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Environmental Technology Verification Report

Reduction of Nitrogen in Domestic Wastewater from Individual Residential Homes

AQUAPOINT, Inc.
Bioclere™ Model 16/12

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:	**BIOCLERE™ MODEL 16/12**	
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NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of a fixed film trickling filter biological treatment system for nitrogen removal for residential homes. This verification statement provides a summary of the test results for the Aquapoint, Inc. Bioclere™ Model 16/12 system. The Barnstable County (Massachusetts) Department of Health and the Environment (BCDHE) performed the verification testing.

The EPA created the Environmental Technology Verification (ETV) Program to facilitate deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups consisting of buyers, vendor organizations, and permitters, and the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and verifiable quality are generated and that the results are defensible.

ABSTRACT

Verification testing of the Aquapoint, Inc. (AQP) Bioclere™ Model 16/12 was conducted over a thirteen month period at the Massachusetts Alternative Septic System Test Center (MASSTC), located at Otis Air National Guard Base in Bourne, Massachusetts. Sanitary sewerage from the base residential housing was used for the testing. An eight-week startup period preceded the verification test to provide time for the development of an acclimated biological growth in the Bioclere™ 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 Bioclere™ system proved capable of removing ammonia nitrogen in the aerobic unit and nitrate in the anaerobic/anoxic primary tank. The influent total nitrogen (TN), as measured by the TKN, averaged 37 mg/L with a median of 38 mg/L. The effluent TN average 16 mg/L over the verification period, with a median concentration of 14 mg/L, which included an average TKN concentration of 10 mg/L and a median concentration of 6.3 mg/L. The system operating conditions (pump and timer settings) remained constant during the test. Only routine maintenance and system checks were performed for most of the test, except when a nozzle-plugging problem occurred. The plugged nozzles impacted treatment performance, but performance improved quickly once they were cleared.

TECHNOLOGY DESCRIPTION

The AQP, Inc. Bioclere™ Model 16/12 uses a fixed film trickling filter for wastewater treatment. A complete treatment system has two stages of treatment. The first stage of treatment occurs in the primary tank (a 1,000 gallon single compartment septic tank) in which the solids are settled and partially digested. Septic tank effluent flows by gravity to the Bioclere™ unit, which is a separate system that provides secondary wastewater treatment. Microorganisms present in the wastewater attach to the Bioclere™ proprietary plastic filter media, and use the nutrients and organic materials provided by the constant supply of fresh wastewater to form new cell mass. The open spaces within the media allow air to freely pass through, providing oxygen to support the microorganisms.

The system has a recycle line for pumping of recycled solids from the Bioclere™ clarifier section (located below the plastic media) back to the primary tank. The pump operated for 1.5 minutes every 2.5 hours during the test, controlling the recycle rate to the primary tank. A dosing pump, set to run on a 3 minutes on/5 minute off cycle, circulated treated effluent from the clarifier section back the top of the unit, where the wastewater is sprayed over the media using a manifold and nozzle system. Air (oxygen) is supplied to the Bioclere™ by a fan located on the top of the unit, which runs continuously.

The Bioclere™ system is designed to remove total nitrogen from the wastewater by nitrification and denitrification. Nitrification occurs in the aerobic Bioclere™ unit, where ammonia nitrogen is converted to nitrite and nitrate (predominately nitrate). Denitrification occurs in the anaerobic/anoxic primary tanks, where the nitrite/nitrate is converted to nitrogen. The verification testing was performed using a full scale, commercially available unit, which was received as a self-contained system ready for installation.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site, initially funded by the State of Massachusetts and operated by BCDHE, is located at the Otis Air National Guard Base in Bourne, Massachusetts. The site uses domestic wastewater from the base residential housing and sanitary wastewater from other military buildings for use in testing. A chamber located in the main sewer line upstream of 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, which are spaced along the channel length to ensure mixing such that the wastewater is of similar quality at all locations along the channel. Wastewater is dosed to the test unit using a pump submerged in the dosing channel. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle.

Methods and Procedures

All methods and procedures followed the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction,* dated November 2000. The Bioclere™ was installed by a contractor, in conjunction with the BCDHE support team in June 1999 as part of an earlier test program. The unit was installed in accordance with the Operations and Maintenance Manual supplied by AQP. In order to prepare for ETV testing, the entire Bioclere™ system was emptied of wastewater and cleaned. Solids were removed from the primary tank and the clarifier section of the Bioclere™ filter unit. All pumps, lines, and associated equipment were cleaned. The filter media was repeatedly flushed and solids removed from the bottom of the unit. Clean water was recirculated to further clean the media and lines. The entire unit was then drained and remained off until the startup period.

In early January 2001, fresh water was added to the unit and the system was cycled for several days to make sure the unit was operating properly, the dosing pumps were calibrated, and the PLC was working properly. An eight-week startup period, following the startup procedures in the AQP Technical Manual, allowed the biological community to become established and allowed the operating conditions to be monitored. Startup of the cleaned Bioclere™ system began on January 15, 2001, when the primary tank was filled approximately two thirds (2/3) full with clean water and one third (1/3) with raw wastewater from the dosing channel. The dosing sequence was then started, with the unit's pumps and timers on the factory default settings.

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

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

The Bioclere^{TM} system has a design capacity of 400 gallons per day. The verification test was designed to load the system at design capacity (± 10 percent) for the entire thirteen-month test, except during the low load and vacation stress tests. The Bioclere™ system was dosed 15 times per day with approximately 26-27 gallons of wastewater per dose. The unit received five doses in the morning, four doses mid-day, and six doses in the evening. The dosing volume was controlled by adjusting the pump run time for each cycle, based on twice weekly pump calibrations.

