institute
BDCHE	Barnstable County Department of Health and the Environment
BOD$_5$	Biochemical Oxygen Demand (five day)
CBOD$_5$	Carbonaceous Biochemical Oxygen Demand (five day)
COC	Chain of Custody
DO	Dissolved Oxygen
DQI	data quality indicators
DQO	data quality objectives
ETV	Environmental Technology Verification
GAI	Groundwater Analytical, Inc.
gal	gallons
gpm	gallons per minute
MASSTC	Massachusetts Alternative Septic System Test Center
mg/L	milligrams per liter
mL	milliliters
NIST	National Institute of Standards and Technology
NH$_3$	Ammonia Nitrogen
NO$_2$	Nitrite Nitrogen
NO$_3$	Nitrate Nitrogen
NSF	NSF International
NRMRL	National Risk Management Research Laboratory
O&M	Operation and maintenance
ORD	Office of Research and Development, USEPA
OSHA	Occupational Safety and Health Administration
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
QMP	Quality management plan
RPD	Relative percent difference
SAG	Stakeholders Advisory Group
SOP	Standard operating procedure
SWP	Source Water Protection Area, Water Quality Protection Center
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TO	Testing Organization
EPA	United States Environmental Protection Agency
VO	Verification Organization
VR	Verification Report
VTP	Verification Test Plan
SeptiTech	SeptiTech, Inc.
WQPC	Water Quality Protection Center

Acknowledgments

The Testing Organization (TO), the Barnstable County Department of Health and the Environment, was responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, and data management. Mr. George Heufelder was the Project Manager for the Verification Test.

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Groundwater Analytical, Inc. (GWI)
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Buzzards Bay, MA 02532
(508) 759-4441
Contact: Mr. Eric Jensen

The Manufacturer of the Equipment was:

SeptiTech, Inc.
220 Lewiston Road
Gray, Maine 04039
(207) 657-5252
Contact: Mr. Don Rousseau, Vice President Operations
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The TO wishes to thank NSF International, especially Mr. Thomas Stevens, Project Manager, and Ms. Maren Roush, Project Coordinator, for providing guidance and program management.

1.0 Introduction

1.1 ETV Purpose and Program Operation

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 innovative, 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, consulting engineers, and regulators; 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 (as appropriate) testing, 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 Water Quality Protection Center (WQPC), one of six Centers in the ETV Program. Source Water Protection (SWP) is one of two technical areas within the WQPC. The WQPC-SWP evaluated the performance of the SeptiTech® Model 400 System for the reduction of nitrogen compounds (TKN, NH_3, NO_2, NO_3), present in residential wastewater. SeptiTech, Inc. sells the Model 400 to treat wastewater from single-family homes. Other models of the SeptiTech® System are available for commercial, institutional or similar applications. The Model 400 is designed to work in conjunction with conventional septic tank systems or a SeptiTech provided septic tank, and to provide nitrogen reduction in addition to the removal of organics and solids present in residential wastewater. The Model 400 System is based on trickling filter technology, using a patented highly permeable hydrophobic media. This report provides the verification test results for the SeptiTech® Model 400, in accordance with the *Protocol for the Verification for Residential Wastewater Treatment Technologies for Nutrient Reduction,* November 2000(1).

1.2 Testing Participants and Responsibilities

The ETV testing of the SeptiTech® Model 400 was a cooperative effort between the following participants:

NSF International
Massachusetts Alternative Septic System Test Center
Barnstable County Department of Health and Environment Laboratory
Groundwater Analytical, Inc.
Scherger Associates

1.2.1 NSF International - Verification Organization (VO)

The Water Quality Protection Center of the ETV is administered through a cooperative agreement between EPA and NSF International (NSF). NSF is the verification partner organization (VO) for the WQPC. NSF manages the center, and contracts with the Testing Organization to develop and implement Verification Test Plan (VTP).

NSF's responsibilities as the Verification Organization included:

- Review and comment on the site specific VTP;
- Coordinate with peer-reviewers to review and comment on the VTP;
- Coordinate with the EPA Project Manager and the technology vendor to approve the VTP prior to the initiation of verification testing;
- Review the quality systems of all parties involved with the Testing Organization and, subsequently, qualify the companies making up the Testing Organization;
- Oversee the technology evaluation and associated laboratory testing;
- Carry out an on-site audit of test procedures;
- Oversee the development of a verification report and verification statement;
- Coordinate with EPA to approve the verification report and verification statement; and,
- Provide QA/QC review and support for the TO.

Key contacts at NSF for the Verification Organization are:

Mr. Thomas Stevens, Program Manager
(734) 769-5347 email: stevenst@nsf.org

Ms. Maren Roush, Project Coordinator
(734) 827-6821 email: mroush@nsf.org

NSF International
789 N. Dixboro Road
Ann Arbor, Michigan 48105
(734) 769-8010

1.2.2 U.S. Environmental Protection Agency

EPA's Office of Research and Development, through the Urban Watershed Management Branch, Water Supply and Water Resources Division, National Risk Management Research Laboratory (NRMRL), provides administrative, technical, and quality assurance guidance and oversight on all ETV Water Quality Protection Center activities. The EPA reviews and approves each phase of the verification project. EPA's responsibilities with respect to verification testing include:

- Verification Test Plan review and approval;
- Verification Report review and approval; and,
- Verification Statement review and approval.

The key USEPA contact for this program is:

Mr. Ray Frederick, Project Officer, ETV Water Quality Protection Center
(732)-321-6627 email: frederick.ray@epa.gov

U.S. EPA, NRMRL
Urban Watershed Management Branch
2890 Woodbridge Ave. (MS-104)
Edison, NJ 08837-3679

1.2.3 Testing Organization

The Testing Organization (TO) for the verification testing was the Barnstable County Department of Health and Environment (BCDHE). Mr. George Heufelder of the BCDHE was the project manager. He had the responsibility for the overall development of the Verification Test Plan (VTP), oversight and coordination of all testing activities, and compiling and submitting all of the test information for development of this final report.

Mr. Dale Scherger of Scherger Associates was contracted by NSF to work with BCDHE to prepare the Verification Report (VR) and Verification Statement (VS).

The BCDHE Laboratory and its subcontractor, Groundwater Analytical, Inc. (GAI), provided laboratory services for the testing program and consultation on analytical issues addressed during the verification test period.

The responsibilities of the TO included:

- Prepare the site specific Verification Test Plan (VTP);
- Conduct Verification Testing, according to the VTP;

- Install, operate, and maintain the SeptiTech® Model 400 in accordance with the Vendor's O&M manual(s);
- Control access to the area where verification testing was carried out;
- Maintain safe conditions at the test site for the health and safety of all personnel involved with verification testing;
- Schedule and coordinate all activities of the verification testing participants, including establishing a communication network and providing logistical and technical support on an "as needed" basis;
- Resolve any quality concerns that may be encountered and report all findings to the Verification Organization;
- Manage, evaluate, interpret and report on data generated by verification testing;
- Evaluate and report on the performance of the technology; and,
- If necessary, document changes in plans for testing and analysis, and notify the Verification Organization of any and all such changes before changes are executed.

The key personnel and contacts for the TO are:

Mr. George Heufelder, Project Manager
Barnstable County Department of Health and the Environment
Superior Court House (P.O. Box 427)
Barnstable, MA 02630
(508) 375-6616
Email: gheufeld@capecod.net

Mr. Sean Foss, Facility Operations Manager
Barnstable County Department of Health and the Environment
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Dr. Thomas Bourne, Laboratory Manager
Barnstable County Department of Health and the Environment Laboratory
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Barnstable, MA 02630
(508) 375-6606
Email: bcdhelab@cape.com

Mr. Eric Jensen
Groundwater Analytical, Inc. (GAI)
228 Main St.
Buzzards Bay, MA 02532
(508) 759-4441

Scherger Associates was responsible for:

- Preparation of the Verification Report; and,
- Preparation of the Verification Statement

The key contact at Scherger Associates is:

Mr. Dale A. Scherger
Scherger Associates
3017 Rumsey Drive
Ann Arbor, MI 48105
(734) 213-8150
Email: Daleres@aol.com

1.2.4 Technology Vendor

The nitrogen reduction technology evaluated during this verification test was the SeptiTech® Model 400 System. The vendor was responsible for supplying all of the equipment needed for the test program, and supporting the TO in ensuring that the equipment was properly installed and operated during the verification test. Specific responsibilities of the vendor include:

- Initiate application for ETV testing;
- Provide input regarding the verification testing objectives to be incorporated into the VTP;
- Select the test site;
- Provide complete, field-ready equipment and the operations and maintenance (O&M) manual(s) typically provided with the technology (including instructions on installation, start-up, operation and maintenance) for verification testing;
- Provide any existing relevant performance data for the technology;
- Provide assistance to the Testing Organization on the operation and monitoring of the technology during the verification testing, and logistical and technical support as required;
- Review and approve the site-specific VTP;
- Review and comment on the Verification Report; and,
- Provide funding for verification testing.

The key contact for SeptiTech is:

Mr. Don Rousseau, Vice President Operations
SeptiTech, Inc.
220 Lewiston Road
Gray, Maine 04039
(207) 657-5252
Email: donrousseau@septitech.com

1.2.5 ETV Test Site

The Massachusetts Alternative Septic System Test Center (MASSTC) was the host site for the nitrogen reduction verification test. The MASSTC is located at Otis Air National Guard Base, Bourne, MA. The site was designed as a location to test septic treatment systems and related technologies. A full description of the technology verification test site is provided in Section 3.2 of this report. MASSTC provided the location to install the technology and all of the infrastructure support requirements to collect domestic wastewater, pump the wastewater to the system, operational support, and maintenance support for the test. Key items provided by the test site were:

- Logistical support and reasonable access to the equipment and facilities for sample collection and equipment maintenance;
- Wastewater that is "typical" domestic, relative to key parameters such as BOD_5, TSS, Total Nitrogen, and phosphorus;
- A location for sampling of raw or screened wastewater and a sampling arrangement to collect representative samples;
- Automatic pump systems capable of controlled dosing to the technology being evaluated to simulate a diurnal flow variation and to allow for stress testing;
- Sufficient flow of wastewater to accomplish the required controlled dosing pattern;
- An accessible but secure site to prevent tampering by outside parties; and,
- Wastewater disposal of both the effluent from the testing operation and for any untreated wastewater generated when testing is not occurring.

1.2.6 Technology Panel

Representatives from the Technology Panel assisted the Verification Organization in reviewing and commenting on the Verification Test Plan. The Technology Panel consists of technical experts from the stakeholder group and other volunteer participants with specific knowledge of wastewater treatment processes. A list of current participants is available from NSF.

1.3 Background – Nutrient Reduction

Domestic wastewater contains a number of physical, chemical and bacteriological constituents, which require treatment prior to release to the environment. Various wastewater treatment processes exist which are designed to reduce the level of oxygen demanding materials, suspended solids and pathogenic organisms. Reduction of nutrients, principally nitrogen and phosphorus, has been practiced since the 1960's at centralized wastewater treatment plants where there is a specific need for nutrient reduction to protect receiving water quality and associated beneficial uses of these waters. The primary reasons for nutrient reduction are to protect water quality for drinking water purposes (drinking water standards for nitrite and nitrate have been established), and to reduce the potential for eutrophication in nutrient sensitive surface waters by the reduction of nitrogen and/or phosphorus.

The reduction of nutrients in domestic wastewater discharged through onsite treatment systems from single-family homes, small businesses and similar locations within watersheds is desirable for the same reasons as for large treatment facilities. First, reduction of watershed nitrogen levels help meet drinking-water quality standards for nitrate and nitrite; and second, the reduction of both nitrogen and phosphorus helps protect the water quality of receiving surface and ground waters from eutrophication and the consequent loss in ecological, commercial, recreational and aesthetic uses of these waters.

Several technologies and processes have been demonstrated to be effective in removing nutrients in on-site domestic wastewater. The SeptiTech® Model 400 process is based on the trickling filter biological process for nitrification, and the anoxic conditions in the septic tank for biological denitrification. SeptiTech also adds Biopack SF 30 Random Stack Media, to the underflow of the unit to enhance denitrification. A brief discussion of these processes is given below.

1.3.1 Fixed Film Trickling Filter - Biological Nitrification

The USEPA has published a fact sheet describing the nitrification process in trickling filter systems, *Wastewater Technology Fact Sheet Trickling Filter Nitrification*, USEPA September 2000(2). This fact sheet provided the information presented below. A more comprehensive source of information is the USEPA Manual for Nitrogen Control (EPA/625/R-93/010)(3).

Nitrification is a process carried out by bacterial populations (*Nitrosomonas* and *Nitrobacter)* that oxidize ammonium to nitrate with intermediate formation of nitrite. These organisms are considered autotrophic, because they obtain energy from the oxidation of inorganic nitrogen compounds. The two steps in the nitrification process and their equations are as follows:

1) Ammonia is oxidized to nitrite (NO_2^-) by *Nitrosomonas* bacteria.

$$2\ NH_4^+ + 3\ O_2 = 2\ NO_2^- + 4\ H^+ + 2\ H_2O$$

2) The nitrite is converted to nitrate (NO_3^-) by *Nitrobacter* bacteria.

$$2\ NO_2^- + O_2 = 2\ NO_3^-$$

Since complete nitrification is a sequential reaction, systems must be designed to provide an environment suitable for the growth of both groups of nitrifying bacteria. These two reactions essentially supply the energy needed by nitrifying bacteria for growth. Several major factors influence the kinetics of nitrification, including organic loading, hydraulic loading, temperature, pH, and dissolved oxygen concentration.

1. Organic loading: The efficiency of the nitrification process is affected by the organic loadings. Although the heterotrophic biomass is not essential for nitrifier attachment, the heterotrophs (organisms that use organic carbon for the formation of cell tissue) form biogrowth to which the nitrifiers adhere. The heterotrophic bacteria grow much faster than nitrifiers at high BOD_5 concentrations. As a result, the nitrifiers can be over grown by heterotrophic bacteria, which can cause the nitrification process to cease. Before nitrification can take place, the soluble BOD must be sufficiently reduced to eliminate this competition, generally down to 20-30 mg/L.

2. Hydraulic loading: Wastewater is normally introduced at the top of the attached growth reactor and trickles down through a medium. The value chosen for the minimum hydraulic loading should ensure complete media wetting under all influent conditions. Both hydraulic and organic loadings are parameters that must be considered. The total hydraulic flow to the filter can be controlled to some extent by recirculation of the treated effluent. Recirculation also increases the instantaneous flow at points in the filter and reduces the resistance to mass transfer. This also increases the apparent substrate concentration and the growth and removal rate. Another benefit of recirculation in nitrifying trickling filters is the reduction of the influent BOD_5 concentration, which makes the nitrifiers more competitive. This in turn increases the nitrification efficiency and increases the dissolved oxygen concentration.

3. Temperature: The nitrification process is very dependent on temperature and occurs over a range of approximately 4 to 45 °C (39 to 113 °F). Typically, at temperatures below 10 °C, nitrification rates slow dramatically, and may stop altogether at around 5 °C.

4. pH: The nitrification process produces acid. The acid formation lowers the pH and can cause a reduction in the growth rate of the nitrifying bacteria. The optimum pH for *Nitrosomonas* and *Nitrobacter* is between 7.5 and 8.5. At a pH of 6.0 or less nitrification normally will stop. Approximately 5.9 pounds of alkalinity (as $CaCO_3$) are destroyed per pound of ammonia oxidized to nitrate.

5. Dissolved Oxygen (DO): The concentration of dissolved oxygen affects the rate of nitrifier growth and nitrification in biological waste treatment systems. The DO concentration at which nitrification is limited can be 0.5 to 2.5 mg/L in either suspended

or attached growth systems under steady state conditions, depending on the degree of mass-transport or diffusional resistance and the solids retention time. The maximum nitrifying growth rate is reached at a DO concentration of 2 to 2.5 mg/L. However, it is not necessary to grow at the maximum growth rate to get effective nitrification if there is adequate contact time in the system. As a result there is a broad range of DO values where DO becomes rate limiting. The intrinsic growth rate of *Nitrosomonas* is not limited at DO concentrations above 1.0 mg/L, but DO concentrations greater than 2.0 mg/L may be required in practice. Nitrification consumes large amounts of oxygen with 3.8 pounds of O_2 being used for every pound of ammonia oxidized.

1.3.2 Biological Denitrification

Denitrification is an anoxic process where nitrate serves as the source of oxygen for bacteria and is reduced to nitrogen gas. Denitrifying bacteria are facultative organisms that can use either dissolved oxygen or nitrate as an oxygen source for metabolism and oxidation of organic matter. If both dissolved oxygen and nitrate are present, the bacteria will tend use the dissolved oxygen first. Therefore, it is important to keep dissolved oxygen levels as low as possible.

Another important aspect of the denitrification process is the presence of organic matter to drive the denitrification reaction. Organic matter can be in the form of raw wastewater, methanol, ethanol, or other organic sources. When these sources are not present, the bacteria may depend on internal (endogenous) carbon reserves as organic matter. The endogenous respiration phase can sustain a system for a time, but may not be a consistent enough source of carbon to drive the reaction to completion or to operate at the rates needed to remove the elevated nitrate levels present in nitrified effluent.

The denitrifying reaction using methanol as a carbon source can be represented as follows:

$$6NO_3^- + 5CH_3OH = 5CO_2 + 3N_2 + 7H_2O + 6OH^-$$

Several conditions affect the efficiency of the denitrification process including the anoxic conditions, the temperature, presence of organic matter, and pH.

1. Dissolved oxygen - The level of dissolved oxygen has a direct impact on the denitrifying organisms. As dissolved oxygen increases, denitrification rate decreases. Dissolved oxygen concentrations below 0.3-0.5 mg/L in the anoxic zone are typically needed to achieve efficient denitrification.

2. Temperature affects the growth rate of denitrifying organisms with higher growth rates occurring at higher temperatures. Denitrification normally occurs between 5 and 35 °C (41 to 95 °F). As in the case of nitrification, denitrifying rates drop as temperature falls below 10 °C.

3. Organic matter – The denitrification process requires a source of organic matter. Denitrification rate varies greatly depending upon the source of available carbon. The highest rates are achieved with addition of an easily assimilated carbon source such as

methanol. Somewhat lower denitrification rates are obtained with raw wastewater or primary effluent as the carbon source. The lowest denitrification rates are observed with endogenous decay as the source of carbon.

4. pH and alkalinity – The optimum pH range for most denitrifying systems is 7.0 to 8.5. The process will normally occur in a wider range, pH 6 – 9, but denitrifying rates may be impacted near the extremes of the range. Acclimation of the population can lower the impact of pH on growth rates. An advantage of the denitrification process is the production of alkalinity that helps buffer the decrease in alkalinity in the nitrification process. Approximately 3.6 pounds of alkalinity is produced for each pound of nitrate nitrogen removed.

2.0 Technology Description and Operating Processes

2.1 Technology Description

The SeptiTech® Model 400 System uses a fixed film trickling filter process in conjunction with a conventional septic tank for wastewater treatment. The septic tank provides solid liquid separation and anaerobic/anoxic conditions for denitrification. The trickling filter consists of a bed of patented highly permeable hydrophobic media, to which wastewater is applied and allowed to trickle through, providing aerobic conditions for organic removal and nitrification. The SeptiTech® Model 400 uses a patented polystyrene material as the medium. Microorganisms in the wastewater use the nitrogen and organic materials provided by the constant supply of fresh wastewater to form new cell mass. The open spaces between the media pieces allow air to freely pass through the bed, providing oxygen to support the microorganisms without the use of a fan or compressor.