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

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

PERFORMANCE VERIFICATION

Overview

Evaluation of the AQP Bioclere™ Model 16/12 at MASSTC began on January 15, 2001, when the Bioclere™ pumps and timers were activated, and the initial dosing cycles activated. Flow was set at 400 gpd, resulting in 15 doses per day with a target of 26.7 gallons per dose. The startup period continued until March 13, 2001. Six samples of the influent and effluent were collected during the startup period. Verification testing began on March 13, 2001 and continued for 13 months until April 17, 2002. The extra month of dosing and sampling (13 months versus the planned 12 months) was added to the test to obtain data on the system response as the temperatures began to rise in the spring. During the verification test, 53 sets of samples of the influent and effluent were collected to determine the system performance.

Startup

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

The Bioclere™ system performance for $CBOD_5$, TSS, and TN remained relatively steady throughout the startup period. Effluent $CBOD_5$ varied between 13 and 51 mg/L, with the lowest value at the end of the startup period. There was some indication of TN reduction occurring, with effluent concentrations varying between 27 and 36 mg/L compared to influent concentrations of 34 to 46 mg/L. However, it did not appear that the nitrifying organisms had established themselves in the system. Low wastewater and ambient temperatures were considered the primary reason for the slow trend toward improved reduction in both $CBOD_5$ and TN. The temperature of the effluent wastewater was about 5 ^oC when the unit was started and remained in the 5 to 7 ^oC range through March 13.

Verification Test Results

The daily dosing schedule during normal operations remained constant through the entire verification test. A daily dosing sequence of 15 doses was performed every day except during the low load (September 2001) and vacation stress (February 2002) periods. Volume per dose and total daily volume varied only slightly during the test period. The daily volume averaged on a monthly basis ranged from 387 to 407 gallons per day. This compared closely to the 400 gallons per day design capacity.

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

The TSS and BOD_5/$CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1. The influent wastewater had an average BOD_5 of 210 mg/L and a median BOD_5 of 200 mg/L. The TSS in the influent averaged 160 mg/L and had a median concentration of 140 mg/L. The Bioclere™ effluent showed an average $CBOD_5$ of 14 mg/L with a median $CBOD_5$ of 10 mg/L. The average TSS in the effluent was 16 mg/L and the median TSS was 10 mg/L. $CBOD_5$ concentrations in the effluent typically ranged from 4 to 20 mg/L, and TSS ranged from 4 to 17 mg/L, except during an apparent upset condition that occurred in July 2001.

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	210	14	93	160	16	90
Median	200	10	95	140	10	93
Maximum	380	60	98	410	62	98
Minimum	72	3.5	78	40	2	63
Std. Dev.	70	11	5.0	71	16	7.0

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

The nitrogen results for the verification test, including all stress test periods, are shown in Table 2. The influent wastewater had an average TKN concentration of 37 mg/L, with a median value of 38 mg/L, and an average ammonia nitrogen concentration of 23 mg/L, with a median of 23 mg/L. Average TN concentration in the influent was 37 mg/L (median of 38 mg/L) based on the assumption that the nitrite and nitrate concentrations in the influent were negligible. The Bioclere™ effluent had an average TKN concentration of 10 mg/L and a median concentration of 6.3 mg/L. The average NH_3-N concentration in the effluent was 6.2 mg/L and the median value was 2.8 mg/L. The nitrite concentration in the effluent was low, averaging 0.45 mg/L. Effluent nitrate concentrations averaged 5.3 mg/L with a median of 4.4 mg/L. Total nitrogen was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), nitrite and nitrate. Average TN in the Bioclere™ effluent was 16 mg/L (median 14 mg/L) for the thirteen month verification period. The Bioclere™ system averaged a 57 percent reduction of TN for the entire test, with a median removal of 64 percent.

Verification Test Discussion

Beginning in late March and early April, temperatures began to increase and the nitrifying population clearly became established, as indicated by the decrease in the TKN and NH_3 concentrations in the effluent. Nitrate concentrations increased somewhat in this same period, but the data show that denitrification was also occurring. The concentration of organic matter in the effluent, as measured by $CBOD_5$ and TSS concentrations, also decreased. During May and June, the TN concentration in the effluent was in the range of 8.8 to 11 mg/L. The Washday stress test in May 2001 showed no negative impact on nitrogen reduction.

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	37	10	23	6.2	37	16	5.2	0.45	15
Median	38	6.3	23	2.8	38	14	4.4	0.34	15
Maximum	46	35	27	22	46	36	14	1.5	23
Minimum	24	1.9	18	0.7	24	6.2	<0.1	0.07	7.4
Std. Dev.	4.4	10	2.1	7.0	4.4	8.4	3.5	0.26	4.9

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

In early July 2001, the data show that there was loss of the nitrifying population in the unit, with total nitrogen levels in the effluent of 25 to 36 mg/L. The effluent concentrations of $CBOD_5$ and TSS also increased during this time, indicating the system was under stress. It was discovered that two of the nozzles in the Bioclere™ unit were clogged. AQP responded to the problem and cleaned the nozzles, and within two to three weeks, the TN concentration decreased to 9.4 mg/L, similar to the period before the problem occurred. The $CBOD_5$ and TSS levels in the effluent also decreased, returning to the levels measured before the nozzle plugging occurred. The loss of nitrogen and $CBOD_5$ removal efficiency during the nozzle-plugging problem makes it unclear whether the Working Parent dose sequence would have had an impact on the system.

Once the nitrifying population was reestablished, the Bioclere™ system continued to reduce the total nitrogen concentration on a consistent basis (7.7 to 11 mg/L) until December. This period included the Low Dose sequence, when the Bioclere™ was dosed with 50 percent of the daily design loading, which appears to have had no impact on the system operation. The temperature of the wastewater began to decrease in October, as would be expected. While the trend was not clear, the late November sample indicated a lower removal of nitrogen was occurring as compared to September and October. The Power Failure stress test (power shut off for 48 hours) was started on December 3, 2001. Sample results for the post stress period showed effluent total nitrogen had increased to 18 mg/L, while subsequent monitoring over the next few weeks showed the total nitrogen concentration to be in the range of 6.2 to 19 mg/L. Most of the concentrations were in the 13 to 19 mg/L range, with influent levels of 35 to 46 mg/L. The lower nitrogen removal efficiencies in the December to February period correspond to lower temperatures in the wastewater. It appears that the Power Failure stress test may have contributed to the change in efficiency by stressing the nitrifying population. The lower temperatures in the wastewater appeared to have slowed the total nitrogen removal and possibly the re-establishment of the nitrifying population.

The Vacation stress test in February had no noticeable impact on the system performance for nitrogen removal. The last scheduled samples for total nitrogen in the first week of March showed that the Bioclere™ system was removing TN in the 60 to 66 percent range, somewhat lower than the efficiencies of the previous summer and fall. The temperature of the wastewater appeared to have an effect on the nitrogen reduction levels based on both the startup data and on the December 2001 to February 2002. The test period was extended one additional month to determine if removal would improve as the wastewater temperature increased. The final sample showed a sharp decrease in TN from 16 mg/L on March 8 to 8 mg/L on April 17. During this period, the temperature of the wastewater increased to 14.3 °C from 9.2 °C.

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 49.5, with a minimum of 45.5 and maximum of 52.8. 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 found during any of the observation periods.

Electrical use was monitored by a dedicated electric meter serving the Bioclere™ system. The average electricity use was 4.2 kW/day. The Bioclere™ system does not require or use any chemical addition as part of the normal operation of the unit.

During the test, very few problems were encountered with the operation of the system with the exception of the plugged nozzles after five and half months of operation. The plugging problem was discovered when the effluent's visual characteristic changed and had notably more suspended solids. In addition, during the nozzle plugging, the noise level of the spray hitting the inside of the media containment structure was slightly louder, signaling higher flow through one of the nozzles and overloading of a portion of the media bed. The nozzles were cleaned again in the fall by AQP in accordance with the quarterly maintenance check recommended in their O&M manual. AQP installed a new set of helical nozzles in January 2002. These nozzles required no additional cleaning through the remainder of the test. AQP believes that the nozzle plugging problem was a unique occurrence as this type of unit had been operated at MASSTC and many other locations without a problem. AQP added a statement regarding the nozzle issue at the end of the Verification Report.

Routine quarterly maintenance by a person knowledgeable of the treatment system was recommended in the O&M manual, and was confirmed to be appropriate by the BCDHE staff during the test. The maintenance should involve checking the two pumps (recirculating and recycling), the fan, and cleaning the distribution manifold and nozzles. The maintenance check should also include measurement of the sludge depth in the primary tank, observation of the condition of the media, and a visual inspection of the effluent. Pump cycle times should be verified and alarms checked.

The treatment unit itself proved durable for the duration of the test and appears to generally be a durable fiberglass design. The piping is standard PVC that is appropriate for the applications. Pump and level switch life are always difficult to estimate, but the components used are made for wastewater applications by a reputable and known manufacturer.

Quality Assurance/Quality Control

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

Original signed by *Hugh W. McKinnon* *5/30/03*	*Original signed by* *Gordon E. Bellen* *6/3/03*
Hugh W. McKinnon Date Director National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency	Gordon E. Bellen Date Vice President Research NSF International

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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From Individual Residential Homes

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Bioclere™ Model 16/12

Prepared for

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Prepared by

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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 following is the final report on an Environmental Technology Verification (ETV) test performed for NSF International (NSF) and the United States Environmental Protection Agency (EPA) by the Barnstable County Department of Health and Environment (BCDHE). Scherger Associates prepared the Verification Report. The verification test was conducted from January 2001 through April 2002 at the Massachusetts Alternative Septic System Test Center (MASSTC) test site in Bourne, Massachusetts.

Throughout its history, the EPA has evaluated the effectiveness of innovative technologies to protect human health and the environment. A new EPA program, the Environmental Technology Verification Program was developed to verify the performance of innovative technical solutions to environmental pollution or human health threats. ETV was created to substantially accelerate the entrance of new environmental technologies into the domestic and international marketplace. Verifiable, high quality data on the performance of new technologies are made available to end users regulators, developers, consulting engineers, and those in the public health and environmental protection industries. This encourages rapid availability of approaches to better protect the environment.

The EPA has partnered with NSF, an independent, not-for-profit testing and certification organization dedicated to public health, safety and protection of the environment, to verify performance of various treatment systems designed to remove pollutants and protect water used as a source for drinking water and other uses under the Source Water Protection (SWP) area of the Water Quality Protection Center (WQPC). A goal of verification testing is to enhance and facilitate the acceptance of small treatment systems and equipment by state regulatory officials and consulting engineers, while reducing the need for testing of equipment at each location where the equipment's use is contemplated. NSF meets this goal by working with manufacturers and NSF-qualified Testing Organizations (TO) to conduct verification testing under the approved protocols. The Barnstable County Department of Health and Environment is one such TO.

NSF is conducting the WQPC-SWP with participation of manufacturers, under the sponsorship of the EPA Office of Research and Development, National Risk Management Research Laboratory, Urban Watershed Management Branch, Edison, New Jersey. It is important to note that verification of the equipment does not mean that the equipment is "certified" by NSF or "accepted" by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the TO.