In the trickling filter, organic material contained in the wastewater is degraded by microorganisms present on or between the media. SeptiTech states that microbes present in the wastewater do not strongly attach to the media, due to the hydrophobic nature of the beads. Rather, the microorganisms are entrained in the wastewater as it flows by gravity through the media. Organic removal ($CBOD_5$) occurs as the wastewater passes through the media into the reservoir below the filter material. Nitrogen compounds, organic nitrogen and ammonia, are converted to nitrite and nitrate as the wastewater passes through the SeptiTech® Model 400 media. A portion of the treated effluent is recycled to the septic tank to enhance the removal of nitrogen by reduction of the nitrate under anoxic conditions in the septic tank. In addition, SeptiTech states that denitrification is enhanced by the addition of Biopack SF 30 Random Stack Media (a different media than used in the bed), which float in the clarifier section below the trickling filter media.

2.2 SeptiTech® Model 400 System Equipment and Process Description

The complete system consists of two stages of treatment. Raw sewage flows into a septic tank, where it undergoes solids separation and initial organics treatment. The septic tank effluent drains by gravity into the reservoir below the trickling filter in the SeptiTech® Model 400 System Processor. The wastewater in the reservoir is pumped to the top of the Processor and sprayed over the media. Air is introduced through venturis in the distribution header for the spay nozzles in the top of the Processor. This oxygenated wastewater maintains aerobic conditions in the filter media. No fan is used to supply air to the unit. The wastewater with entrained microbes passes through the filter and reenters the reservoir. The treated water, mixed with incoming wastewater from the septic tank, is recycled many times per day. A portion of the treated water in the reservoir is pumped back to the septic tank to provide denitrification in the anoxic conditions present in the septic tank. Wastewater pumped back to the septic tank also helps to remove solids that settle in the Processor reservoir. A separate pump transfers treated water from the Processor reservoir through the discharge line for dosing a disposal field or other discharge location, eliminating the need for a separate pump station.

The SeptiTech® Model 400 System Processor unit consists of a 1000 gallon HDPE tank that contains all of the pumps, media, vents, etc. for the unit. The polystyrene media is supported in the upper portion of the tank. The system relies on oxygenated wastewater to supply oxygen to the biomass. Air is supplied through venturis in the distribution header for the spray nozzles in the top of the Processor. The Processor has a reservoir section below the filter media that collects wastewater passing through the media by gravity and receives wastewater from the septic tank system. Whenever the septic tank system receives raw sewage flow from the household, treated septic tank effluent is displaced to the Processor reservoir. 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 recycle wastewater from the reservoir back to the septic tank. The fourth pump is for the discharge of treated wastewater to the disposal field or other disposal location. Each SeptiTech® Model 400 System is supplied with a programmable logic controller (PLC), which controls pump operation, both frequency and duration, as well as all alarm functions, data collection, and communication packages.

The SeptiTech Processor is sized based on the projected design flow, with additional capacity to accommodate surges. The SeptiTech® Model 400 is designed to handle 440 gallons per day, which was the dosing target set for the verification test. Under surge conditions, the PLC senses the increased flow into the system and adjusts the treatment process to gradually accommodate the accumulated flow. If the PLC senses reduced flow, it will slow the system down accordingly. After several days of no flow, the PLC will enter "sleep mode" during which the Processor operates only long enough to maintain the microbial population. Any new wastewater input will start the system automatically. The recirculation system remains in operation continuing to reset as long as wastewater is being discharged from the septic tank to the Processor, or all accumulated surge flow is discharged.

SeptiTech indicates that a key issue in the effectiveness of the system is the hydrophobic nature of the filter material. SeptiTech states that microbes do not strongly attach to this material and thus are present as entrained microorganisms in the wastewater stream. In this suspended state, the microbes use and transform the nutrients and organic materials, provided by the constant supply of fresh wastewater, to form new cell mass. The open spaces in the media allow air to flow freely. Due to the physical nature of the media, the wastewater and microbes also do not wet or strongly adhere, thereby reducing the potential for clogging. SeptiTech states that instead of being stationary on the media, the microbes migrate along with the wastewater and drain into the reservoir. Biomass solids are flushed through media into the reservoir where they are periodically pumped back to the septic tank through the recycle line. The vendor also states that the selected media provides the necessary area to volume ratio to provide effective treatment, and also reduces the clogging problems caused by the attachment of microbes to normal trickling filter media are avoided.

Figures 2-1 and 2-2 show the basic system flow diagram and schematic representation of the SeptiTech® Model 400 System. The system provided for verification testing is designed to handle 440 gpd. Additional detailed information on the unit is presented in the Appendix A, which includes the information SeptiTech provides to engineers, contractors, and homeowners.

The Model 400 System used for verification testing included a 1,500-gallon, two-compartment HDPE septic tank (9’ 5” L, 5’ 9” W, 5’ 11” H), which was baffled to prevent flow from channeling directly through the tank, and to promote settling of solids. The 1,500 gallon tank was used in place of the normally supplied 1,000 gallon tank, because Massachusetts Title 5 requires a minimum capacity in the septic tank of 1,500 gallons. The outlet pipe was set at 60 ¼ inches above the bottom of the tank to provide a water/solids depth of five feet. Septic tank effluent flowed by gravity through a 4-inch Schedule 40 PVC pipe connected to the Processor reservoir. There was no filter in the septic effluent line.

The Processor was a 1000-gallon HDPE tank equipped with the media and all needed pumps, level controllers, switches, and alarms. Wastewater from the septic tank entered the Processor reservoir and mixed with treated water flowing down through the media. Wastewater from the reservoir was pumped to the treatment area (top of the processor) and sprayed over the media using low-pressure nozzles. Outside air was passively drawn into the wastewater flow through a 2-inch Schedule 40 PVC pipe with one end open to the atmosphere. The media used in the unit were polystyrene beads, contained in mesh bags that provided a hydrophobic surface with a high treatment area to volume ratio. The wastewater was recirculated through the filter media over many times per day. The normal cycle includes an active recirculation period, followed by a rest period, a second recirculation period, followed by a rest period, and then a discharge to the leaching field. This cycle is repeated whenever water is present in the reservoir (number of cycles per day is solely dependent in amount of influent flow). Under design flow conditions, 900 to 1000 gallons per hour is sprayed on the media.

The PLC activates the recirculation and discharge pumps through a program that self adjusts these operations, based on actual wastewater flow into the Processor reservoir, as monitored by the PLC. The PLC constantly evaluates the water levels and meters out effluent discharge in equal doses over a 24-hour period. A dosing schedule can be customized to a specific application. During the verification test, the discharge pump was operated for 46 seconds, once per hour, to handle the 440 gallons per day influent dosing rate. The discharge is normally pumped through a 2-inch polyethylene (PE) pipe (160/200 psi) to a disposal field or location. This line was not installed for the test as the discharge flow was routed through the sampling location, and then discharged to the sanitary sewer line at the test site.

A portion of the reservoir wastewater (mixture of septic influent and treated water) is recycled back to the front end of the septic tank, by pumping through 1-inch polyethylene pipe (160/200 psi). The recycle flow carries solids that are present in the Processor back to the septic tank for settling and anaerobic decomposition. The recycle flow also returns wastewater with increased nitrate concentrations (due to nitrification in the Processor) to the septic tank, where denitrification can occur. The anoxic conditions in the septic tank provide an environment conducive to the denitrification process. The recycle flow was set to return 20 percent of the daily flow to the septic tank. The PLC controlled this return flow, which was set to average 88 gallons per day.

Verification testing was conducted on an enhanced SeptiTech System designed for nitrogen removal which uses an additional media (BioPack SF 30 Random Stack Media) in the Processor reservoir to assist denitrification. This additional media is added to the Processor reservoir to provide sites for denitrifying organisms. The media is not fixed in position in the reservoir and is allowed to move as the water levels rise and fall. According to SeptiTech, this approach provides zones of submerged media with the required conditions of temperature, alkalinity, and BOD to promote denitrification. The verification test did not differentiate between denitrification occurring in the septic tank and that occurring in the reservoir. The treated effluent from the reservoir received the benefit of denitrification at both locations in the system.

The SeptiTech® Model 400 System Homeowners Manual (Manual) and general literature provides additional details for the system. A copy of the literature and Manual is presented in Appendix A.

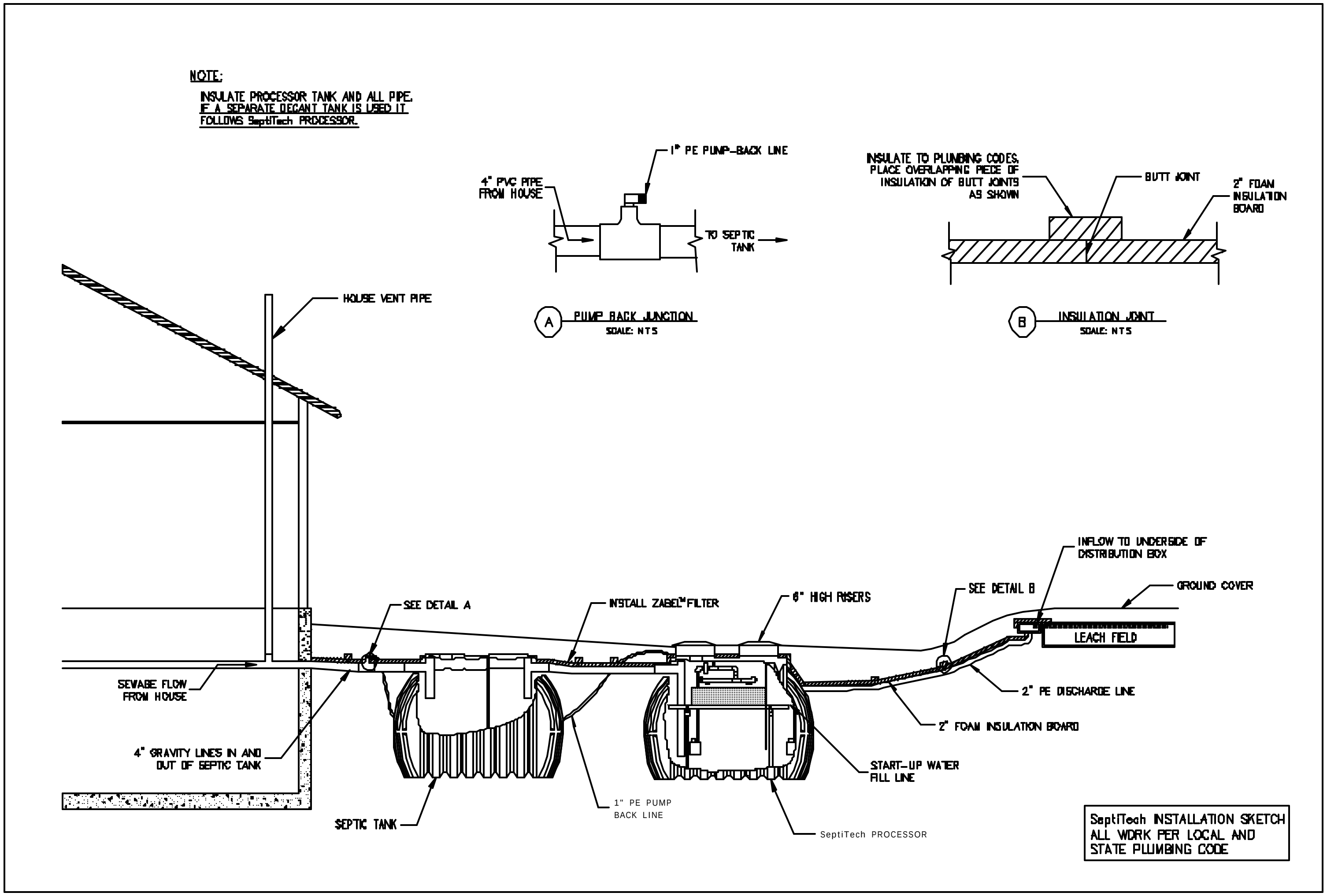

Figure 2-1. SeptiTech® Model 400 General Layout

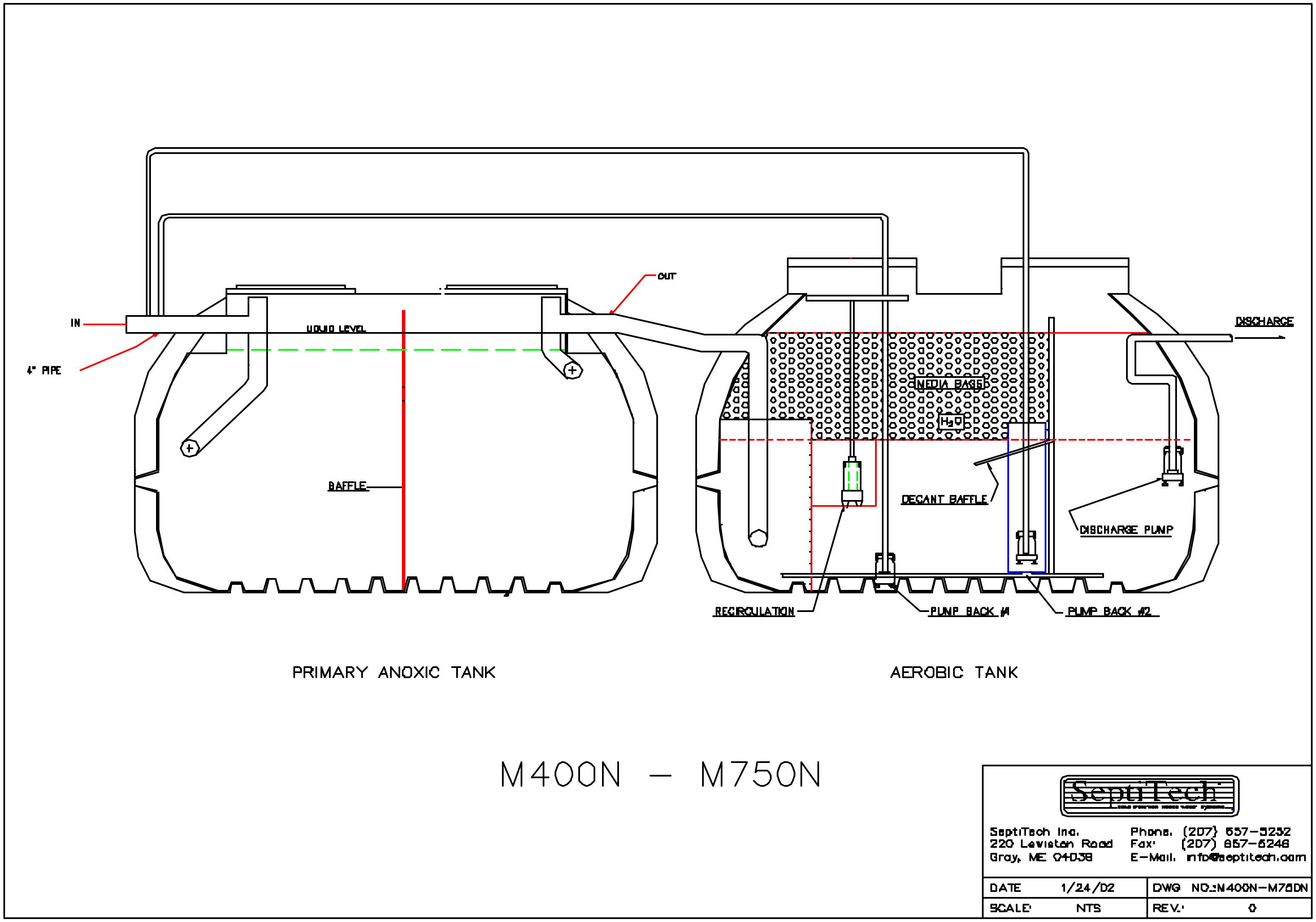

Figure 2-2. SeptiTech® Model 400 Process Diagram

2.3 Equipment Specifications

The specifications for the SeptiTech® Model 400 System are summarized in Table 2-1. All of the piping used in the systems is either Schedule 40 PVC pipe or polyethylene (PE) pipe supplied by the contractor hired for installation.

Table 2-1. SeptiTech® Model 400 Specifications

Item	Quantity
Septic Tank – 1000 gallon HDPE tank when called for in the contract	1
SeptiTech® Processor – all equipment preinstalled 1000 gallon HDPE Tank Polystyrene Media Recirculation pump (1) Discharge pump (1) Recycle pumps (2) Media High and low levels alarm switches Float switches Spray nozzles and manifold	1
Programmable Logic Controller (PLC)	1
Operations and Maintenance Manual	1

2.4 Operation and Maintenance

SeptiTech provides an informational binder to installers, engineers and homeowners with important information about the SeptiTech® Model 400 System. Specific sizing and installation instructions are provided to installers and service companies. A copy of this information is presented in Appendix A. The binder also provides installation and startup information for the unit. SeptiTech requires that a SeptiTech representative be present to startup the unit after installation is complete.

A five page Homeowners Manual is provided by SeptiTech that gives a very basic overview of the process. The Manual states that a homeowner should call SeptiTech if an alarm sounds. They are requested to read the PLC for the error code and then call a main phone number.

A two-year warranty for parts and maintenance is included with the purchase of the unit. This warranty includes an annual inspection and free parts and service labor for the system. SeptiTech recommends that a service contract be arranged to provide periodic maintenance for their units after the warranty period. SeptiTech also offers an optional remote access dial up service to monitor the PLC, which allows SeptiTech to monitor and adjust the system through the PLC interface. The remote access system was installed and operational during the verification test.

Based on the literature provided, it appears that SeptiTech believes that once per year maintenance is sufficient for the unit. SeptiTech claims that the system is operationally maintenance free. Some states require quarterly or semi-annual inspections and sampling of the effluent. A Maintenance Check List (included in Appendix A), provided as part of a sample service contract, was based on quarterly inspections of the system. The checklist includes the following tasks:

- Visually check media and spray pattern
- Run system in maintenance mode:
  - Check recirculation pump
  - Check the recycle/pump back pump
  - Check discharge pump
- Perform maintenance/cleaning tasks
  - Clean spray headers
  - Media check
  - Clean screens
- Check that the pump controller and record readings
  - Days Runtime
  - Hours Runtime
  - Seconds Runtime
- Read Controller version and firmware version
- Return system to “run” mode
- Check air intake muffler for obstruction and proper draw

2.5 Vendor Claims

SeptiTech, Inc. claims the SeptiTech® Model 400 System is designed to consistently remove 95 percent of the organics, as measured by $CBOD_5$ and 95 percent of the total suspended solids (TSS) in the influent wastewater on a year round basis. SeptiTech claims the total nitrogen removal averages 50 percent in systems using the BioPack media in the reservoir, which is the system tested in this verification.

3.0 Methods and Test Procedures

3.1 Verification Test Plan and Procedures

A Verification Test Plan (VTP) was prepared and approved for the verification of the SeptiTech, Inc., SeptiTech® Model 400, and is included in Appendix B. The VTP, *Test Plan for The Massachusetts Alternative Septic System Test Center for the Verification Testing of the SeptiTech, Inc. Nutrient Reduction Technology* (4), August 2001, detailed the procedures and analytical methods to be used to perform the verification test. The VTP was prepared in accordance with the SWP protocol, *Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction* (1), November 2000. The VTP included tasks designed to verify the nitrogen reduction capability of the SeptiTech® Model 400 and to obtain information on the operation and maintenance requirements of the SeptiTech® Model 400. There were two distinct phases of fieldwork to be accomplished as part of the VTP, startup of the unit, and a one-year verification test that included normal dosing and stress conditions. The Protocol requires twelve months of sampling, which was completed between August 2001 and August 2002.

Each of the testing elements, performed during the technology verification, is described in this section. In addition to descriptions of sample collection methods, equipment installation, and equipment operation, this section also describes the analytical protocols. Quality Assurance and Quality Control procedures and data management approach are discussed in detail in the VTP.

3.2 MASSTC Test Site Description

The Massachusetts Alternative Septic System Test Center (MASSTC) was constructed at the Massachusetts Military Reservation, Otis Air National Guard Base, on Cape Cod, by the Buzzards Bay Project National Estuary Program (BBP), a unit of the Massachusetts Office of Coastal Zone Management, in collaboration with Massachusetts Department of Environmental Protection (DEP), Barnstable County Department of Health and the Environment (BCHED), and University of Massachusetts, Dartmouth's School of Marine Science and Technology (SMAST). Completed in 1999, the construction and operation of the facility was initially funded with a grant from EPA with subsequent funding received from the Massachusetts Environmental Trust, the Massachusetts Office of Coastal Zone Management, Massachusetts DEP, and EPA Region I. The facility is operated cooperatively by the BBP, DEP, BCHED and SMAST.

The site is designed to provide domestic wastewater for use in testing various types of residential wastewater treatment systems. The domestic wastewater source is the sanitary sewerage from the base residential housing and other military buildings. The sewer system for the base flows to an on-base wastewater treatment facility. An interceptor chamber, located in the main sewer line to the base wastewater treatment facility was constructed when the MASSTC was built, and provides a location to obtain untreated wastewater. The raw wastewater passes through a bar screen (grate) located ahead of the transfer pump. This bar screen has one inch spacing between the bars to remove large or stringy materials that could clog the pump or lines. Screened raw wastewater is pumped through an underground two-inch line to the dosing channel at the test site. The design of the interceptor chamber provides mixing of the wastewater just ahead of the transfer pump to ensure a well-mixed raw wastewater is obtained for the influent feed at the test site. Wastewater is pumped to the dosing channel at a rate of approximately 29 gallons per minute (gpm) on a continuous basis for 18 hours per day, yielding at total flow of approximately 31,000 gallons per day (gpd). Wastewater enters the dosing channel, an open concrete channel, sixty-five feet long by two feet wide by three feet deep, via two pipes midway in the channel. Approximately 4,000 to 6,000 gallons per day is withdrawn for test purposes in various treatment units. The excess wastewater flows by gravity to the base sanitary sewer and is treated at the base wastewater treatment plant. The dosing channel is equipped with four recirculation pumps. These pumps, spaced along the channel length, keep the wastewater in the channel constantly moving to ensure the suspension of solids, and to ensure that the wastewater is of similar quality at all locations along the channel.

Dosing of wastewater to the test units is accomplished by individual pumps submerged in-line along the dosing channel. The pumps are connected to the treatment technology being tested by underground PVC pipe. A custom designed, programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle. Each technology feed pump can be controlled individually for multiple start and stop times, and for pump run time.

MASSTC maintains a small laboratory at the site to monitor basic wastewater treatment parameters. Temperature, dissolved oxygen, pH, specific conductance, and volumetric measurements are routinely performed to support the test programs at the site. These field parameters were performed at the site during the SeptiTech® System test.

Screened wastewater quality has been monitored as part of several previous test programs, and is within the requirements established in the Protocol for raw wastewater quality. The data are presented in Table 3-1. Influent wastewater monitoring was part of the startup and verification testing, and is described later in this section. Results of all influent monitoring during the verification test are presented in Chapter 4.

Table 3-1. Historical MASSTC Wastewater Data

Parameter	Average (mg/L)	Standard Deviation
BOD_5	180	61
TSS	160	59
Total Nitrogen	34	4.6
Alkalinity	170	28
pH	7.4	0.13

3.3 Installation and Startup Procedures

3.3.1 Introduction

SeptiTech provided installation instructions (included in Appendix A) for the SeptiTech® Model 400 and was present at the site during the installation. The installation instructions are presented in Appendix A. The system delivered by SeptiTech consisted of a two compartment, 1,500 gallon HDPE septic tank, and a complete SeptiTech® Model 400 Processor. This system was installed by a contractor in June 2001 and used for the startup and verification tests for the ETV program.

3.3.2 Objectives

The objectives of the installation and start-up phase of the VTP were to:

- Install the SeptiTech® Model 400 in accordance with the instructions;
- Start-up and test the SeptiTech® Model 400 to ensure all processes were operating properly, the PLC and pumps are set for proper automatic operation, and any leaks that occurred during the installation are eliminated;
- Make any modifications needed to achieve operation; and,
- Record and document all installation and start-up conditions prior to beginning the verification test.

3.3.3 Installation and Startup Procedure

The VTP and Protocol allow for an eight-week startup period. During this period, the biological community is established and operating conditions are adjusted, if needed, for site conditions. The primary tank and filter system of the Model 400 was filled with clean water and each component of the system checked for proper operation. The water was also used to check the dosing pump flow rates. After the initial component check was completed, the primary tank was filled with raw wastewater from the dosing channel and the dosing sequence was started.

The system was monitored during the startup period (June 14 through August 12, 2001) by visual observation of the system, routine calibration of the dosing system, and the collection of influent and effluent samples. Samples for analysis were collected three times over the eight-week startup period. Influent samples were analyzed for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS analyses. The effluent was also analyzed for pH, alkalinity, temperature, $CBOD_5$, TKN, NH_3, TSS, dissolved oxygen, NO_2, and NO_3. Procedures for sample collection, analytical methods, and other monitoring procedures were the same procedures used during the one-year verification period. These procedures are described later in this section.

3.4 VERIFICATION TESTING - PROCEDURES

3.4.1 Introduction

The verification test procedures were designed to verify nitrogen reduction by the SeptiTech® System. The verification test consisted of a twelve-month test period, incorporating five stress periods with varying stress conditions simulating real household conditions. Dosing volume was set based on the design capacity of the SeptiTech® Model 400 System. Monitoring for nitrogen reduction was accomplished by measurement of nitrogen species (TKN, NH_4, NO_2, NO_3). Carbonaceous biochemical oxygen demand ($CBOD_5$) and other basic parameters (pH, alkalinity, TSS, temperature) were monitored to provide information on overall treatment performance. Operational characteristics such as electric use, residuals generation, noise and odor were also monitored.

3.4.2 Objectives

The objectives of the verification test were to:

- Determine nitrogen reduction performance of the SeptiTech® Model 400 System;
- Monitor removal of other oxygen-using contaminants (BOD_5 $CBOD_5$, TSS);
- Determine operation and maintenance characteristics of the technology; and,
- Assess chemical usage, energy usage, generation of byproducts or residuals, noise and odors.

3.4.3 System Operation- Flow Patterns and Loading Rates

The flow and loading patterns used during the twelve-month verification test were designed in accordance with the Protocol, as described in the VTP (Appendix B). The flow pattern was designed to simulate the flow from a "normal" household. Several special stress test periods were also incorporated into the test program.

3.4.3.1 Influent Flow Pattern

The influent flow dosed to SeptiTech® Model 400 was controlled by the use of timed pump operation. The dosing pump was set to provide 15 doses of equal volume (target - 29.3 gallons per dose) in accordance with the following schedule:

- 6 a.m. – 9 a.m. approximately 33 percent of total daily flow in 5 doses
- 11 a.m. – 2 p.m. approximately 27 percent of total daily flow in 4 doses
- 5 p.m. – 8 p.m. approximately 40 percent of total daily flow in 6 doses

The influent dosing pump was controlled by a programmable logic controller, which permitted timing of the fifteen individual doses to within one second. The pump flow rate and time setting was calibrated by sequencing the dosing pump for one cycle and collecting the entire volume of flow in a "calibrated" barrel. The barrel was initially calibrated by placing measured volume of water into it. The dosing flow volume was checked by this calibration method at least twice per week. Calibration results were recorded in the field logbook.

After each calibration test, the measured volume was compared to the 440 gallons per day target rate. If the volume was more than 10 percent above or below the target, the pump run time was increased or decreased to adjust the volume per dose back to the target volume. If the run time was changed, then a second calibration was performed to determine the total volume for the new timer setting. The QC requirement for the dosing volume was 100 ± 10 percent of the target flow based on a thirty (30) day average, with the exception of periods of stress testing. All calibration tests were recorded in the field logbook.

In addition to the twice-weekly direct calibrations, the PLC system results were checked on a daily basis. The PLC system recorded the number of doses delivered each day for each pump operated by the system. The PLC was checked to confirm that 15 doses were delivered each day. The PLC was also checked to ensure that the start and stop times were set properly. Any changes made to the settings or problems with dose cycles were recorded in the field log.

Flow information was entered into a spreadsheet that showed each day of operation, the pump run time, the gallons pumped per dose, and the number of doses delivered to the unit.

3.4.3.2 Stress Testing Procedures

One stress test was performed during the verification test following every two months of operation at the normal design loading. Five stress scenarios were run during the twelve-month evaluation period. These special tests were designed to test the SeptiTech® System response to differing load conditions and a power/equipment failure.

Stress testing included the following simulations:

- Washday stress
- Working Parent stress
- Low Load stress
- Power/Equipment Failure stress
- Vacation stress

Washday stress simulation consisted of three (3) washdays in a five (5) day period, with each washday separated by a 24-hour period of dosing at the normal design loading rate. During a washday, the system received the normal flow pattern; however, during the course of the first two (2) dosing periods per day, the hydraulic loading included three (3) wash loads [three (3) wash cycles and six (6) rinse cycles]. The volume of wash load flow was 28 gallons per wash load. The hydraulic loading rate was adjusted so that the loading on washdays did not exceed the design loading rate. Common detergent (Arm and Hammer Fabri-care) and non-chlorine bleach was added to each wash load at the manufacturer recommended amount.

The working parent stress simulation consisted of five (5) consecutive days when the SeptiTech® System was subjected to a flow pattern where approximately 40 percent of the total daily flow was dosed between 6 a.m. and 9 a.m., and approximately 60 percent of the total daily flow was dosed between 5 p.m. and 8 p.m. This simulation also included one (1) wash load [one (1) wash cycle and two (2) rinse cycles] during the evening dose cycle. The hydraulic loading did not exceed the design loading rate during the stress test period.

The low load stress simulation consisted of testing the unit at 50 percent of the target flow (220 gallons per day) loading for a period of 21 days. Approximately 35 percent of the total daily flow was dosed between 6 a.m. and 11 a.m., approximately 25 percent of the flow was dosed between 11 a.m. and 4 p.m., and approximately 40 percent of the flow was dosed between 5 p.m. and 8 p.m.

The power/equipment failure stress simulation consisted of a standard daily flow pattern until 8 p.m. on the day when the power/equipment failure stress was initiated. Power to the system was turned off at 9 p.m. and the flow pattern was discontinued for 48 hours. After the 48-hour period, power was restored and the system dosed with approximately 60 percent of the total daily flow over a three (3) hour period, which included one (1) wash load [one (1) wash cycle and two (2) rinse cycles].

The vacation stress simulation consisted of a flow pattern where, on the day that the stress is initiated, approximately 35 percent of the total daily flow was dosed between 6 a.m. and 9 a.m. and approximately 25 percent of the total daily flow was received between 11 a.m. and 2 p.m. The flow pattern was discontinued for eight (8) consecutive days, with power continuing to be supplied to the technology. Between 5 p.m. and 8 p.m. of the ninth day, the technology was dosed with 60 percent of the total daily flow, which included three (3) wash loads [three (3) wash cycles and six (6) rinse cycles].

3.4.3.3 Sampling Locations, Approach, and Frequency

3.4.3.3.1 Influent Sampling Location

Influent wastewater was sampled from the dosing channel at a point near the SeptiTech® Model 400 dosing pump intake, approximately four to six inches from the channel floor to ensure a representative sample of the wastewater was obtained. The influent sampling site selection was based on the layout of the dosing channel at the MASSTC facility. Screened wastewater enters the sixty-five foot long dosing channel via two pipes midway between the channel end and the channel outlet. Dosing pumps for individual systems are located in-line along the dosing channel.

3.4.3.3.2 SeptiTech® Model 400 Effluent Sampling Location

For the SeptiTech® Model 400 System effluent, the sampling site was located in the normal effluent pipe from the processor. During installation and setup, a sampling point was constructed in the manhole where the effluent from the two-inch force main from the system discharged to the MASSTC sewer line. The sampling point, consisting of a tee-cross with sump of sufficient size to retain sample volume for both grab and automated sampler, was installed in the effluent pipe. The sump was only large enough to retain approximately one liter of fluid and was readily flushed and replenished by the normal flow of treated effluent. The sump was located so that it could be cleaned of any attached and settled solids. Cleaning of the sampling location, by brushing to remove any accumulated solids, was performed on a regular basis prior to each sampling period. This cleaning was performed to remove biomass that tended to grow in the effluent pipe during the weeks between sampling events. Cleaning would not be required in normal system, as the sampling location in the discharge pipe was installed for the verification test only and would not be present in a normal installation.

3.4.3.3.3 Sampling Procedures

Both grab and 24-hour flow weighted composite samples were collected at the influent and effluent sampling locations. Grab samples were collected from both locations for the measurement of pH and temperature. Dissolved oxygen was measured at the treated effluent location when flow across the sampling point was occurring. The grab samples were collected by dipping a sample collection bottle into the flow at the same location as the automatic sampler used for composite sample collection. The sample bottle was labeled with the sampling location, time and date. All pH and temperature measurements were performed at the on-site laboratory immediately after sample collection.

Composite samples were collected using automated samplers at each sample collection point. The automated samplers were programmed to draw equal volumes of sample from the waste treatment stream at the same frequency and timing as influent wastewater doses. Samples taken in this manner were therefore flow proportional. The effluent sampler timing was set to correspond to the passage of a flow through the SeptiTech® Model 400 System discharge line. The automatic samplers were calibrated before each use and the volume of sample collected was checked to ensure that the proper number of individual samples was collected in the composite container. Detailed sampling procedures are described in the MASSTC SOPs (Appendix C).

Table 3-2 shows a summary of the sampling matrix for the verification test.

Table 3-2. Sampling Matrix

		Sample Location		
PARAMETER	**SAMPLE TYPE**	**INFLUENT**	**FINAL EFFLUENT**	**TESTING LOCATION**
BOD$_5$	24 Hour composite	√		Laboratory
CBOD$_5$	24 Hour composite		√	Laboratory
Suspended Solids	24 Hour composite	√	√	Laboratory
pH	Grab	√	√	Test Site
Temperature (°C)	Grab	√	√	Test Site
Alkalinity (as CaCO$_3$)	24 Hour composite	√	√	Laboratory
Dissolved Oxygen	Grab	√	√	Test Site
TKN (as N)	24 Hour composite	√	√	Laboratory
Ammonia (as N)	24 Hour composite	√	√	Laboratory
Total Nitrate(as N)	24 Hour composite		√	Laboratory
Total Nitrite (as N)	24 Hour composite		√	Laboratory

3.4.3.3.4 Sampling Frequency

Table 3-3 shows a summary of the sampling schedule followed during the test. Sample frequency followed the VTP, and included sampling under design flow conditions on a monthly basis and more frequent sampling during the special stress test periods.

Normal Monthly Frequency

Samples of the influent and effluent were collected at least once per month for the twelve-month test period (August 2001 – August 2002).

Stress Test Frequency

Samples were collected on the day each stress simulation was initiated and when approximately 50 percent of each stress sequence was completed. For the vacation and power/equipment failure stresses, there is no 50 percent sampling. Beginning twenty-four (24) hours after the completion of washday, working parent, low load, and vacation stress scenarios, samples were collected for six (6) consecutive days. Beginning forty-eight (48) hours after the completion of the power/equipment failure stress, samples were collected for five (5) consecutive days.

Final Week

Samples were also collected for five (5) consecutive days at the end of the yearlong evaluation period.

3.4.3.3.5 Sample Handling and Transport

Samples collected in the automatic samplers were collected with ice surrounding the sample bottle to keep the sample cool. The composite sample container was retrieved at the end of the sampling period, shaken vigorously, and poured into new bottles that were labeled for the various scheduled analysis. Sample bottles used for TKN and ammonia analyses were supplied by the laboratory with preservative. Sample container type, sample volumes, holding times, and sample handling and labeling procedures were detailed in the VTP (Appendix B) and in the MASSTC SOP, Attachment I (Appendix C).

BCDHE personnel transported the samples to the BCDHE laboratory via automobile. The samples were packed in coolers with ice to maintain the temperature of all transported samples at 4 ^{o}C. Subsample containers analyzed at the GAI laboratory were transported from BCDHE laboratory to GAI by GAI personnel. Travel time to BCDHE was approximately 40 minutes. Travel time from BCDHE to GAI was approximately 45 minutes.

Table 3-3. Sampling Schedule for SeptiTech® Model 400 System

Month/Day	Sampling Event
July 3 and 18, 2001	Startup – 2 sampling events
August 1, 2001	Startup – 1 sampling events
August 22, 2001	Normal monthly sample
September 20, 2001	Normal monthly sample
October 9, 11, and 14-19, 2001	Washday stress - 8 samples
November 7, 2001	Normal monthly sample
December 5, 2001	Normal monthly sample
December 11, 13, and 16-21, 2001	Working parent stress – 8 samples
December 28, 2001	Normal monthly sample - extra
January 16, 2002	Normal monthly sample
February 4, 2002	Normal monthly sample
February 14, 18, 19, 28 and March 12-17, 2002	Low load stress – 10 Samples Test started on February 18, 2002
April 3, 2002	Normal monthly sample
April 17, 2002	Normal monthly sample - extra
May 6 and 11-15, 2002	Power/equipment failure stress – 6 samples
June 5, 2002	Normal monthly sample
June 26, 2002	Normal monthly sample- extra
July 8 and 18-22, 2002	Vacation stress – 6 samples
August 5-9, 2002	Final week sampling – 5 samples

3.4.3.4 Residuals Monitoring and Sampling

Solids in the raw wastewater settle in the primary (septic) tank and accumulate slowly over time. Byproducts or residuals generated by the processor are also returned to the primary tank with the recycle (pump-back) water flow from the reservoir in the bottom of the processor. Measurements of solids depth in the septic tank were made in February 2002, after eight months of operation, and again on August 5, 2002 after approximately fourteen months of operation. A coring solids measurement tool (Core Pro) was used to estimate the depth of solids/, liquid, and scum layers in the 1,500 gallon primary tank. The sampling device is a clear tube with a check valve on the bottom. The tube is pushed through the solids to the bottom of the tank. The valve closes and the entire sample column, water and solids, are removed from the tank. The column height is checked to ensue no sample has leaked from the device. The solids depth is then determined by measuring the height of the solids in the clear tube using a tape measure or ruler. This approach gives a direct measurement of depth of solids. The thickness of any scum layer present is measured by ruler or tape also. Three measurements of the solids depth and scum depth were made at each of the two access manholes.

Samples of solids were recovered from the Core Pro during the final measurement period by emptying the probe contents into a clean container and sending the sample to the BCDHE laboratory for VSS and TSS analysis. This sample included both the solids in the tube and the water present in the column as well. Thus, the concentration measurements for solids represent the concentration as if the entire septic tank were mixed. To estimate the solids concentration in the settled material at the bottom of the tank, the depth of solids and the depth of the water column need to be accounted for and the ratio used to calculate an estimated solids percent.