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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 EPA 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
AQP	Aquapoint, Inc.
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
EPA	United States Environmental Protection Agency
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/NH_4	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, EPA
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
VO	Verification Organization
VR	Verification Report
VTP	Verification Test Plan
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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The laboratories that conducted the analytical work for this study were:

Barnstable County Department of Health and the Environment Laboratory
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Barnstable MA 02630
(508) 375-6606
Contact: Dr. Thomas Bourne
Email: bcdhelab@cape.com

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

The Manufacturer of the Equipment was:

Aquapoint, Inc.
241 Duchaine Blvd.
New Bedford, MA 027455
(508) 998-7577
Contact: Mr. John Lafreniere
Email: aquapoint@aquapoint.com

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 under ETV. Source Water Protection (SWP) is one area within the WQPC. The WQPC-SWP evaluated the performance of the Aquapoint (AQP) Bioclere™ Model 16/12 for the reduction of nitrogen (TKN, NH_3, NO_2, NO_3) present in residential wastewater. AQP sells the Bioclere™ to treat wastewater from single-family homes, small commercial businesses, and similar applications. The unit is designed to replace conventional septic tank systems and to provide nitrogen reduction in addition to the removal of organics and solids present in these wastewaters. The Bioclere™ system is based on fixed film trickling filter technology and uses highly permeable plastic filter media. This document provides the verification test results for the AQP Bioclere™ Model 16/12, 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 Bioclere™ system 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 for the WQPC and the Source Water Protection (SWP) area within the center. NSF administers the center, and contracts the Testing Organization to develop and implement the 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

The EPA 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. The 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 EPA 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., provided the laboratory services for the testing program and provided consultation on analytical issues addressed during the verification test period.

The responsibilities of the TO included:

- Preparation of the site specific Verification Test Plan;

- Conducting Verification Testing, according to the Verification Test Plan;
- Installation, operation, and maintenance of the Bioclere™ system in accordance with the Vendor's O&M manual(s);
- Controlling access to the area where verification testing was carried out;
- Maintaining safe conditions at the test site for the health and safety of all personnel involved with verification testing;
- Scheduling and coordinating all the 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;
- Managing, evaluating, interpreting and reporting on data generated by verification testing;
- Evaluation and reporting 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
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Mr. Sean Foss, Facility Operations Manager:
Barnstable County Department of Health and the Environment
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Dr. Thomas Bourne, Laboratory Manager
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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 was the Bioclere™ Model 16/12 sold by AQP. AQP 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 period. Specific responsibilities of the vendor include:

- Initiate application for ETV testing;
- Provide input regarding the verification testing objectives to be incorporated into the Verification Test Plan;
- 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 AQP is:

Mr. John Lafreniere
Aquapoint, Inc.
241 Duchaine Blvd.
New Bedford, MA 027455
(508) 998-7577
Email: Aquapoint@aquapoint.com

1.2.5 ETV Test Site

The Massachusetts Alternative Septic System Test Center (MASSTC) was the host site for the nutrient reduction verification test. MASSTC was initially funded by the State of Massachusetts. The Barnstable County Department of Health and the Environment operates the center and provides all staff for the center. 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. 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 wastewater and a sampling arrangement to collect representative samples;
- Automatic influent pumping 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.

1.3 Background – Nutrient Reduction

Domestic wastewater contains various physical, chemical and bacteriological constituents, which require treatment prior to release to the environment. Various wastewater treatment processes exist which provide for the reduction of oxygen demanding materials, suspended solids and pathogenic organisms. Reduction of nutrients, principally phosphorus and nitrogen, has been practiced since the 1960's at treatment plants where there is a specific need for nutrient reduction to protect the water quality and, hence, the uses of the receiving waters, whether ground water or surface water. 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 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 inputs helps 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 can remove nutrients in on-site domestic wastewater. The Bioclere™ Process is based on the fixed film (trickling filter) biological process for nitrification and the anoxic conditions in the septic tank for biological denitrification. A brief discussion of these processes is given below.

1.3.1 Fixed Film Trickling Filter - Biological Nitrification

The EPA has published a fact sheet describing the nitrification process in trickling filter systems, *Wastewater Technology Fact Sheet Trickling Filter Nitrification,* EPA September 2000 [(2)]. This fact sheet provided the information presented below. A more comprehensive source of information is the EPA 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 important 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. The third major 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. Above 10 °C, the nitrification rate increases with temperature, and reaches a maximum at 30 to 35 °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 7.1 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 4.6 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 the nitrate 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 significantly 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 (as $CaCO_3$) are produced per pound of nitrate nitrogen removed.

2.0 Technology Description and Operating Processes

2.1 Technology Description

The AQP, Inc. Bioclere™ Model 16/12 uses a fixed film trickling filter for wastewater treatment. Trickling filters consist of a bed of highly permeable media over which wastewater is applied and allowed to trickle through. The Bioclere™ uses a proprietary plastic filter media. Microorganisms present in the wastewater attach to this media and use the nutrients and organic materials provided by the constant supply of fresh wastewater to form new cell mass. The open spaces within the media allow air to freely pass through, providing oxygen to support the microorganisms.

In the trickling filter, the organic material in the wastewater is degraded by microorganisms attached to the media in the form of a biological film or slime layer. The outer portions of the slime layer remain aerobic. As the microorganisms multiply, the thickness of the slime layer increases and the diffused oxygen is consumed before it can penetrate the full depth of the layer, resulting in an anaerobic environment near the surface of the media. As the layer increases in thickness, the absorbed organic matter is metabolized before it can reach the microorganisms near the media face. As a result, of having no external organic source available for cell carbon, the microorganisms near the media face enter into an endogenous growth phase and loose their ability to cling to the media. The wastewater flowing through the filter then washes the slime off the media and a new slime layer begins to form. This phenomenon is called sloughing and is primarily a function of the organic and hydraulic loading on the filter. The hydraulic loading accounts for shear velocities and the organic loading accounts for the rate of metabolism in the slime layer. Since treatment is achieved by the wastewater being in direct contact with the biomass on the media, recirculation of wastewater through the media is typically required to achieve treatment.

2.2 Equipment Description and Process Description

The Bioclere™ unit is a separate system that provides secondary wastewater treatment. A complete treatment system has two stages of treatment. The first stage of treatment occurs in the primary tank in which the solids are settled and partially digested. This primary tank can be an existing or new septic tank, or a similar type of tank. A return line is installed in the tank to carry treated wastewater and solids from the Bioclere™ clarifier section back to the primary tank. The typical primary tank size is 1,000 gallons.