3.4.4 Analytical Testing and Record Keeping

As shown in Table 3-3**,** fifty-four (54) samples of the influent and effluent for the SeptiTech® Model 400 System were collected over the twelve-month verification period. Table 3-2 presented the parameter list. Samples included grab and composite samples for each sampling day. Industry standard procedures (EPA Methods (5,6) or Standard Methods (7)) were used for all sample analysis. The methods used for each constituent are shown in Table 3-4. Temperature, dissolved oxygen and pH were measured onsite. All other analyses were performed by off site laboratories. The Barnstable County Department of Health and Environment Laboratory performed the analyses for alkalinity, total suspended solids, biochemical oxygen demand (BOD_5), carbonaceous biochemical oxygen demand ($CBOD_5$), nitrite, and nitrate. Groundwater Analytical, Inc. (GAI) was responsible for the analyses for Total Kjeldahl Nitrogen and ammonia.

Table 3-4. Summary of Analytical Methods and Precision and Accuracy Requirements

Parameter	Facility	Acceptance Criteria	Acceptance Criteria	Analytical Method
		Duplicates (%)	Spikes (%)	
pH	On-site	N/A	N/A	SM #4500 H^+B
Temperature (^oC)	On-site	N/A	N/A	SM #2550
Dissolved Oxygen	On-site	N/A	N/A	SM #4500 G
Suspended Solids	BCDHE Laboratory	80-120	N/A	SM #2540 D
$CBOD_5$	BCDHE Laboratory	80-120	N/A	SM #5210 B
Alkalinity	BCDHE Laboratory	80-120	N/A	SM #2320
Total Nitrite (as N)	BCDHE Laboratory	90-110	60-140	EPA 353.3
Total Nitrate (as N)	BCDHE Laboratory	90-110	60-140	EPA 353.3
TKN (as N)	GAI Laboratory	80-120	80-120	EPA 351.4
Ammonia (as N)	GAI Laboratory	80-120	80-120	EPA 350.1

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A Quality Assurance Project Plan was developed as part of the VTP, and provided quality control requirements and systems to ensure the integrity of all sampling and analysis. Precision and accuracy limits for the analytical methods are shown in Table 3-4. The QAPP included procedures for sample chain of custody, calibration of equipment, laboratory standard operating procedures, method blanks, corrective action plan, etc. Additional details are proved in the VTP (Appendix B). Three laboratory audits were also performed during the verification test to confirm that the analytical work was being performed in accordance with the methods and the established QC objectives.

The results of all analyses from the off site laboratories were reported to the TO by hardcopy laboratory reports. The laboratory data are presented in Appendix D. The off site laboratories also provided QA/QC data for the data sets. This data is included in Appendix D with the laboratory reports. The on site laboratory maintained a laboratory logbook to record the results of all analyses performed at the site. Copies of the on-site laboratory logbook are presented in Appendix E.

The data received from the laboratories were summarized in an Excel spreadsheet by BCDHE personnel at the test site. The data were checked against the original laboratory reports by the site staff, and were checked by NSF to ensure the data was accurately entered. The spreadsheets are included in Appendix F.

3.4.5 Operation and Maintenance Performance

Both quantitative and qualitative performance of the SeptiTech® System was evaluated during the verification test. A field log was maintained that included all observations made during the startup of the unit and throughout the verification test. Observations regarding the condition of the system, operation, or any problems that required resolution were recorded in the log by the field personnel.

Observation and measurement of operating parameters included electric use, chemical use, noise, odor, and evaluation of mechanical components, electrical/instrumentation components, and by-product volumes and characteristics.

3.4.5.1 Electric Use

Electrical use was monitored by a dedicated electric meter serving the SeptiTech® System. The meter reading was recorded twice weekly in the field log by BCDHE personnel. The meter manufacturer and model number and any claimed accuracy for the meter was recorded in the field log. At the end of the testing period, the electric meter was returned to the manufacturer for calibration and the calibration data entered in the field log.

3.4.5.2 Chemical Use

Verification testing of the SeptiTech® System did not require the use any process chemicals to achieve treatment.

3.4.5.3 Noise

Noise levels associated with mechanical equipment were measured once during the verification period, using a decibel meter to measure the noise level. Measurements were taken one meter from the unit and one and a half meters above the ground, at 90° intervals in four (4) directions. The meter was calibrated prior to use. Meter readings were recorded in the field log. Duplicate measurements at each quadrant were made to account for variations in ambient sound levels.

3.4.5.4 Odors

Odor observations were made during the verification test, beginning in September 2001 and ending in July 2002. The observation was qualitative based on odor strength (intensity) and type (attribute). Intensity was stated as not discernable; barely detectable; moderate; or strong. Observations were made during periods of low wind velocity (<10 knots). The observer stood upright at a distance of three (3) feet from the treatment unit, at 90° intervals in four (4) directions. All observations were made by the same BCDHE employee.

3.4.5.5 Mechanical Components

Performance and reliability of the mechanical components, such as wastewater pumps, were observed and documented during the test period. These observations included recording in the field log of equipment failure rates, replacement rates, and the existence and use of duplicate or standby equipment.

3.4.5.6 Electrical/Instrumentation Components

Electrical components, particularly those that might be adversely affected by the corrosive atmosphere of a wastewater treatment process, and instrumentation and alarm systems were monitored for performance and durability during the course of verification testing. Observations of any physical deterioration were noted in the field log. Any electrical equipment failures, replacements, and the existence and use of duplicate or standby equipment were recorded in the field log.

4.0 Results and Discussion

4.1 Introduction

This chapter presents the results of the sampling and analysis of the influent and effluent to/from the unit, a discussion of the results, and observations on the operation and maintenance of the unit during startup and normal operation. Summary of results are presented in these sections. Complete copies of all spreadsheets with individual daily, weekly, or monthly results are presented in Appendix F.

Evaluation of the SeptiTech® System at MASSTC began on June 14, 2001. The unit was filled with wastewater, the pumps were activated, and the initial dosing cycles started. The startup period continued until August 12, 2001. Three samples of the influent and effluent were collected during the startup period. Verification testing began on August 13, 2001 and continued for 12 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.

4.2 Startup Test Period

The startup period provided time for the SeptiTech® System to develop a biological growth and acclimate to the site-specific wastewater. The startup also provided an opportunity for the system to be adjusted, if needed, to optimize performance at the site. These first eight weeks of operation also provided site personnel an opportunity to become familiar with the system operation and maintenance requirements. Samples were collected during weeks 3, 5 and 7 of the startup period.

4.2.1 Startup Flow Conditions

The flow conditions for the SeptiTech® System were established at the target capacity of 440 gallons per day in accordance with the VTP. The volume of wastewater dosed to the unit during the startup remained mostly constant and only minor adjustments to the dosing pump run time were required. Table 4-1 shows a summary of the flow volumes during the startup period. The daily flow records are in Appendix F.

Table 4-1. Flow – Volume Data during the Startup Period

Date	Average		Actual Daily Volume
	Doses/day	Gallons/dose	(Gallons)
June 14 – 15	15	30.5	458
June 16 - 17	15	22.5	338
June 18 – 30	15	29.5	442
July 1 – 24	15	29.5	442
July 25 - 26	15	32.5	488
July 27 – 28	15	30.3	454
July 29 – 31	15	29.5	442
Aug 1 - 4	15	30.2	453
Aug 5- 7	15	29.5	442
Aug 8 - 11	15	29.7	446
Aug 12	15	30.1	452

4.2.2 Startup Analytical Results

The results of the influent and effluent monitoring during the startup period are shown Tables 4-2 and 4-3. The first sets of samples were taken eighteen (18) days after the unit was started. The initial data showed that the unit reduced the $CBOD_5$ and TSS to 4.1 mg/L and 1 mg/L, respectively, and the SeptiTech® System was removing some of the total nitrogen (40 mg/L in the influent, 24 mg/L in the effluent). Observations and additional sampling to determine the condition of the unit continued for the next six weeks. No adjustments were made to the system. The treatment performance continued to improve through the end of the startup period.

At the end of the eight weeks allotted for the startup, the verification test period began. The biological growth appeared to be fully established. The $CBOD_5$ of the effluent was < 2.0 mg/L and TSS was 2 mg/L on the last sampling day before the start of the verification test. The System was removing both organic and ammonia nitrogen, with TKN in effluent of 2.3 mg/L and ammonia nitrogen of 1.0 mg/L. These data show that nitrification was established in the Processor. Denitrification was also occurring as shown by the nitrate, nitrite, and the total nitrogen concentrations in the effluent. Nitrate was 6.0 mg/L and the Total Nitrogen was 8.5 mg/L on August 1, 2002. Total Nitrogen removal was 72 percent. The establishment of the denitrification process can also be seen by reviewing the alkalinity and pH data. At the beginning of the startup, nitrification was occurring almost immediately and alkalinity and pH were lower than the influent (nitrification consumes alkalinity). As the denitrification, process became established the alkalinity and pH increased (denitrification produces alkalinity). It is quite clear from the August 1, 2002 results that the system was acclimated and the producing expected results.

Table 4-2. Influent Wastewater Quality - Startup Period

Date	BOD_5 (mg/L)	TSS (mg/L)	Alkalinity (mg/L)	pH (S.U.)	Ammonia (mg/L)	TKN (mg/L)	TN (mg/L)	DO (mg/L)	Influent Temp. (^oC)
07/03/01	260	250	190	7.4	24	40	40	0.4	18
07/18/01	290	300	190	7.3	24	42	42	0.2	21
08/01/01	110	96	180	7.4	20	30	30	0.2	21

N/S – no sample

Table 4-3. SeptiTech® Model 400 Effluent Quality during the Startup Period

Date	$CBOD_5$ (mg/L)	TSS (mg/L)	Alkalinity (mg/L)	PH (S.U.)	Ammonia (mg/L)	TKN (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TN (mg/L)	DO (mg/L)	Discharge Temp (^oC)
07/03/01	4.1	1	32	6.6	2.5	1.8	11	11	24	6.0	19
07/18/01	11	2	68	6.6	2.2	3.9	13	0.28	17	N/S	N/S
08/01/01	<2.0	2	80	7.0	1.0	2.3	6.0	0.18	8.5	3.0	18

4.2.3 Startup Operating Conditions

The SeptiTech® System was started using the vendor's recommended settings. The PLC controls all pump times and system operation. The recirculation pump (dosing to the media via the spray nozzles) was setup to operate in normal mode. The typical cycle of dosing the media, resting, dosing the media, resting, and then discharge occurred throughout each day when flow to the system was occurring. Since flow was dosed on an 18-hour cycle (no doses over night), the system would normally not cycle during the night period. The pump-back or recycle rate from the reservoir to the septic tank was initially set at 44 gallons per day, or 10 percent of the flow. The discharge pump was set to operate at 24 gpm, which is a PLC setting that accounts for the dynamic head on the discharge line. The discharge pump runtime was set for 38 seconds. The actual discharge pump cycle is based on PLC control that monitors the flow rate to the processor, and adjusts the number of discharge cycles based on the flow received by the Processor.

No changes were made to the unit during the startup period. Regular observations showed that biological growth was being established and the effluent quality was visually improving. SeptiTech staff visited the site periodically during startup to check on the unit. A system check was performed on July 25, which included pump calibrations. The muffler on the air intake to the Processor was removed because SeptiTech was performing a separate study of airflow and oxygen. The muffler is a simple piece of three-inch pipe with foam. This change was not considered a major alteration to the system and should not impact treatment, assuming the unit continued to receive sufficient airflow to maintain oxygen levels. However, the muffler remained off the unit during the entire verification test. There were no mechanical problems during the startup, and overall, the unit started up without any difficulty.

4.3 Verification Test

In accordance with the startup period set forth in the VTP and the Protocol, the verification test was started officially on August 13, 2001. A last startup sample was collected on August 1, 2001. All results for the balance of the test were considered part of the verification test period. The data presented for the verification results do not include data from the startup period.

As stated above, there were no changes made to the basic operation of the system during the startup period. On August 21, 2001, shortly after the verification test period started, some adjustments to the pump cycles and settings in the PLC were made as part of a routine check on the system.. SeptiTech changed the discharge pump setting from 24 gpm to 32 gpm. This adjustment is used to calibrate the discharge pump to the site-specific dynamic head of the system. This setting was changed based on the experience of the two-month startup at the site. The discharge pump run time was also changed from 38 seconds to 46 seconds to handle the 440 gpd flow for this system. The original setting of 38 seconds is used to handle a flow of 330 gpd, which is the factory default setting for a standard SeptiTech Model 400 System. The adjustment was needed to match the influent flow of 440 gpd used for the test. Based on the changes, the system ran 18 duty cycles per 24-hour period. These adjustments are expected and normal, as stated in the SeptiTech literature, as part of system startup and optimization to site-specific conditions.

4.3.1 Verification Test - Flow Conditions

The dosing was performed every day from August 13, 2001 through August 12, 2002, except during the stress periods. Volume per dose and total daily volume varied only slightly during this period. Table 4-4 shows the average monthly volumes for the verification period. As this data shows, the actual wastewater volume dosed to the SeptiTech® System was very close to the targeted volume of 440 gallons per day for the entire verification test.

Table 4-4. SeptiTech® Model 400 Influent Volume Summary

	Target		Ave Monthly	
Mon/Year	**Gallon/dose**	**Doses/day**	**Gallon/dose**	**Gallon/day**
Aug-01	29.33	15	29.7	446
Sep-01	29.33	15	29.4	441
Oct-01	29.33	15	29.5	443
Nov-01	29.33	15	29.5	439
Dec-01	29.33	15	29.3	439
Jan-02	29.33	15	29.1	436
Feb-02	29.33	15	28.8	432(1)
Mar-02	29.33	15	29.2	438(1)
Apr-02	29.33	15	29.3	439
May-02	29.33	15	29.4	441(2)
June-02	29.33	15	29.7	445
July-02	29.33	15	29.9	449(3)
Aug-02	29.33	15	29.3	439
Average			**29.4**	**440**
Maximum			**29.9**	**449**
Minimum			**28.8**	**432**
Std. Dev.			**0.28**	**4.45**

(1) February/March – low load test run in February and March; average flow data does not include the low flow days. Only normal flow days are included. During the low load test, flow was set at 50 percent of normal flow. Actual average flow during the low load test (February 18 to March 10) was 215 gpd.

(2) May – During the power failure stress test there is one day with no flow and one day with reduced flow. These data point are not included in the monthly average.

(3) July 2002 – vacation test – 10-day test; no flow for 8 days,
Only nine doses on first and last day; low or no flow days excluded from the calculation of monthly averages

4.3.2 BOD$_5$/CBOD$_5$ and Suspended Solids Results

Figures 4-1 and 4-2 show the results for BOD$_5$/CBOD$_5$ and total suspended solids (TSS) in the influent and effluent for the verification test. Table 4-5 presents same results with a summary of the data (average, median, maximum, minimum, standard deviation). CBOD$_5$ was measured in the effluent as required in the Protocol. The use of the CBOD$_5$ analysis was specified because the effluent from nutrient reduction systems was expected to be low in oxygen demanding organics, and have a large number of nitrifying organisms, which can cause nitrification to occur during the first five days of the test. The $CBOD_5$ analysis inhibits nitrification during the analysis, and provides a better measurement of the oxygen demanding organics in the effluent. The BOD_5 test was used for the influent, which had much higher levels of oxygen demanding organics, and was expected to have a very low population of nitrifying organisms. In the standard BOD_5 test, it is assumed that little nitrification occurs within the five days of the test. Therefore, the oxygen demanding organics are the primary compounds measured in the wastewater influent. Using the BOD_5 of the influent and the $CBOD_5$ in the effluent should provide a good comparison of the oxygen demanding organics removal of the system.

The verification test 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 the stress test or an upset condition occurring during the concentrated sampling can have an impact on the calculation of average values. Both average and median results are presented in Table 4-5, as the median values compared to average values can help in analyzing these impacts. In the case of the SeptiTech® System results, the effluent median values are very similar to the average values for $CBOD_5$ and TSS, because the performance of the unit for removal of these constituents was consistent throughout the verification test.

The influent wastewater had an average BOD_5 of 250 mg/L and a median BOD_5 of 240 mg/L. The average influent TSS was 150 mg/L with a median concentration of 140 mg/L. The SeptiTech® System effluent had an average $CBOD_5$ of 5.4 mg/L and a median $CBOD_5$ of 4.7 mg/L. The average effluent TSS concentration was 3 mg/L, with a median concentration of 2 mg/L. The SeptiTech® System averaged 98 percent reduction of BOD_5/$CBOD_5$ with a median removal of 98 percent. TSS removal averaged 98 percent over the twelve-month period, with a median removal of 98 percent. $CBOD_5$ 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 test.

At the end of the startup period, the SeptiTech® System was removing TSS and $CBOD_5$ at a high level of efficiency. The data suggests that an acclimated microbial population was present. The unit came on line quickly and showed removal of $CBOD_5$ and TSS within a few days.

By the start of the first stress test, the washday stress, the unit was producing effluent concentrations of 5.2 mg/L $CBOD_5$ and 1 mg/L for TSS. After the first day of the washday stress test on October 8, the effluent $CBOD_5$ increased to 14 mg/L and the TSS to 6 mg/L. The levels dropped almost immediately and remained low for the balance of the stress period. Overall, the washday stress did not have an impact on the $CBOD_5$ and TSS performance. Post stress period monitoring showed steady performance into December 2001. Effluent $CBOD_5$ was less than 5 mg/L and TSS less than 2 mg/L during the two-month period.

The working parent stress test was started on December 10, 2001 and was completed on December 14. There was no apparent change in the effluent quality during the stress test. The January 16, 2002, sample showed a very slight increase in $CBOD_5$ to 6.2 mg/L and TSS increased to 4 mg/L, but still showed excellent organic and solids treatment. Data collected during the low load stress test in February/March showed no change in overall removal. The low load test did not appear to have any impact on the system performance. Effluent $CBOD_5$ increased slightly in the samples collected prior to the stress test (January 16, February 4 and 14), averaging 7.0 mg/L. During the stress test, the average $CBOD_5$ was 6.1 mg/L. While the pre-stress period and stress test period results were slightly higher than the previous months, effluent levels for both $CBOD_5$ and TSS were below 10 mg/L. The power/equipment failure test in May 2002 also showed no change in either $CBOD_5$ or TSS performance.

The vacation stress test started on July 8, 2002. There was an increase in effluent $CBOD_5$ (10 and 22 mg/L) and TSS (13 and 13 mg/L) on the first two days of sampling after the end of the stress period, indicating that the stress test may have impacted effluent quality. During the vacation stress period, there is an eight-day period with no flow to the system, although power is maintained. The SeptiTech® System PLC adjusts pump rates when low flow is measured to the Processor. It is likely that the system went into “sleep” mode after a few days. It is likely that this period of no flow with no fresh wastewater fed to the unit stressed the biomass population in the system. Whatever the cause of the increase in effluent $CBOD_5$ and TSS for these two days, the performance improved rapidly and levels of both $CBOD_5$ and TSS were below 10 mg/L by the third day of sampling. Effluent $CBOD_5$ and TSS were below 5 mg/L for the remaining month of the verification test.