The Bioclere™ is a single complete unit that includes a top section that holds the trickling filter media (plastic media), and a bottom section that serves as a clarifier to settle and remove solids. A media dosing pump conveys treated wastewater from the clarifier/sump to the top of the unit, where the wastewater is sprayed over the media. A treated wastewater/solids return pump, located in the bottom of the clarifier, pumps treated wastewater and accumulated solids back to the primary tank. A fan located on the top of the unit provides an air supply (oxygen) to the media.

Figures 2-1 through 2-4 show the basic system flow diagram and schematic representation of the Bioclere™ Model 16/12. The system operated for this test is designed to handle 400 gpd. Additional information on the unit is presented in the Technical Manual in Appendix A.

Wastewater flows by gravity from the 1,000 gallon single compartment primary tank to the clarifier section of the Bioclere™ filter module. The primary tank effluent enters the baffled zone in the 350 gallon clarifier section beneath the Bioclere™ filter module, where it mixes with the wastewater from the trickling filter. The clarified wastewater (mixture of primary tank wastewater and trickling filter treated wastewater) is pumped by a media dosing pump to the distribution assembly, which doses the surface of the filter media. The media dosing pump operates on a timed sequence that is specific to the site wastewater characteristics. The operating cycle for the dosing is alternating periods (3 minutes) of dosing followed by a period of no dosing (5 minutes), repeated continuously over a 24-hour day. Adjustments are made to the timing sequence to optimize the filter performance.

The biological film on the filter media (35.3 cubic feet of media) thickens over time until carbonaceous material and oxygen can no longer penetrate to the bacteria on the inside surfaces nearest the media. When this occurs, the biological film begins to slough from the media and passes through the media bed and into the clarifier section of the unit. The solids settle in the clarifier. The treated wastewater/solids return pump in the bottom of the clarifier periodically pumps the nitrified wastewater and settled solids back to the primary tank. The approach provides a self-cleaning mechanism for the filter media and solids do not build up in the clarifier. The return of nitrified wastewater (with elevated nitrate levels) to the septic tank allows denitrification to occur under anoxic conditions present in the septic tank.

Oxygen is supplied by a fan, located in the top of the housing of the Bioclere™ unit. The air is forced through the Biofilter and vented through the effluent line. The fan is sized to provide a supply of oxygen from the ambient air to the treatment system. The oxygen supply is critical to the operation of the aerobic system.

All wastewater flow, including the discharge flow, is by gravity thorough the Bioclere™ system. The pumps are used only for the actual treatment process. The media dosing pump moves the wastewater from the clarifier back to the top of the filter media and the wastewater trickles over the media. If the pump is not operating or there is a power failure, wastewater will flow through the primary settling chamber and into the clarifier section. Wastewater will then exit the clarifier section by gravity and out to the tile field. Under this condition, the wastewater will not backup in the system, but also will not receive the aerobic biological treatment provided by the filter unit.

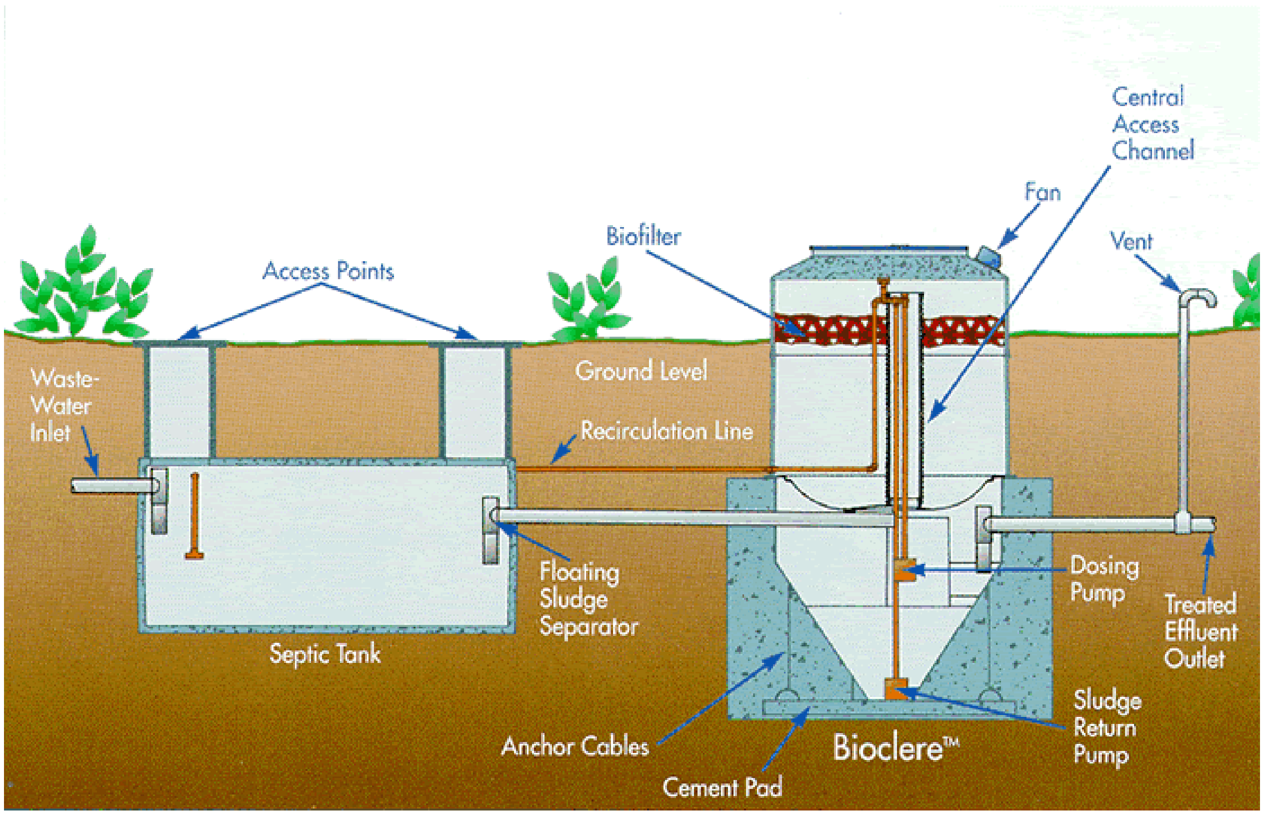

Figure 2-1. Bioclere™ Schematic Representation

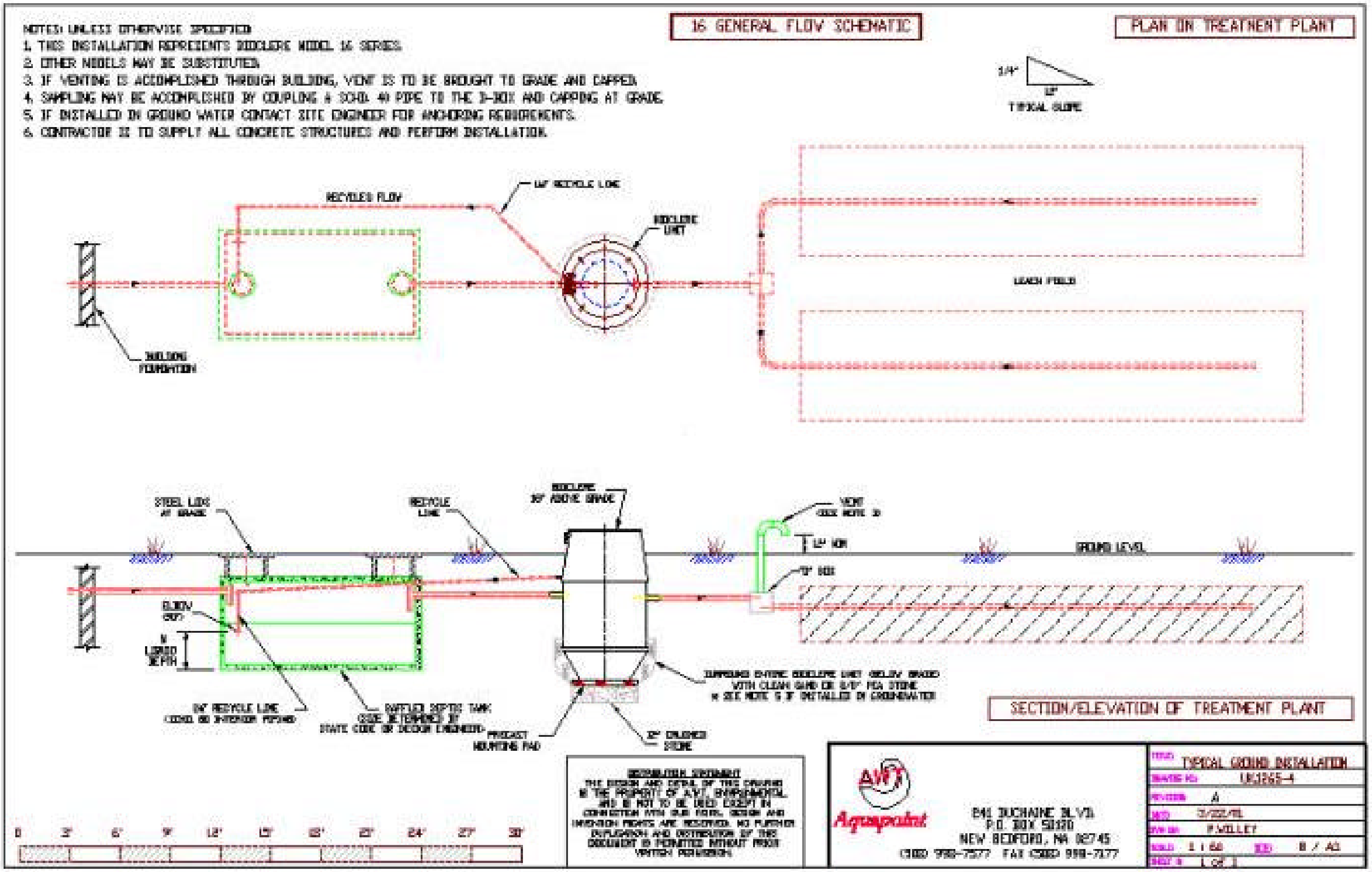

Figure 2-2. Flow Schematic of Bioclere™ System

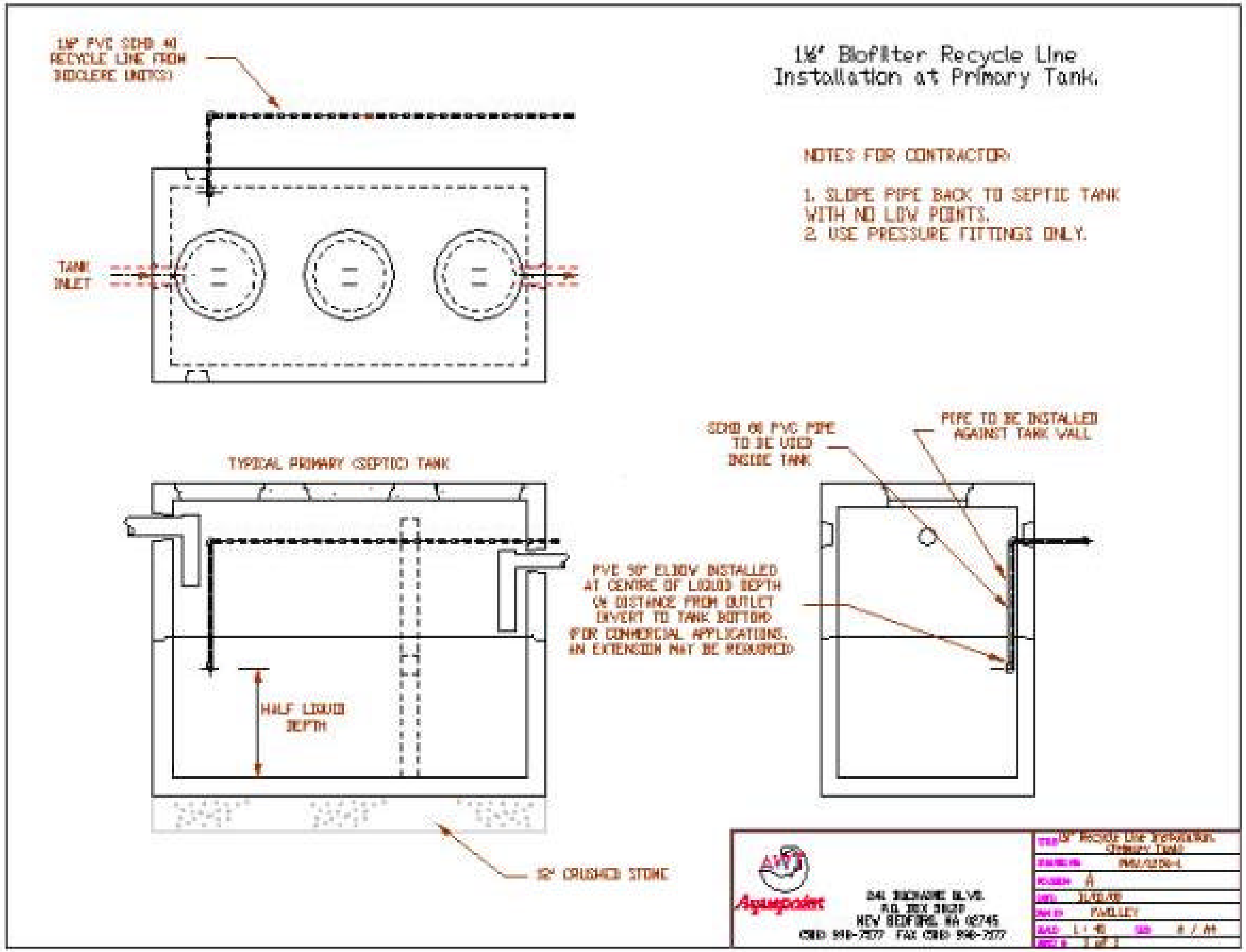

Figure 2-3. Bioclere™ Primary Tank

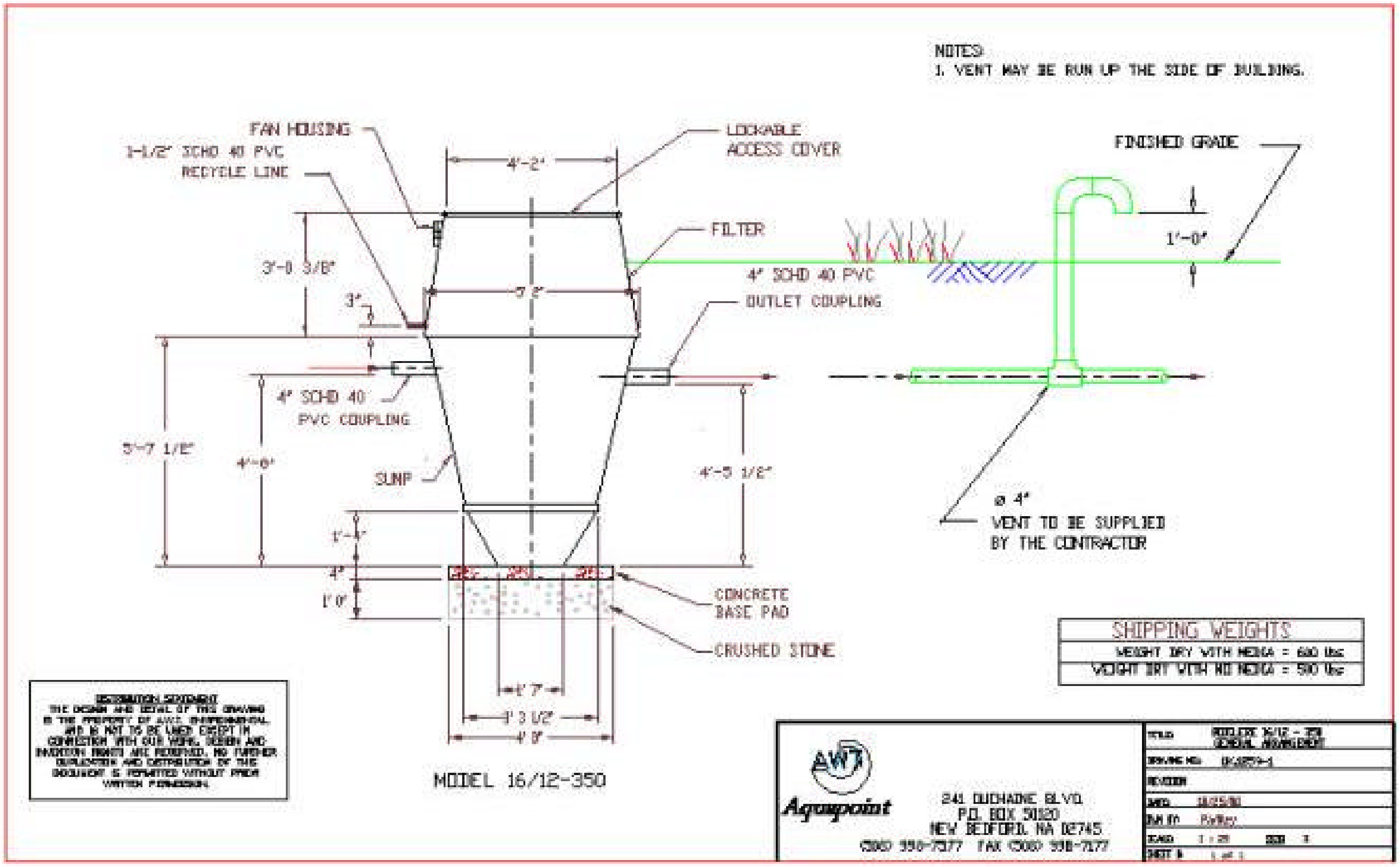

Figure 2-4. Bioclere™ Unit

2.3 Equipment Specifications

The specifications for the Bioclere™ Model 16/12 are summarized in Table 2-1. All of the piping used in the systems is either schedule 40 or 80 PVC pipe. Figures 2-1 through 2-4 show additional information on the specifications for the unit. The Technical Guide, presented in Appendix A, provides information on the timer system and other system details.