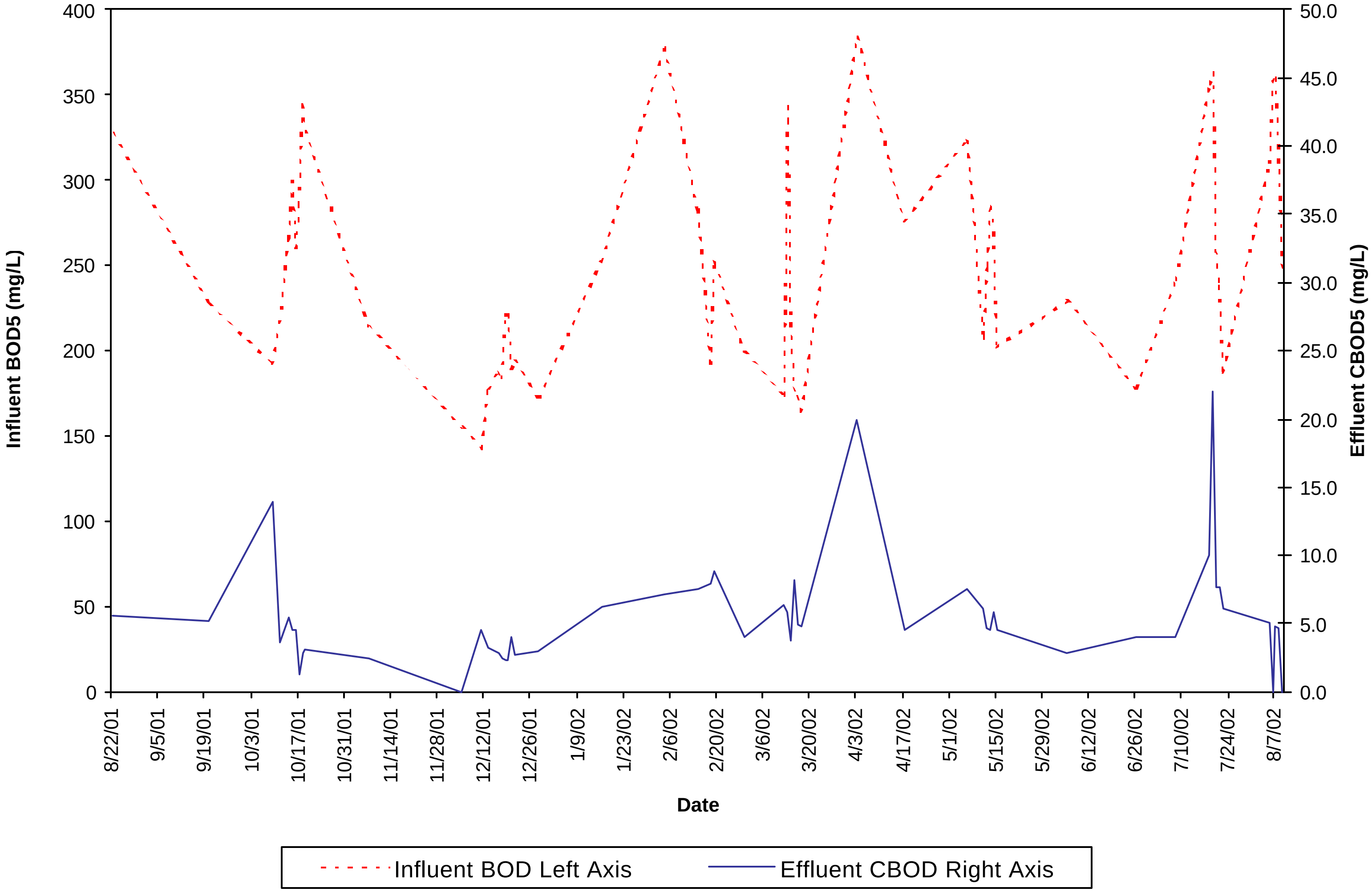

Figure 4-1. SeptiTech® Model 400 System $BOD_5/CBOD_5$ Results

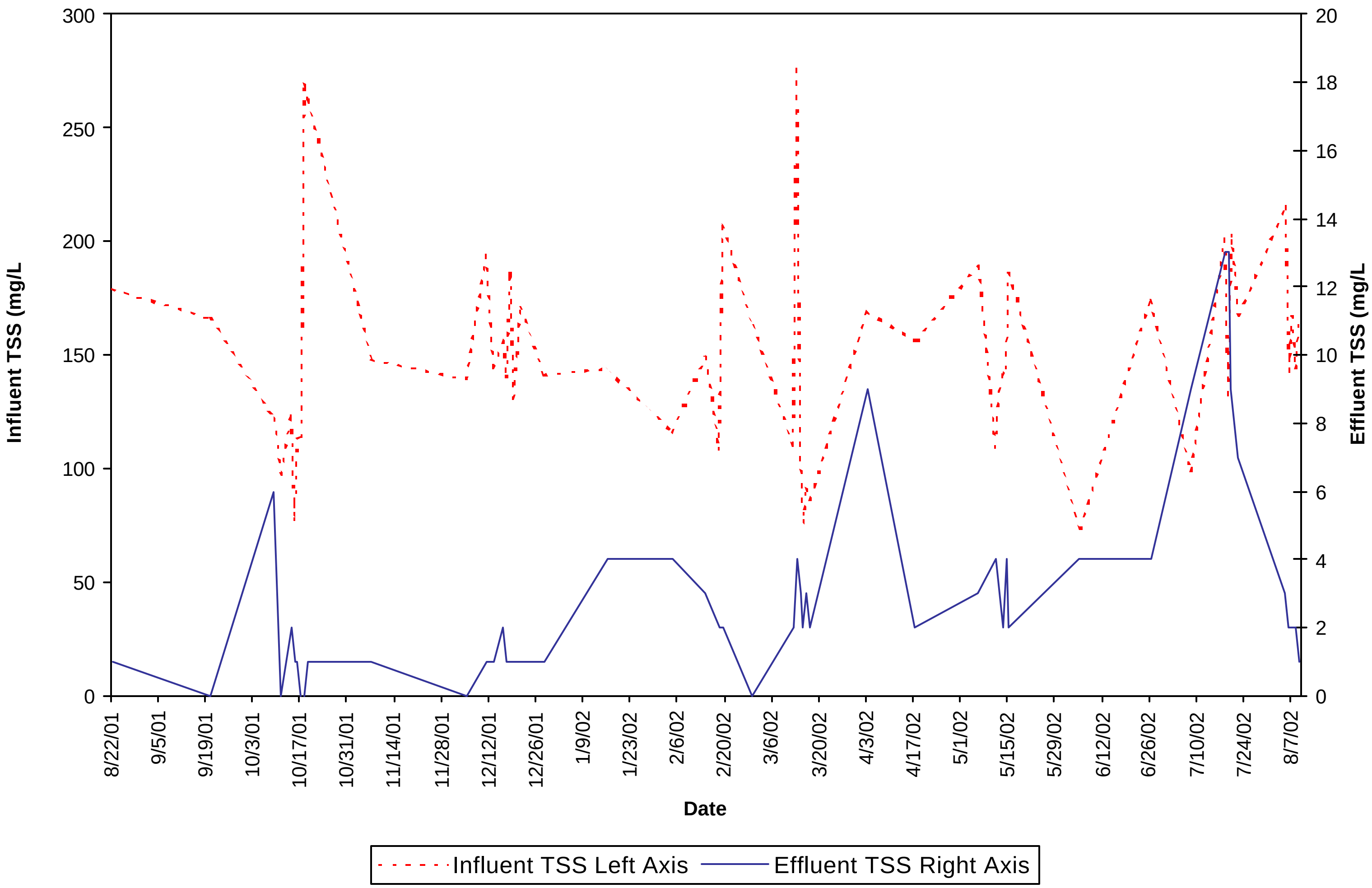

Figure 4-2. SeptiTech® Model 400 System Total Suspended Solids Results

Table 4-5. SeptiTech® Model 400 System BOD_5/$CBOD_5$ and TSS Results

	BOD_5	$CBOD_5$		TSS		
Date	Influent (mg/L)	Effluent (mg/L)	Removal (Percent)	Influent (mg/L)	Effluent (mg/L)	Removal (Percent)
08/22/01	330	5.6	98	180	1	99
09/20/01	230	5.2	98	170	<1	>99
10/09/01	190	14	93	120	6	95
10/11/01	220	3.6	98	97	<1	>99
10/14/01	270	5.5	98	120	2	98
10/15/01	300	4.5	98	77	1	99
10/16/01	260	4.5	98	110	1	99
10/17/01	290	<2	>99	110	<1	>99
10/18/01	340	2.8	99	270	<1	>99
10/19/01	330	3.1	99	260	1	100
11/07/01	210	2.5	99	150	1	99
12/05/01	160	<2	>99	140	<1	>99
12/11/01	140	4.6	97	190	1	99
12/13/01	180	3.3	98	140	1	99
12/16/01	190	2.9	98	160	2	99
12/17/01	180	2.5	99	140	1	99
12/18/01	220	2.3	99	190	1	99
12/19/01	220	2.3	99	130	1	99
12/20/01	190	4.1	98	150	1	99
12/21/01	190	2.7	99	170	1	99
12/28/01	170	3.0	98	140	1	99
01/16/02	250	6.2	98	140	4	97
02/04/02	380	7.1	98	120	4	97
02/14/02	280	7.6	97	150	3	98
02/18/02	190	7.9	96	110	2	98
02/19/02	250	8.9	96	210	2	99
02/28/02	200	4.1	98	160	<1	>99
03/12/02	170	6.4	96	110	2	98
03/13/02	340	5.8	98	280	4	99
03/14/02	220	3.8	98	100	3	97

Table 4-5. SeptiTech® Model 400 System BOD_5/$CBOD_5$ and TSS Results (continued)

	BOD_5	$CBOD_5$		TSS		
	Influent (mg/L)	Effluent (mg/L)	Removal (Percent)	Influent (mg/L)	Effluent (mg/L)	Removal (Percent)
03/15/02	180	8.2	95	76	2	97
03/16/02	170	4.9	97	91	3	97
03/17/02	160	4.8	97	86	2	98
04/03/02	380	20	95	170	9	95
04/17/02	280	4.6	98	160	2	99
05/06/02	320	7.5	98	190	3	98
05/11/02	210	6.1	97	110	4	96
05/12/02	250	4.7	98	130	3	98
05/13/02	280	4.5	98	140	2	99
05/14/02	280	5.8	98	140	4	97
05/15/02	200	4.6	98	190	2	99
06/05/02	230	2.9	99	73	4	95
06/26/02	180	4.0	98	170	4	98
07/08/02	240	4.0	98	99	9	91
07/18/02	360	10	97	200	13	94
07/19/02	360	22	94	130	13	90
07/20/02	260	7.7	97	200	9	96
07/21/02	240	7.7	97	190	8	96
07/22/02	190	6.1	97	170	7	96
08/05/02	310	5.0	98	220	3	99
08/06/02	360	<2	>99	140	2	99
08/07/02	360	4.8	99	170	2	99
08/08/02	310	4.7	98	140	2	99
08/09/02	240	<2	>99	170	1	99
Samples	54	54	54	54	54	54
Average	250	5.4	98	150	3	98
Median	240	4.7	98	140	2	99
Maximum	380	22	>99	280	13	>99
Minimum	140	<2	93	73	<1	90
Std. Dev.	66	4.0	1.3	46	3	2.0

Values below the detection limit are set to zero for concentration averages

Note: Effluent samples shown as 2/4/02 and 2/14/02 were actually dated 2/5/02 and 2/13/02. They were compared to the influent data and influent sample dates were used for comparison..

4.3.3 Nitrogen Reduction Performance

4.3.3.1 Results

Figures 4-3 through 4-5 present the results for the TKN, ammonia, and total nitrogen (TN) in the influent and effluent during the verification test. Figure 4-6 shows the results for nitrite and nitrate in the effluent from the SeptiTech® System. Table 4-6 presents all of the nitrogen results with a summary of the data (average, median, maximum, minimum, standard deviation).

The influent wastewater had an average TKN concentration of 39 mg/L and an average ammonia nitrogen concentration of 24 mg/L, with median concentrations of 39 mg/L and 24 mg/L, respectively. Average TN concentration in the influent was 39 mg/L (median of 39 mg/L), based on the generally accepted assumption that the nitrite and nitrate concentration in the influent was negligible. The SeptiTech® System effluent had an average TKN concentration of 6.8 mg/L, with a median of 5.7 mg/L. The average ammonia nitrogen concentration in the effluent was 5.1 mg/L, with a median concentration of 2.4 mg/L. The nitrite concentration in the effluent averaged 0.32 mg/L, with a median concentration 0.31 mg/L. Effluent nitrate concentrations averaged 6.7 mg/L over the twelve-month test, with a median concentration of 7.0 mg/L. Total nitrogen was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), nitrite and nitrate, resulting in an average TN in the SeptiTech® System effluent of 14 mg/L for the twelve-month verification period, with a median concentration of 14 mg/L. The SeptiTech® System averaged 63 percent reduction of TN for the verification test period, with a median removal of 67 percent.

Alkalinity, pH, dissolved oxygen (DO), and temperature were measured during the verification test. These parameters can provide insight into the condition of the system and can impact total nitrogen removal. Table 4-7 shows the results for alkalinity, DO, and pH. Temperature measurements are shown in Figure 4-7 and Table 4-6.

The pH of the influent was very consistent throughout the test, ranging from pH 7.1 to 7.7. The effluent from the SeptiTech® System showed a decrease in pH, but in a similar range, consistently remaining in the pH 6.7 to 7.6 range. The alkalinity of the influent averaged 180 mg/L as $CaCO_3$ with a maximum concentration of 220 mg/L and minimum of 90 mg/L. The effluent alkalinity was consistently lower than the influent (as expected when nitrification/denitrification is occurring), with an average concentration of 91 mg/L and a median concentration 85 mg/L. The effluent alkalinity did vary based on the performance of the nitrification and denitrification process.

The Dissolved Oxygen in the influent wastewater was low, as would be expected. The average DO in the influent to the septic tank was 0.2 mg/L, and was less than 1.0 mg/L on all days tested. The SeptiTech® System is designed to operate as an aerobic system, with the vents on the unit allowing air to move through the media. The DO in the effluent from the System was normally in the range of 3 to 6 mg/L, and averaged 5.5 mg/L over the twelve months of verification testing. DO did increase above 8 mg/L in February and March when wastewater temperature was the coldest. High DO levels could impact denitrification in the Biopack media and in the septic tank; if the high DO water recycled to the septic tank raised the DO in the tank. This did not seem to occur in the February-March period based on the nitrate concentrations in the effluent.

4.3.3.2 Discussion

As discussed earlier in the startup section, at the end of the startup period (June 14 to August 12, 2001), the SeptiTech® System effluent was showing removal of total nitrogen. An acclimated microbial population appeared present based on reduction of TKN and ammonia, as well as reduction in nitrate concentration. Both the nitrification and denitrification processes appeared to be established in the system, as the effluent alkalinity was lower than the influent by about 100 mg/L (August 22 data). The theoretical relationship of alkalinity consumed to TN removed shows that 3.5 mg/L is consumed for each 1 mg/L of TN (7.1 mg alkalinity is consumed per 1 mg nitrogen converted in the nitrification process, and 3.6 mg alkalinity is produced per mg TN removed by the denitrification process). The alkalinity data would predict that approximately 28 mg/L of TN was being removed. The actual data showed that 26 mg/L was removed. It is quite apparent that both processes were functioning in the system.

During September and October, the TN in the effluent was typically in the 8 to 10 mg/L range, which represented a removal of 61 to 78 percent. The washday stress test, performed in October 2001 did not appear to impact the system. The first day of the test did show the highest TN effluent concentration (11 mg/L) and there was slight increase in $CBOD_5$ as well. Overall, if there was any impact it was minor and of short duration.

In December 2001, the working parent stress test was performed. The performance of the system remained steady during and following this stress period. The system continued to reduce the total nitrogen concentration on a consistent basis with effluent concentration in the 8 to 10 mg/L range. The January 16 and February 4 monthly samples showed a decrease in performance, with effluent TN concentrations of 13 and 20 mg/L respectively. There was a slight increase in $CBOD_5$ from levels less than 5 mg/L to 6.2 and 7.1 mg/L. This time corresponds to the first wastewater temperatures that were below 10 ^{0}C. While a possible unknown stress on the system may have occurred, it is most likely that the lower temperatures were having an impact on the treatment performance.

The low load stress test began on February 18 and continued until March 10, 2002. During this stress period, TN levels varied from 7.5 to 20 mg/L. Nitrification was still occurring but not at the same effectiveness as in the earlier months. The alkalinity data tracks with the TN data indicating that both nitrification and denitrification were still occurring, but the nitrification process was not converting as much of the TKN and ammonia to nitrate. At the end of the low level stress test in March, the System was still reducing the TN levels to 11 to 18 mg/L. It does not appear that the low level stress had a direct impact on the system, as the data during the stress period was similar to the TN levels immediately before and after the stress test.

The post stress test period from mid March through May showed consistent results, with TN levels ranging from 15 to 18 mg/L, except for one day at 27 mg/L. During this time, the largest contribution to the TN concentration was the TKN level, indicating that the nitrification process was not as effective as in the summer/fall 2001 period. The power/equipment failure stress test was performed from May 6 to 8, 2002. There was no apparent change in the system due to the two-day power failure.

The June 5 sampling results showed a major change in the effluent quality, with TN levels dropping to 10 mg/L. The change was that TKN and ammonia levels in the effluent decreased to 6.0 and 3.7 mg/L respectively. During the previous several months, the concentrations had been above 10 mg/L. Alkalinity levels decreased at the same time. The nitrification process had suddenly become more efficient and was approaching the low concentrations measured in the previous summer and fall. As the levels of TKN and ammonia decreased in June and July, the levels of nitrate began to increase somewhat indicating that the denitrification process was not removing the increasing nitrate load to the system.

The vacation stress test was started on July 8 and continued until July 16. During this period, there was no influent flow to the system. The TKN and ammonia concentrations in the effluent remained low following the vacation stress test. There was no apparent impact on the nitrification process. However, the nitrate concentration in the effluent continued to increase, and in the post stress test monitoring period, nitrate became the major contributor to the TN in the effluent. TN concentrations ranged from 16 to 24 mg/L in July. Nitrate levels in the effluent ranged from 9 to 15 mg/L. Alkalinity levels were also much lower during this time, indicating that the nitrification process was active and consuming alkalinity, but that the denitrification process was not producing alkalinity to offset some of the loss. 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 processor reservoir to the septic tank. Therefore, there was less nitrified wastewater being recycled and this may have impacted the response time for the denitrifying organisms. In any case, TN was still being removed, but the effluent was in the 16 to 24 mg/L range, as compared to the previous summer and fall results that were typically less than 10 mg/L.

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

The verification test provided a sufficiently long test period to collect data that included both a long run of steady performance by the SeptiTech® Model 400 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 system continued to remove substantial amounts of TN in the later periods when 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 concentration 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 increased the average TN concentration in the effluent to 14 mg/L.

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. The alkalinity and pH data also show the swings in the dominant processes. At times the alkalinity reductions vs actual reductions differed by as much as 30 mg TN, but the effluent remained relatively stable during this period. This implies that although the individual nitrogen removal mechanisms may be unstable, the system performed consistently throughout the period. The periodic advantages of either nitrification or denitrification could be due to stressors that are not apparent from the data.

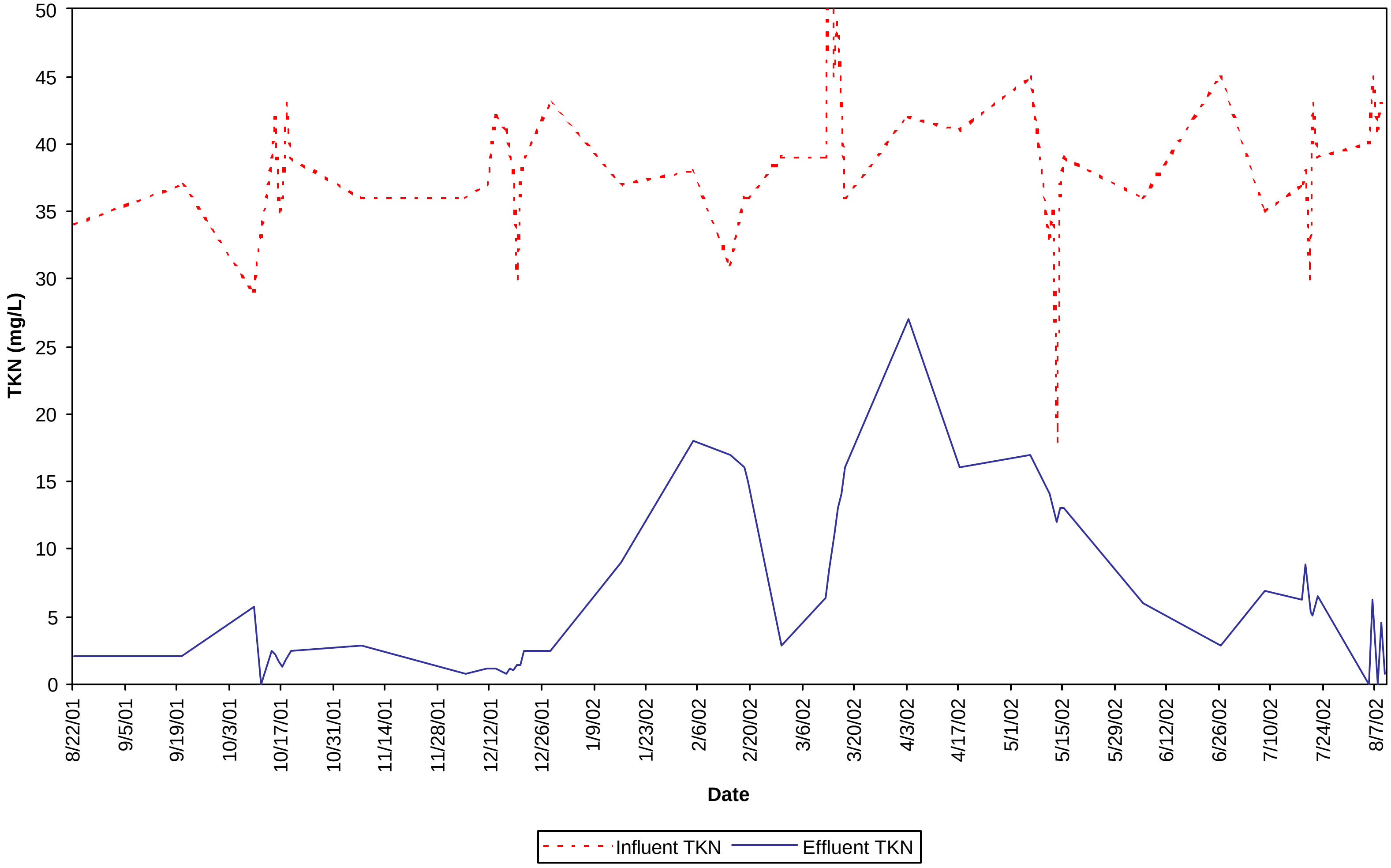

Figure 4-3. SeptiTech® Model 400 System Total Kjeldahl Nitrogen Results

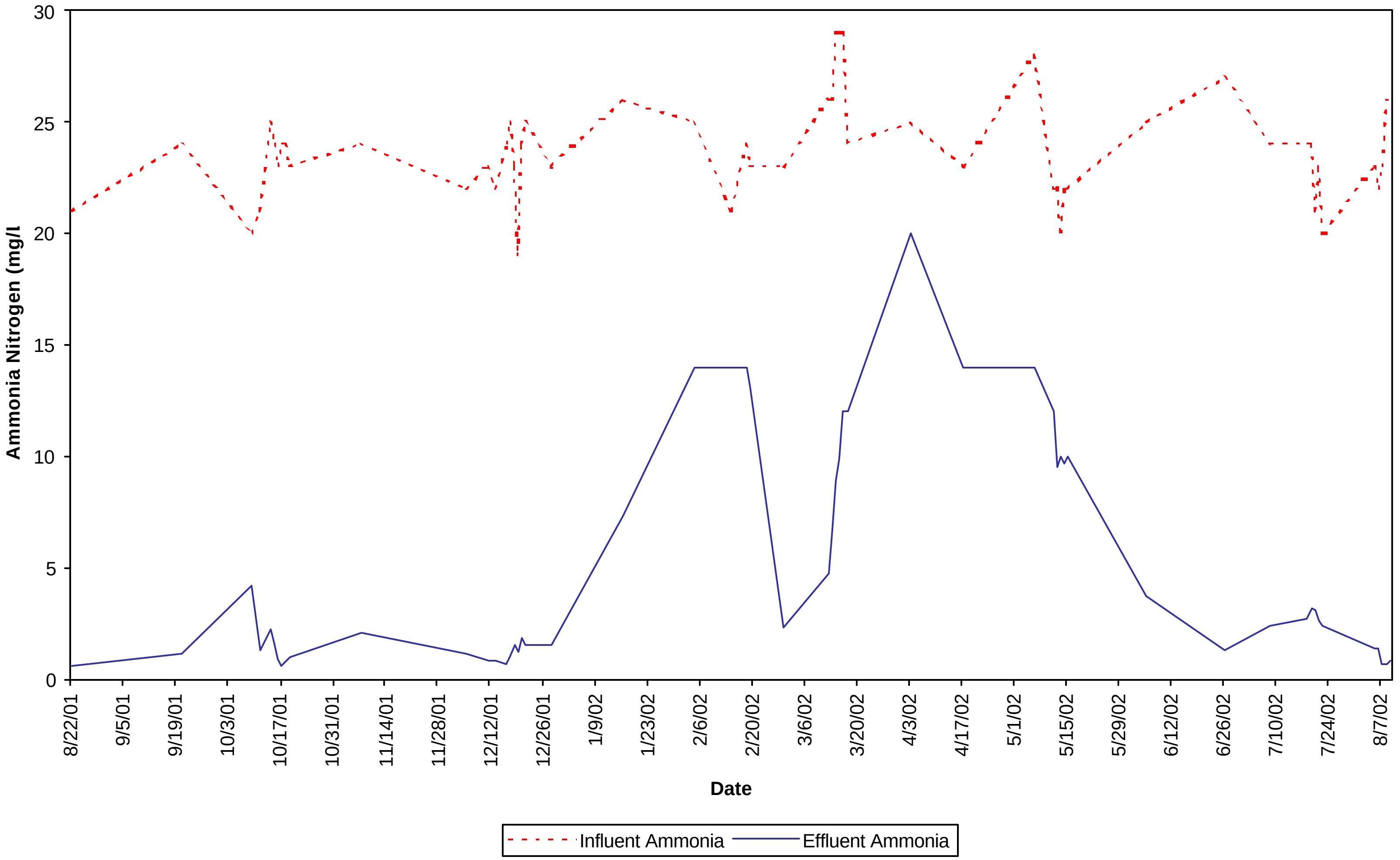

Figure 4-4. SeptiTech® Model 400 System Ammonia Nitrogen Results

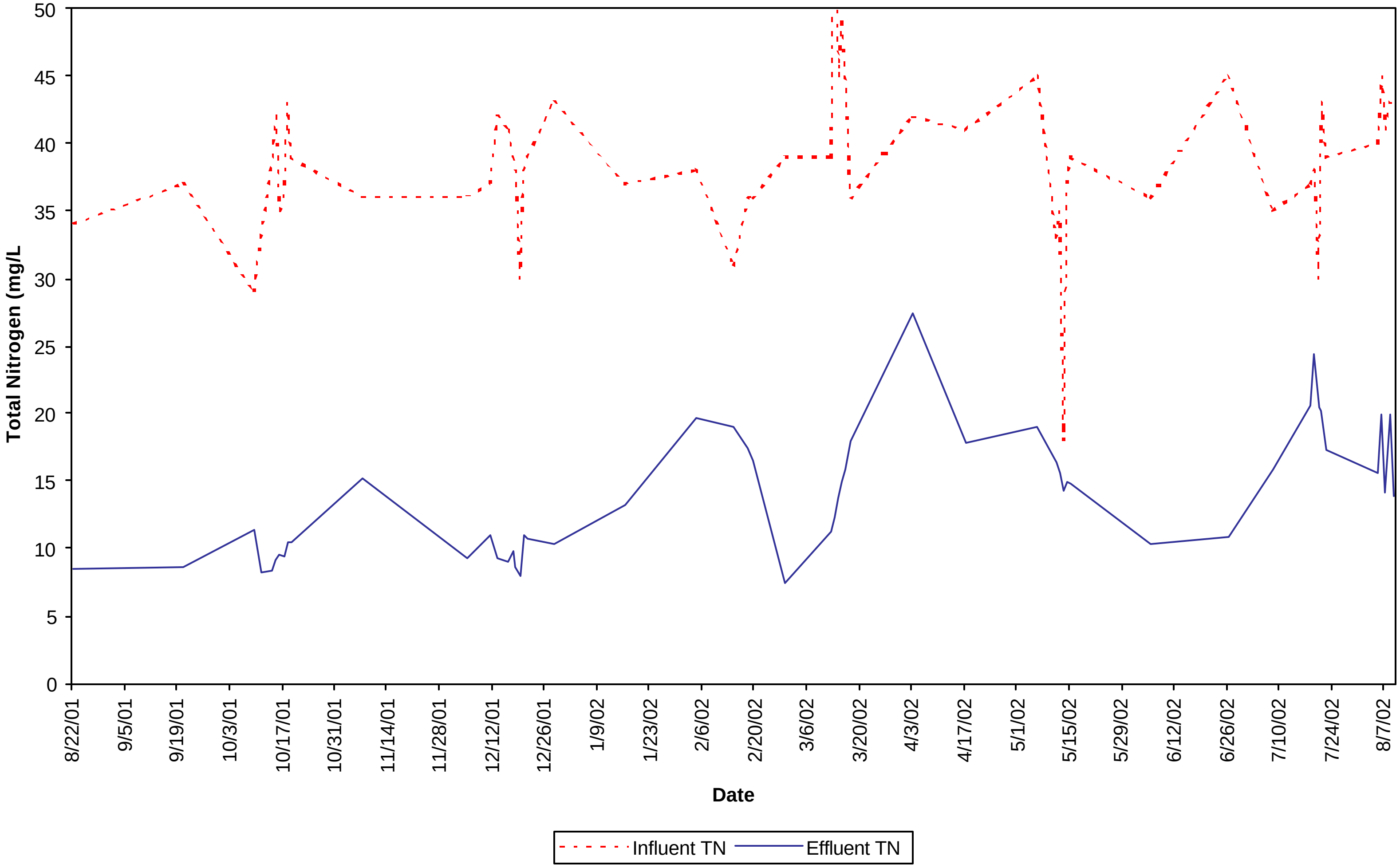

Figure 4-5. SeptiTech® Model 400 System Total Nitrogen Results

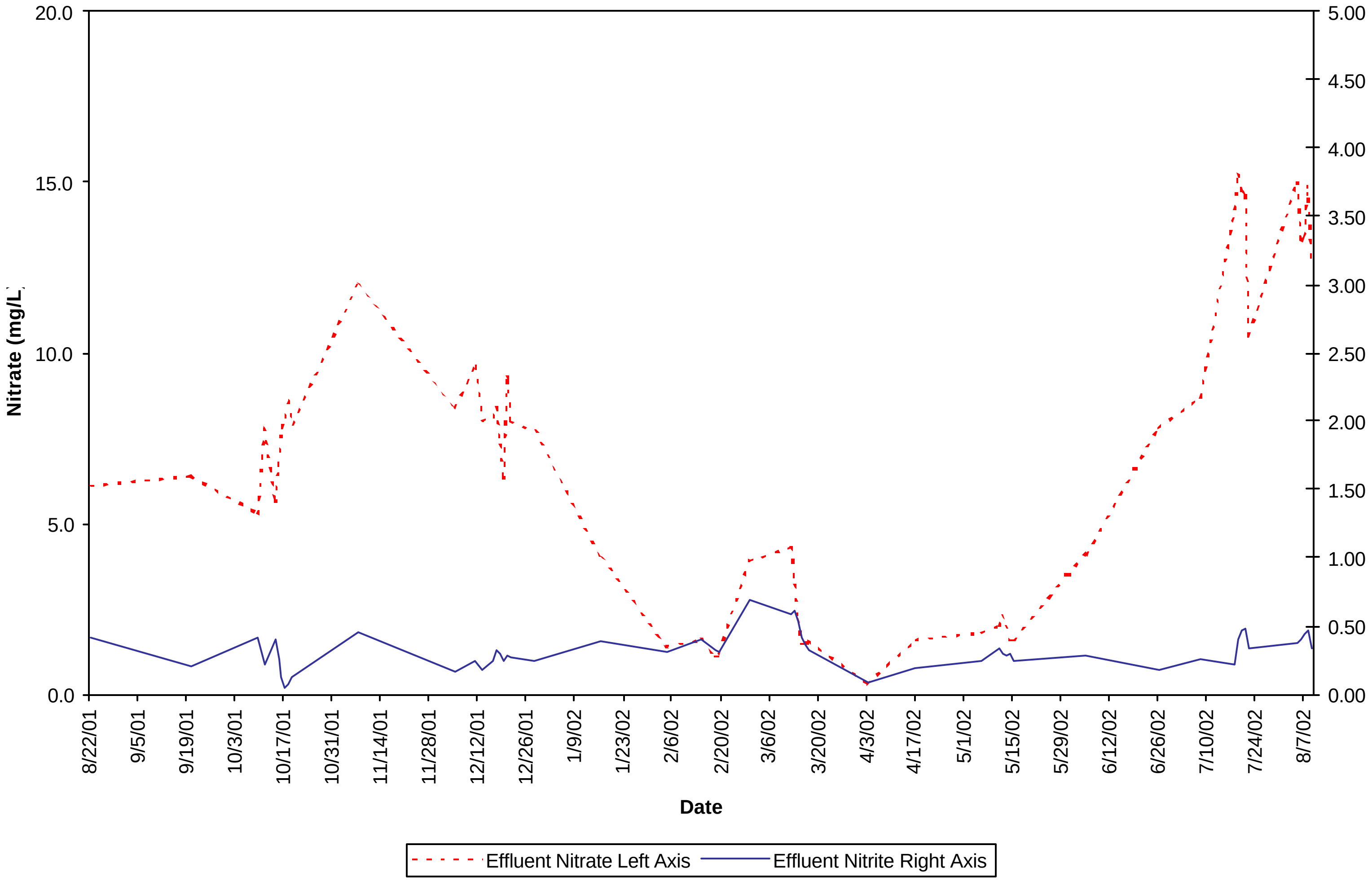

Figure 4-6. SeptiTech® Model 400 System Nitrite and Nitrate Effluent Concentrations

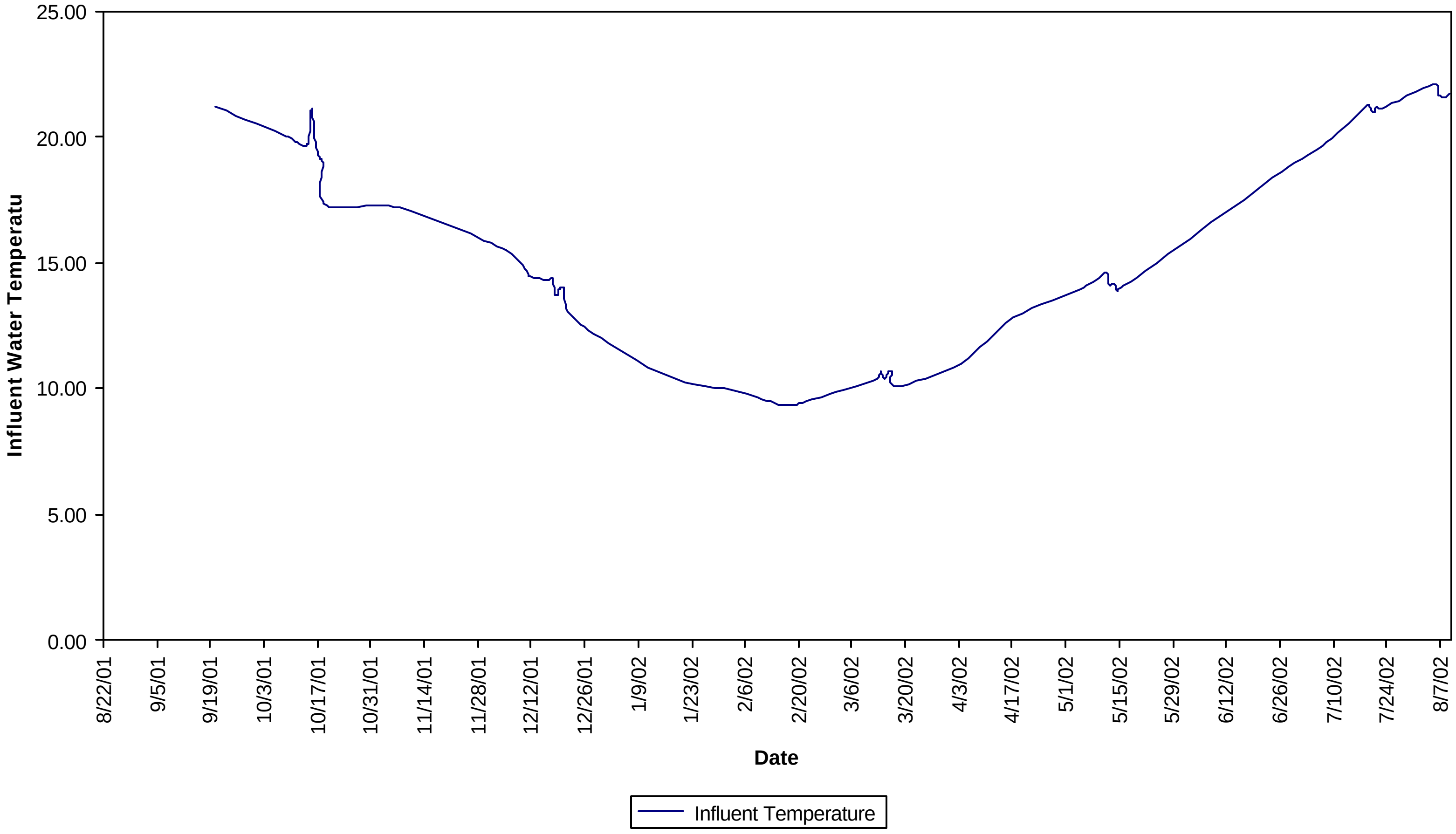

Figure 4-7. SeptiTech$^{®}$ Model 400 System Influent Temperature

Table 4-6. SeptiTech® Model 400 System Influent and Effluent Nitrogen Data

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)
Date	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Effluent
08/22/01	34	2.0	21	0.6	34	8.5	6.1	0.42	N/R
09/20/01	37	2.0	24	1.1	37	8.6	6.4	0.20	19.4
10/09/01	29	5.7	20	4.2	29	11	5.3	0.42	17.6
10/11/01	33	<0.5	21	1.3	33	8.3	7.8	0.22	18.6
10/14/01	39	2.4	25	2.2	39	8.4	5.6	0.40	18.3
10/15/01	42	2.2	24	1.6	42	9.2	6.7	0.26	20.2
10/16/01	35	1.6	23	0.9	35	9.5	7.8	0.13	18.3
10/17/01	36	1.3	24	0.6	36	9.4	8.1	0.04	15.4
10/18/01	43	1.8	24	0.8	43	10	8.6	0.07	13.1
10/19/01	39	2.4	23	1.0	39	10	7.9	0.13	10.4
11/07/01	36	2.8	24	2.1	36	15	12	0.46	17.1
12/05/01	36	0.7	22	1.1	36	9.3	8.4	0.16	16.3
12/11/01	37	1.1	23	0.8	37	11	9.6	0.24	9.9
12/13/01	42	1.1	22	0.8	42	9.3	8.0	0.18	13.4
12/16/01	41	0.7	24	0.7	41	9.0	8.1	0.24	12.8
12/17/01	39	1.1	25	1.0	39	9.8	8.4	0.32	13.0
12/18/01	38	1.0	23	1.5	38	8.6	7.3	0.30	13.3
12/19/01	30	1.4	19	1.2	30	7.9	6.3	0.24	11.4
12/20/01	38	1.4	24	1.8	38	11	9.3	0.28	12.0
12/21/01	39	2.4	25	1.5	39	11	8.0	0.27	12.5
12/28/01	43	2.4	23	1.5	43	10	7.7	0.25	11.1
01/16/02	37	8.9	26	7.3	37	13	4.0	0.39	7.8
02/04/02	38	18	25	14	38	20	1.4	0.31	N/R
02/14/02	31	17	21	14	31	19	1.6	0.40	8.9
02/18/02	36	16	24	14	36	17	1.1	0.32	7.5
02/19/02	36	15	23	13	36	17	1.2	0.31	5.8
02/28/02	39	2.9	23	2.3	39	7.5	3.9	0.70	9.3
03/12/02	39	6.5	26	4.7	39	11	4.3	0.58	9.4
03/13/02	69	8.5	26	6.7	69	12	3.2	0.62	6.5
03/14/02	45	11	29	8.9	45	14	2.2	0.53	10.4

Table 4-6. SeptiTech® Model 400 System Influent and Effluent Nitrogen Data (continued)

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L	Nitrite (mg/L)	Temperature (°C)
Date	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Effluent
03/15/02	49	13	29	9.9	49	15	1.5	0.42	10.5
03/16/02	44	14	29	12	44	16	1.5	0.36	11.6
03/17/02	36	16	24	12	36	18	1.6	0.33	8.8
04/03/02	42	27	25	20	42	27	0.3	0.09	11.3
04/17/02	41	16	23	14	41	18	1.6	0.19	15.7
05/06/02	45	17	28	14	45	19	1.8	0.25	15.1
05/11/02	33	14	22	12	33	16	2.0	0.34	16.7
05/12/02	35	13	22	9.5	35	16	2.3	0.30	16.4
05/13/02	18	12	20	10	18	14	2.0	0.28	N/R
05/14/02	37	13	22	9.7	37	15	1.6	0.30	N/R
05/15/02	39	13	22	10	39	15	1.6	0.25	N/R
06/05/02	36	6.0	25	3.7	36	10	4.1	0.29	17.6
06/26/02	45	2.9	27	1.3	45	11	7.8	0.18	22.4
07/08/02	35	6.9	24	2.4	35	16	8.7	0.26	24.8
07/18/02	37	6.2	24	2.7	37	21	14	0.22	28.2
07/19/02	38	8.8	24	3.2	38	24	15	0.40	27.3
07/20/02	30	5.3	21	3.1	30	20	15	0.47	N/R
07/21/02	43	5.1	23	2.6	43	20	15	0.48	24.4
07/22/02	39	6.5	20	2.4	39	17	10	0.34	24.9
08/05/02	40	<0.5	23	1.4	40	16	15	0.37	26.9
08/06/02	45	6.2	22	1.4	45	20	13	0.40	26.3
08/07/02	41	<0.5	23	0.7	41	14	13	0.44	26.1
08/08/02	43	4.5	26	0.7	43	20	15	0.47	25.6
08/09/02	43	0.7	26	0.8	43	14	13	0.34	24.8
Samples	54	54	54	54	54	54	54	54	48
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	<0.5	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

Values below the detection limit set equal to zero (0) for statistical calculations
N/R – not reported
Note: Effluent samples shown as 2/4/02 and 2/14/02 were actually dated 2/5/02 and 2/13/02.
They were compared to the influent data and influent sample dates were used for comparison purposes.

Table 4-7. SeptiTech® Model 400 System Alkalinity, pH, and Dissolved Oxygen Results

Date	Alkalinity (mg/L as $CaCO_3$)		Dissolved Oxygen (mg/L)		pH (S.U.)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
08/22/01	180	80			7.2	7.2
09/20/01	180	82	0.4	4.5	7.4	7.4
10/09/01	180	100	0.1	4.2	7.4	6.8
10/11/01	190	78	0.1	4.0	7.3	7.0
10/14/01	180	96	<0.1	4.8	7.4	6.8
10/15/01	200	86	0.3	4.6	7.2	7.2
10/16/01	190	80	0.1	4.1	7.1	7.2
10/17/01	180	74	0.3	8.1	7.2	7.3
10/18/01	180	78	0.2	3.8	7.1	7.1
10/19/01	180	78	0.4	4.9	7.2	6.9
11/07/01	180	68	0.4	4.4	7.1	6.7
12/05/01	180	70	0.3	6.1	7.4	7.1
12/11/01	180	64	0.2	5.0	7.3	6.8
12/13/01	190	70	0.2	5.9	7.5	6.8
12/16/01	200	90	0.1	4.8	7.5	7.0
12/17/01	200	90	0.2	4.4	7.5	6.8
12/18/01	190	90	0.1	5.6	7.4	7.1
12/19/01	170	84	0.1	5.7	7.3	7.1
12/20/01	190	82	0.1	5.9	7.6	7.1
12/21/01	180	86	0.5	5.1	7.4	7.2
12/28/01	200	74	0.3	5.5	7.5	6.8
01/16/02	190	110	0.3	7.5	7.6	7.1
02/04/02	170	140	0.5	N/R	7.4	7.4
02/14/02	170	130	0.2	6.2	7.4	7.4
02/18/02	190	140	0.2	7.1	7.5	7.3
02/19/02	180	130	0.3	5.7	7.4	7.4
02/28/02	190	78	0.3	8.0	7.4	7.3
03/12/02	180	90	0.7	8.6	7.4	7.0
03/13/02	200	100	0.4	10	7.3	7.2
03/14/02	190	110	0.4	7.4	7.5	7.3

N/A – not applicable

N/R- not reported

Note: Effluent samples shown as 2/4/02 and 2/14/02 were actually dated 2/5/02 and 2/13/02. They were compared to the influent data and influent sample dates were used for comparison purposes.

Table 4-7. SeptiTech® Model 400 System Alkalinity, pH, and Dissolved Oxygen Results (continued)

Date	Alkalinity (mg/L as $CaCO_3$)		Dissolved Oxygen (mg/L)		pH (S.U.)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
03/15/02	220	120	0.3	7.8	7.5	7.2
03/16/02	200	130	0.4	8.5	7.5	7.2
03/17/02	190	130	0.4	7.9	7.4	7.1
04/03/02	210	180	0.5	7.0	7.3	6.9
04/17/02	190	150	0.1	6.0	7.4	7.5
05/06/02	210	140	0.3	5.6	7.1	7.3
05/11/02	170	120	0.7	6.0	7.7	7.3
05/12/02	180	120	0.6	6.6	7.3	7.3
05/13/02	160	120	0.2	5.2	7.1	7.2
05/14/02	170	120	0.1	5.3	7.3	N/R
05/15/02	180	120	0.1	5.5	7.2	7.1
06/05/02	180	98	0.4	4.5	7.4	7.6
06/26/02	90	72	0.2	3.3	7.3	6.9
07/08/02	150	74	0.2	3.7	7.3	7.2
07/18/02	160	32	<0.1	3.3	7.3	7.0
07/19/02	160	54	0.1	2.2	7.2	6.9
07/20/02	160	62	<0.1	4.3	7.2	7.0
07/21/02	160	57	<0.1	3.4	7.2	7.2
07/22/02	170	54	<0.1	4.9	7.3	7.0
08/05/02	170	44	<0.1	3.7	7.4	7.1
08/06/02	180	40	0.1	3.6	7.4	7.1
08/07/02	180	42	0.2	4.2	7.4	7.0
08/08/02	200	42	<0.1	4.7	7.5	7.0
08/09/02	190	39	0.1	4.6	7.6	7.0
Samples	54	54	53	52	54	53
Average	180	91	0.2	5.5	N/A	N/A
Median	180	85	0.2	5.2	7.4	7.1
Maximum	220	180	0.7	10	7.7	7.6
Minimum	90	32	<0.1	2.2	7.1	6.7
Std. Dev	19	33	0.2	1.6	N/A	N/A

N/A – not applicable
N/R- not reported

4.3.4 Residuals Results

During the treatment of wastewater in the SeptiTech® System, solids accumulate in the primary tank. Inert solids are removed in the primary tank just as in a normal septic tank. Biological solids accumulate from influent wastewater solids and from the recycling of solids generated during aerobic treatment in the processor tank. Eventually, a buildup of solids reduces the capacity of the primary tank and the solids will need to be removed.

The approximate quantity of the residuals accumulated in the system was estimated by measuring the depth of solids in the primary tank. Measurement of solids depth was difficult in the primary tank (septic tank), as access to the unit is limited to manways in the top of the unit. Solids depth was estimated at three locations from each of the two manways using a Core Pro solids-measuring device. A column of water and solids was removed from the tank, and the undisturbed solids depth in the clear tube was measured with a ruler. The measurements were made in February 2002 after 8 months of operation, and again in August 2002 after approximately fourteen months (June 14, 2001 to August 5, 2002) of operation. The results are presented in Table 4-8.

Table 4-8. Solids Depth Measurement

	Primary Tank Solids/Scum Depth in Inches			
Manway Location	East	Middle	West	Average
February 4, 2002-Septic Tank Influent End	26	26	32	28
February 4, 2002-Spetic Tank Effluent End	13	24	27	21
February 4, 2002 Scum Depth on Influent End	0	0	0	0
February 4, 2002 Scum Depth on Effluent End	7	13	4	8
August 5, 2002-Septic Tank Influent End	10	11	11	11
August 5, 2002-Spetic Tank Effluent End	3	1	3	2
August 5, 2002- No scum depth noted				
August 5, 2002-Processor Reservoir	7	6	6	6

In order to characterize the solids in the primary tank, total suspended solids and volatile suspended solids were measured in samples collected in August 2002. These data are presented in Table 4-9. These concentrations represent the solids concentration in the total sample collected, which included the solids and the water present in the sample tube. Based on an average of seven inches of solids present in the tube and an additional 53 inches of water (septic tank sample), the concentration needs to be multiplies by a factor of 8.6 to estimate the actual solids concentration in the settled solids layer.

Table 4-9. TSS and VSS Results for the SeptiTech® Model 400 Solids Samples

Date	Location	TSS (mg/L)	VSS (mg/L)
8/5/02	Septic Tank	1900	1700
8/5/02	Processor Reservoir	1300	930

The mass of solids present in the septic tank can be estimated from these data. The average concentration of solids in the septic tank, 1900 mg/L, multiplied by the tank total volume of 1,500 gallons shows that the solids accumulated during the test was approximately 24 pounds. The percent solids in the settled solids layer can be estimated using the average solids depth of 7 inches and the total water column height of 60 inches. Multiplying the “dilution” ratio of 8.6 (60/7) times the concentration solids (1900 mg/L) shows that the actual solids layer had a concentration of approximately 1.6 % or 16,000 mg/L. The total mass can be estimated using the average depth of solids and the tank dimensions. This calculation estimates the solids mass to be approximately 27 pounds of solids. Both methods give a similar solids estimate.

4.4 Operations and Maintenance

Operation and maintenance performance of the SeptiTech® System was monitored throughout the verification test. A field log was maintained that included all observations made over the thirteen-month test period. Data was collected on electrical and chemical usage, noise, and odor. Observations were recorded on the condition of the system, any changes in setup or operation (pump adjustments, nozzle cleaning, etc.) or any problems that required resolution. A complete set of field logs is included in Appendix G. There were no major mechanical component failures during the verification test. The modem was replaced after a lightening apparently struck the MASSTC electrical and phone system.

4.4.1 Electric Use

Electrical use was monitored by a dedicated electric meter serving the SeptiTech® Model 400 System. The meter reading was recorded biweekly in the field log by BCDHE personnel. Table 4-10 shows a summary of the electrical use from startup through the end of the verification test. The complete set of electrical readings is presented in a spreadsheet in Appendix F. The average electrical use was 8.4 kilowatts per day based on the entire data set. The system tested used four pumps; one pump to dose the media, two pumps to recycle water back to the septic tank, and one pump for the discharge. The unit did not have a fan for supplemental air supply to the filter. The electrical usage measured during the test was higher than the average of 3.93 kilowatts per day stated by SeptiTech in the literature (Appendix A). This is most likely due to the difference in daily volumes processed by the test unit as compared to a typical residential system surveyed by SeptiTech. The SeptiTech data is based on a data set of 14 units with an average daily flow of 124 gpd versus the verification test that challenged the unit at 440 gpd. The pumps would run more often at the higher daily flow using more electricity. In addition, the PLC setup at MASSTC was outside. The PLC must be kept above freezing, so a heater was installed to maintain temperature near 72 ^{0}F. In a normal residential installation, the PLC is placed in the home or the basement so a heater is not required. According to SeptiTech, the heater can use up to 2.4 KWH per day.

Table 4-10. Summary of SeptiTech® Model 400 System Electrical Usage

	KW/day
Readings	194
Average	8.4
Median	8.5
Maximum	19.5
Minimum	1.00
Std. Dev.	2.19

4.4.2 Chemical Use

The SeptiTech® Model 400 System did not require or use any chemical addition as part of the normal operation of the unit.

4.4.3 Noise

Noise levels associated with mechanical equipment were measured once during the verification period. A decibel meter was used to measure the noise level. Measurements were taken one meter from the unit and one and a half meters above the ground, at 90° intervals in four (4) directions. The meter was calibrated prior to use. Table 4-11 shows the results from this test.

Table 4-11. SeptiTech® Model 400 System Noise Measurements

Location	First Reading (decibels)	Second Reading (decibels)	Average
Background	37.5	38.0	37.7
East	60.1	59.0	59.6
South	60.8	61.5	61.2
West	60.0	60.7	60.3
North	59.2	58.9	59.0
All Locations			60.0

Decibels are a log scale so averages are calculated on a log basis

It should be noted that the muffler on the air intake line was removed earily in the test by SeptiTech. The muffler was not reinstalled and the noise tests were run without the muffler in place. The muffler may reduce noise levels, but could also reduce airflow to the unit.

4.4.4 Odor Observations

Monthly odor observations were made over the last eleven months of the verification test. The observation was qualitative based on odor strength (intensity) and type (attribute). Intensity was stated as not discernable; barely detectable; moderate; or strong. Observations were made during periods of low wind velocity (<10 knots). The observer stood upright at a distance of three (3) feet from the treatment unit, and recorded any odors at 90° intervals in four (4) directions (minimum number of points). All observations were made by the same BCDHE employee. During the twelve monthly observations conducted as part of the verification test, there were no discernible odors found during any of the observation periods.

4.4.5 Operation and Maintenance Observations

The basic operation of the system is described in the SeptiTech literature and a short Owner's Manual (Appendix A). Septic tank effluent enters the reservoir in the Processor and mixes with treated water that has passed over the media. There are four pumps in the reservoir. One pump recirculates the water to the top of the unit and sprays the wastewater over the media multiple times per hour. Air is introduced through a passive vent system using a venturi (a fan is not used) to maintain oxygen in the wastewater. The water passes through the media and back into the reservoir. Two pumps recycle wastewater from the reservoir and any accumulated solids back to the septic tank. The wastewater is pumped back to provide a recycle rate of 20 percent of incoming flow. The fourth pump is the discharge pump. This pump removes treated wastewater from the reservoir and discharges it to the receiving system, such as a leach field. The PLC monitors and controls the pump(s) cycle time and pumping duration for each system. The PLC is connected to a modem to allow SeptiTech to remotely monitor the system operation.

During the test, only a few problems were encountered with the operation of the system. The system was cleaned and checked by SeptiTech in July 2001 during the startup period. Cleaning involved simply spraying the top area of the Processor unit with water, using a standard hose under normal potable water pressure, to clean the nozzles and top of the media. The cleaning process did not require any special equipment or procedures. The unit was cleaned using the same procedure in April, May, and June 2002 when SeptiTech was on site to check on the unit or repair equipment, as discussed below. There was no routine maintenance or cleaning performed for the first eight months of the verification test (Aug 2001 to April 2002). The cleaning and checks performed in April and June were done because SeptiTech was called to the site based on observations by the onsite operators (service type call). SeptiTech indicated that they routinely clean and check the system anytime they make a service call for the unit.

In April, it was noted that there was no apparent sound coming from the air vent line or the system, and the effluent appeared cloudy. The problem was reported to SeptiTech and they came to the site check the unit. The system was cleaned, the pump settings were checked, and connections on the PLC verified. The unit appeared in operational order and after resetting the controller, the unit continued in operation.

In May, a SeptiTech representative visited the site to collect samples. During this visit, he sprayed the top of the unit with water to clean the nozzles and media. However, This was not a scheduled maintenance visit, and there was no service call or problem reported to SeptiTech from the test site operators. The fact that a vendor representative performed unscheduled maintenance on the test unit was recorded in the site log books and is provided in this Verification Report for informational purposes. Periodic and unscheduled visits by a vendor representative to a private residence for the purpose spot-checking the treatment system may or may not be part of services included in the vendor's warrantee.

In June, the high alarm activated and a call was placed to SeptiTech. They could not establish a remote connection with the PLC to check on the system, so the MASSTC operator was talked through a reset procedure. This procedure put the system back on line. SeptiTech made a service call and found the discharge pipe had collapsed due to apparent installation problems. It appears that the soil around the pipe had shifted, probably due to ineffective soil compaction at the time of installation. The pipe was repaired and the system operated until the end of the test in August without any additional alarms being activated. As is the case with all septic tank and other underground treatment systems, it is important that great care be taken during installation to properly prepare the soil near the unit. Pipe and connections to underground tanks are susceptible to soil settlement and shifting, which can result in broke or failed connections.

The modem connecting the PLC to the SeptiTech office was also replaced to solve the communication problems that had occurred when trying to access the PLC. The MASSTC site had received a lightening strike that disrupted the electrical system. It appears that a voltage spike was transmitted through the phone lines to the PLC. Once this occurred the unit placed itself in "safe mode" and shut down, thus triggering the high alarm. The modem was replaced and the new modem solved the communication problem. While the system was setup during the test to allow SeptiTech to monitor the System, no changes were made to the system, except those reported to MASSTC personnel.

SeptiTech provides a two-year warranty covering all parts and maintenance. The two-year warranty includes an annual inspection by a SeptiTech technician and free parts and labor for any repairs or upgrades that must be made during the two-year period. SeptiTech recommends that after the two-year warranty, the owner contract for continued maintenance to keep the system in proper working order.

In the opinion of the test site operators, the system was easy to operate and maintain. In fact, there is very little a homeowner can service given the PLC controlled system. The owner can be aware of unusual noises (or lack of sound from the system), alarms, or any unusual odors. If changes to the system are observed, the homeowner is requested to report them to SeptiTech. SeptiTech provides a phone number to call on the unit and the phone number is included in the Owners Manual. The on-line connection for the PLC (an option) allows SeptiTech to remotely check the unit and diagnose controller, pump, and alarm problems. The MASSTC operators believe quarterly maintenance checks of the system would be adequate and appropriate to address any anticipated problems. Based on twelve months of observation, it is estimated that quarterly maintenance checks, requiring about one to two hours by a qualified service provider, would ensure the system is in good operating condition. The skill level needed is the equivalent of a Class II Massachusetts treatment plant operator.

Maintenance activities, provided by a qualified service provider, should include cleaning the nozzles and top of the media. The pump, alarms, and floats should be checked for proper operation using the maintenance mode on the PLC. The vent system should be checked for proper draw and cleared of any obstructions. The PLC controller should be checked, and the modem and communications verified, for installations with that option.

The primary tank should be checked by a qualified service provider for solids depth and if solids have built up in the septic tank, pumping of the septic tank should be scheduled. There is no guidance on the solids depth in the septic tank that would indicate that the tank should be pumped. The SeptiTech manual does indicate that solids removal should occur every 3 to 5 years (a typical or standard practice in residential system). More frequent pumping of solids from the septic tank can be expected based on the additional solids load generated by the Processing system. The regular maintenance checks should include measurement of solids level in the primary tank. When the level of solids buildup to 36 to 42 inches (60 inches of depth available to the outlet) in depth, the tank will need to be pumped to ensure that good solids separation continues in the tank.

The verification test ran for a period of twelve months, which provided sufficient time to evaluate the overall performance of the unit. The equipment seemed to be properly constructed and used appropriate materials of construction for wastewater treatment applications. The use of HDPE and PVC components, pumps designed for wastewater service, and the overall design of the system would indicate that it should have reasonable life expectancy. The verification did not run long enough to truly evaluate length of equipment life or provide life cycle information. The basic components of the system appear durable.
No particular design considerations are necessary relative to placement, as the unit makes little noise.

The Homeowners Manual (Appendix A) provided by SeptiTech provides very basic information on the system. The installation instructions for contractors are brief, but cover the basic requirements.

4.5 Quality Assurance/ Quality Control

The VTP included a QA/QC Plan (QAPP) with critical measurements identified and several QA/QC objectives established. The verification test procedures and data collection followed the QAPP, and summary results are reported in this section. The full laboratory QA/QC results and supporting documentation are presented in Appendices D, E, and F.

4.5.1 Audits

Two audits of the MASSTC and Barnstable County Health Department Laboratory were conducted by NSF during the verification test. These audits, in August 2001 and January 2002, found that the field and laboratory procedures were generally being followed. Recommendations for changes or improvements were made and the responsible organizations responded quickly to these recommendations. The finding of these audits was that the overall approach being used in the field and the laboratory were in accordance with the established QAPP.

The only finding that needed immediate attention during the first lab audit in August 2001 was the lack of method blanks in the nitrite and nitrate tests at the proper frequency. The calibration standards gave a very good linear relationship and the analyses were considered valid. Corrective action was accomplished immediately. All other findings were paper work related, such as updating training records and SOPs. Recommendations were made to improve the detail placed in the field logs, and to be sure, that calibrations were documented and field duplicate samples collected as planned. The second audit in January 2002 found that recommendations had been implemented and no new findings were identified for immediate corrective action. The field and lab managers were reminded of activities that needed to be completed before the end of the test in accordance with the Test Plan.

A third audit was conducted at the end of the verification test. This audit reviewed the records and procedures that were used. A list of documents and data needed for the final report was prepared and discussed with the field and laboratory managers.

Internal audits of the field and laboratory operations were also conducted at least quarterly by BCDHE. These audits specifically reviewed procedures and records for the ETV project. Any shortcomings found during these internal audits were corrected as the test continued.

4.5.2 Daily Flows

One of the critical data quality objectives was to dose the unit on a daily basis to within 10 percent of the design flow. For the SeptiTech® System, the design flow was 440 gpd. The QC objective was to dose the unit at 440 gpd plus or minus 10 percent, based on a monthly average of the daily flows. The dose volume was calibrated twice per week and if the volume changed by more than ten percent the dosing pump run time was adjusted in the PLC. The objective was met for all 12 months of the verification test period. The monthly averages were presented in Table 4-4. The daily flows for all months are presented in spreadsheet format in Appendix F. The field logs in Appendix G provide the twice per week calibration data that is summarized in the spreadsheets.

4.5.3 Precision

Precision measurements were performed throughout the verification test by collection and analysis of duplicate samples. Field duplicates were collected to monitor the overall precision of the sample collection and laboratory analyses. There were three or four similar verification tests running simultaneously at the MASSTC. Field duplicates were generally collected on each sampling day, with the sample selected for replication rotating among the three or four technologies. The results for the field duplicates are presented in a spreadsheet in Appendix D. Summaries of the data are presented in Tables 4-13 through 4-15.

The precision for nitrogen compounds was generally excellent, particularly given the low levels of ammonia, TKN, and nitrate in some of the effluent samples. A few sample results were outside the target window of either 10 percent RPD (nitrite, nitrate) or 20 RPD percent (TKN, NH_3), but in most cases, the results were for samples that were very low in concentration. As an example, one set of data for TKN showed replicate one as 0.9 mg/L and replicate two as 0.5 mg/L with a detection limit of 0.5 mg/L. The calculated RPD for this sample is 57 percent. Even though the relative percent difference (RPD) is high, the data is reasonable given the low concentration found in the samples.

The test plan did not differentiate between laboratory precision and field precision. Typically, field precision targets are wider than laboratory goals to account for sampling variation, in addition to the laboratory variation. Also, the precision goals for nitrite and nitrate were set very tight (10 percent RPD), which would appear to be tighter than required for acceptable wastewater analysis and evaluation of these parameters. Using the 10 percent RPD criteria, 8 out of 49 field duplicates for nitrate exceeded the target, and 7 out of 50 duplicates for nitrite exceeded the window. TKN showed 10 out of 59 field duplicates exceeded the target of 20 percent RPD. Ammonia results were similar with 6 out of 60 samples above the target of 20 percent RPD, with all exceedances for samples having a concentration of less than 1 mg/L.

Table 4-12. Duplicate Field Sample Summary – Nitrogen Compounds

	TKN (mg/L)			Ammonia (mg/L)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	60	60	59	60	60	60
Average	14	15	13	8.9	8.8	11
Median	7.5	8.1	6.5	5.0	5.0	4.5
Maximum	49	51	135	29	28	133
Minimum	<0.5	<0.5	0.0	<0.2	<0.2	0
Std. Dev.	14	14	22	9.1	9.0	21
	Nitrite (mg/L)			Nitrate (mg/L)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	50	50	46	50	50	49
Average	0.32	0.33	5.3	6.9	6.9	6.3
Median	0.30	0.30	2.0	6.2	6.1	4.3
Maximum	0.95	1.1	33	15	15	36
Minimum	<0.05	<0.05	0.0	<0.1	0.70	0.0
Std. Dev.	0.20	0.22	8.4	4.1	4.2	8.3

Table 4-13. Duplicate Field Sample Summary – CBOD, BOD, Alkalinity, TSS

	CBOD$_5$ (mg/L)			BOD$_5$ (mg/L)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	50	50	50	10	10	10
Average	10	10	20	220	210	10
Median	6.7	6.7	14	230	220	11
Maximum	60	54	110	280	270	23
Minimum	1.9	2.3	0.51	140	150	1.1
Std. Dev.	11	9.5	19	44	43	6.6
	TSS (mg/L)			Alkalinity (mg/L as CaCO$_3$)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	60	60	59	60	60	60
Average	32	31	31	120	120	3.4
Median	7	9	12	110	100	1.8
Maximum	260	260	190	220	220	27
Minimum	1	<1	0	56	54	0
Std. Dev.	57	54	43	46	46	5.6

Table 4-14. Duplicate Field Sample Summary – pH, Dissolved Oxygen

	pH (S.U.)			Dissolved Oxygen (mg/L)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	60	55	55	12	12	12
Average	7.4	7.4	0.4	5.9	5.9	0
Median	7.4	7.5	0.1	5.8	5.8	0
Maximum	8.0	8.0	3.8	9.9	9.9	0
Minimum	6.6	6.8	0	2.5	2.5	0
Std. Dev.	1.0	0.3	0.6	2.2	2.2	0
	Calculated using log scale			All replicates gave same value		

The CBOD$_5$ and TSS data tended to have poorer precision than the other analyses, because this data is based on treated effluent samples that are below 10 mg/L. Comparison of average values and median values shows that much of the TSS data is at low concentration. Both CBOD$_5$ and TSS have detection limits of 1 or 2 mg/L. TSS are generally reported to one significant figure at levels below 10 mg/L. It is expected that precision will be poorer at the lower concentrations and near the detection limit of the methods. Further, the influence of variability in sample collection can be seen in this data as well. The laboratory precision data presented in Table 4-17 shows a tighter precision for TSS (13 percent in lab versus 31 percent for field duplicates). The difficulty of getting a well-mixed sample for low level suspended solids undoubtedly added to the lower precision for the TSS test. Overall, the TSS results showed 26 out of 59 samples were outside the target of 20 percent RPD and 18 out of 50 samples were outside the target for CBOD$_5$. Only 2 out of 16 CBOD$_5$ samples exceeded the target when the concentration was above 10 mg/L. While this data indicates that precision is lower at the lower concentrations, the overall data set provides the needed information that showed the ability of the treatment unit to reduce TSS and CBOD$_5$ in the wastewater. Laboratory procedures, calibrations, and data were audited and found to be in accordance with the published methods and good laboratory practice.

The laboratories performed lab duplicates on a frequency of at least one per batch or 10 percent of samples. The laboratory precision data is summarized in Tables 4-16 and 4-17. The various nitrogen analyses showed excellent precision, as did the alkalinity results. Nitrite results showed no samples (60 total) exceeded the tight target of 10 percent RPD. Nitrate results showed 14 out of 211 values exceeded the 10 percent RPD target, but only 1 result out of 211 exceeded a 20 percent difference. Only one ammonia duplicate out of 53 was outside the ± 20% RPD objective for field duplicates, and only 4 out of 59 TKN replicates exceeded ± 20%. The laboratory duplicates included ETV samples and other samples that were part of the GAI batch runs.

The CBOD$_5$ and TSS precision was generally within the target objective of 20 percent RPD, except when the concentrations were low. As discussed earlier, when effluent samples were below 10 mg/L the calculated percent differences were higher, as would be expected. The CBOD$_5$ and BOD$_5$ analyses used very similar procedures, and were performed together under the same conditions in the laboratory. The BOD$_5$ data showed much higher precision (average of 8 percent) than the CBOD$_5$ (average 15 percent). This is primarily due to the higher concentrations of BOD_5 (influent wastewater samples). In summary, 18 out of 57 results exceeded the $CBOD_5$ target of 20 percent RPD, but none of the samples over 10 mg/L exceeded the target (0 out of 17); BOD_5 results showed 7 out of 64 results were above the target; and 8 out of 44 TSS samples showed RPD above 20 percent. On-site audits and review of procedures and calibrations indicated that good laboratory practice was being followed. There were no identified, systematic errors that would account for the difference. The data for all analyses was judged acceptable and useable for evaluating the treatment efficiency.

Table 4-15. Laboratory Precision Data – Nitrogen Compounds

	TKN	Ammonia	Nitrite	Nitrate
Statistics	RPD	RPD	RPD	RPD
Number	59	53	67	211
Average	7.6	3.1	2.7	3.1
Median	4.7	0	0.0	2.1
Maximum	55	36	18	25
Minimum	0.0	0	0.0	0.0
Std. Dev.	11	6.6	4.3	3.7

Table 4-16. Laboratory Precision Data – $CBOD_5$, BOD_5, Alkalinity, TSS

	$CBOD_5$ (mg/L)			BOD_5 (mg/L)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	57	57	57	64	64	64
Average	18	18	15	160	160	7.7
Median	5.9	6.7	7.6	170	170	4.4
Maximum	100	100	73	500	530	32
Minimum	<2.0	2.0	0	<2.0	<2.0	0
Std. Dev.	24	24	15	120	120	8.1
	TSS (mg/L)			Alkalinity (mg/L as $CaCO_3$)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	44	44	44	48	48	48
Average	72	73	13	83	84	6.1
Median	52	54	5	80	80	1.8
Maximum	290	310	130	190	190	40
Minimum	1	4	0	2	2	0
Std. Dev.	73	72	24	58	59	12

4.5.4 Accuracy

Method accuracy was determined and monitored using a combination of matrix spikes and lab control samples (known concentration in blank water) depending on the method. Recovery of the spiked analytes was calculated and monitored during the verification test. Accuracy was in control throughout the verification test. All TKN and ammonia recoveries for lab control samples were within the accuracy window of 80 to 120 percent. Matrix spike samples for TKN and ammonia, in real world samples not necessarily ETV samples, were generally within the window of 70 to 130 percent recovery. One matrix spike sample out of 50 was low for ammonia and 4 samples gave low recoveries for TKN. Each data set was examined and each dataset was judged valid and useable. All recoveries for all spiked samples for alkalinity, BOD_5, nitrite, and nitrate were within the established windows. Only 1 result out of 51 spiked samples was outside the recovery target for $CBOD_5$. Tables 4-18 and 4-19 show a summary of the recovery data. All quality control data is presented in Appendix D.

Table 4-17. Accuracy Results – Nitrogen Analyses

	TKN (% Recovery)		Ammonia (% Recovery)	
Statistics	Matrix Spike	Lab Control Sample	Matrix Spike	Lab Control Sample
Number	54	59	50	57
Average	95	100	99	107
Median	96	99	100	107
Maximum	137	114	112	120
Minimum	62	86	51	91
Std. Dev.	16	6.2	9.3	7.2
	Nitrite (% Recovery)		Nitrate (% Recovery)	
Statistics	Matrix Spike	Lab Control Sample	Matrix Spike	Lab Control Sample
Number	50	54	24	119
Average	104	99	98	99
Median	104	99	97	98
Maximum	123	120	113	116
Minimum	80	82	85	81
Std. Dev.	10	9.7	8.4	8.0

Table 4-18. Accuracy Results – CBOD, BOD, Alkalinity

	$CBOD_5$ (% Recovery)	BOD_5 (% Recovery)	Alkalinity (% Recovery)
Statistics	Lab Control Sample	Lab Control Sample	Lab Control Sample
Number	51	54	61
Average	100	101	100
Median	101	101	100
Maximum	106	109	113
Minimum	77	84	93
Std. Dev.	5	4	3

The balance used for TSS analysis was calibrated routinely with weights that were NIST traceable. Calibration records were maintained by the laboratory and inspected during the on site audits. The temperature of the drying oven was also monitored using a thermometer that was calibrated with a NIST traceable thermometer. The pH meter was calibrated using a three-point calibration curve with purchased buffer solutions of known pH. Field temperature measurements were performed using a thermometer that was calibrated using a NIST traceable thermometer provided to the field lab by the BCDHE laboratory. The dissolved oxygen meter was calibrated daily using ambient air and temperature readings in accordance with the SOP. The noise meter was calibrated prior to use and all readings were recorded in the field logbook. All of these traceable calibrations were performed to ensure the accuracy of measurements.

4.5.5 Representativeness

The field procedures, as documented in the MASSTC SOPs (Appendix C), were designed to ensure that representative samples were collected of both influent and effluent wastewater. The composite sampling equipment was calibrated on a routine basis to ensure that proper sample volumes were collected to provide flow weighted sample composites. Field duplicate samples and supervisor oversight provided assurance that procedures were being followed. As discussed earlier, the challenge in sampling wastewater is obtaining representative TSS samples and splitting the samples into laboratory sample containers. The field duplicates showed that there was some variability in the duplicate samples. However, based on 60 sets of field duplicates, the overall average TSS of the replicates was very close (32 and 31 mg/L). This data indicated that while individual sample variability may occur, the long-term trend in the data was representative of the concentrations in the wastewater.

The laboratories used standard analytical methods and written SOP's for each method to provide a consistent approach to all analyses. Sample handling, storage, and analytical methodology were reviewed during the on-site and internal audits to verify that standard procedures were being followed. The use of standard methodology, supported by proper quality control information and audits, ensured that the analytical data was representative of the actual wastewater conditions.

4.5.6 Completeness

The VTP set a series of goals for completeness. During the startup and verification test, flow data was collected for each day and the dosing pump flow rate was calibrated twice a week as specified. The flow records are 100 percent complete. Electric meter records were maintained in the field logbook. Electric meter readings were performed twice a week and summarized in a spreadsheet. Only one electric meter reading was missed (the first reading at startup) during the startup and verification test. Out of 195 readings, one was incomplete giving a completeness of 99 percent complete.

The goal set in the VTP for sample collection completeness for both the monthly samples and stress test samples was 83 percent. All monthly samples were collected and all stress test samples were collected in accordance with the VTP schedule. Therefore, sample collection was 100 percent complete.

A goal of 90 percent was set for the completeness of analytical results from the BCDHE laboratory and GAI. All scheduled analyses for delivered samples were completed and found to be acceptable, useable data. Completeness is 100 percent for the laboratory.

5.0 References

5.1 Cited References

(1) NSF International, *Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction*, November 2000, Ann Arbor, Michigan.

(2) USEPA, *Wastewater Technology Fact Sheet Trickling Filter Nitrification*, September 2000, Office of Water, Washington D.C., EPA 832-F-00-015

(3) USEPA, *Manual for Nitrogen Control*, 1993, 625/R-93/010

(4) NSF International, *Test Plan for The Massachusetts Alternative Septic System Test Center for Verification Testing of SeptiTech Nutrient Reduction Technology*, August 2001

(5) United States Environmental Protection Agency: *Methods and Guidance for Analysis of Water*, EPA 821-C-99-008, 1999. Office of Water, Washington, DC.

(6) United States Environmental Protection Agency*: Methods for Chemical Analysis of Water and Wastes*, Revised March 1983, EPA 600/4-79-020

(7) APHA, AWWA, and WEF: *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, 1998. Washington, DC.

5.2 Additional Background References

(8) United States Environmental Protection Agency: *Environmental Technology Verification Program - Quality and Management Plan for the Pilot Period (1995 – 2000)*, USEPA/600/R-98/064, 1998. Office of Research and Development, Cincinnati, Ohio.

(9) NSF International, Environmental Technology Verification – *Source Water Protection Technologies Pilot Quality Management Plan*, 2000. Ann Arbor, Michigan.

(10) United States Environmental Protection Agency: *USEPA Guidance for Quality Assurance Project Plans, USEPA QA/G-5*, USEPA/600/R-98-018, 1998. Office of Research and Development, Washington, DC

(11) United States Environmental Protection Agency, *Guidance for the Data Quality Objectives Process, USEPA QA/G-4*, USEPA/600/R-96-055, 1996. Office of Research and Development, Washington, DC.

(12) ANSI/ASQC*: Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (E4)*, 1994.

Appendix A

SeptiTech Literature and
Homeowners Manual
Contactor Design and Installation Information

Appendix B

Verification Test Plan

Appendix C

MASSTC Field SOP’s

Appendix D

Lab Data and QA/QC Data

Appendix E

Field Lab Log Book

Appendix F

Spreadsheets with calculation and data summary

Appendix G

Field Operations Logs