Table 2-1. Bioclere™ 16/12 Specifications

Item	Quantity
Tank Assembly	1
Filter Media	1 (2 cubic meters)
Distribution system	1
Nozzles	3
Media Dosing Pump	1 Grundfos KP 150
Wastewater/Solids Return Pump	1 Grundfos KP 250
Latches	4 Moore 702-L-C-SS
Baffle	1
Fan Module assembly	1
Control Panel	1
Technical Manual	1
Padlocks	2 Abus
1 ½ key	2

The initial pump timer settings are designed for a five-bedroom house. The pre-programmed timer is setup for denitrification. Settings are preprogrammed as follows:

Media Dosing Pump on	3 minutes
Media Dosing Pump off	5 minutes
Wastewater/Solids Return Pump on	1.5 minutes
Wastewater/Solids Return Pump off	2.5 hours

The flow rates for the media dosing pump and treated wastewater/solids return pump vary by the head at a particular installation. In a typical installation, as was the used at MASSTC, the media dosing pump flow rate is 20 to 25 gpm. The treated wastewater/solids return pump operates at 30-35 gpm.

2.4 Operation and Maintenance

AQP provides a Technical Manual with the unit. A copy of this manual is presented in Appendix A. The manual provides installation, startup, operation and maintenance descriptions for the unit. Bioclere™ provides periodic maintenance service for their units. According to the manual, the unit is checked weekly for the first two weeks of operation with the assistance of the homeowner. The manual indicates that these first two checks are primarily focused on determining that the fan is running and that the timer is sequencing the two pumps correctly. After the first two weeks, the recommended maintenance interval is quarterly (every three months). A maintenance checklist is provided in the Technical Manual. The following items are listed as items to be checked:

- Check pumps and fan operation visually and adjust if necessary
- Check and clear spray nozzles, if necessary
- Check condition of biomass
- Check clarity of final effluent
- Verify accuracy of timers on control panel through two complete dosing cycles
- Adjust irrigation rate, if necessary
- Check control panel
- Lubricate fan module, if necessary

2.5 Vendor Claims

AQP claims the Bioclere™ can be designed to consistently reduce ammonia nitrogen in wastewater despite seasonal temperature variations. They claim that nitrogen is reduced substantially and cost effectively by recirculating nitrified wastewater from the Bioclere™ to the primary settling tank. AQP claims Bioclere™ is a cost-effective system for the secondary treatment of wastewater, designed for years of dependability. The manufacturer claims the natural fixed film biological process is extremely stable, simple to manage and inexpensive to operate. AQP states that the Bioclere™ reduces the biochemical oxygen demand (BOD_5) and total suspended solids (TSS) to levels that meet or exceeds NSF and EPA standards. Vendor test data is provided in Appendix A of the Technical Manual.

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 Aquapoint, Bioclere™ Model 16/12, and is included in Appendix B. This VTP, *Test Plan for The Massachusetts Alternative Septic System Test Center for the Verification Testing of the AWT Bioclere™ Nutrient Reduction Technology* [4], February 2001 detailed all of 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 Bioclere™ unit and to obtain information on the operation and maintenance requirements of the Bioclere™. There were two distinct phases of fieldwork to be accomplished as part of the VTP. The first phase was startup of the unit. The second phase was a one year verification test that included normal dosing and stress conditions. While the Protocol requires twelve months of sampling, an extra month was added since the testing ended in a cold weather month (March). The extra one-month of data was collected to show the response of the system coming out of a cold weather period.

Each of the testing elements performed, during the technology verification, are described in this section. In addition to a description 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 MASSTC site is located at Otis Air National Guard Base in Bourne, Massachusetts. 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 upstream of the base wastewater treatment facility, constructed when the MASSCTC was built in 1999, provides a location to obtain untreated wastewater. The screened 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 wastewater is obtained for the influent feed at the test site. The raw wastewater passes through a bar grate located before the transfer pump. This bar grate has one inch spacing between the bars to remove large or stringy materials that could clog the pump or lines.

The screened 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 top concrete channel, sixty-five feet long by 2 feet wide by 3 feet deep, via two pipes midway in the channel. Approximately 4-6,000 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 mixing 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 individual test units is accomplished by individual influent dosing pumps submerged in-line along the dosing channel. The influent dosing pumps are connected to the treatment technology being tested by underground PVC pipe. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle. The PLC was custom designed by Orenco, Inc. for this application. Each technology influent dosing pump can be controlled individually for multiple start and stop times, and for pump run time. For the Bioclere™ system, the volumetric dosages were set to meet the dosing sequence described in the VTP. The Bioclere™ system was dosed 15 times per day with approximately 26-27 gallons of wastewater. The volume was controlled by adjusting the influent dosing pump run time for each cycle.

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 Bioclere™ test.

The MASSTC has been in operation since 1999. 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 is 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

AQP provided an installation, operation, and maintenance manual for the Bioclere™. This manual is presented in Appendix A. The Bioclere™ system had been installed at MASSTC in June 1999, as part of an on-going testing program. The existing system, a single compartment, 1,000 gallon primary tank and a Bioclere™ filtration unit, were 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 Aquapoint Bioclere™ Model 16/12 in accordance with the Technical Manual;
- Start-up and test the Bioclere™ to ensure all processes were operating properly, timers were set for proper automatic operation, and any leaks that occurred during the installation were 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 Procedures

The installation of the Bioclere™ was performed by a contractor in conjunction with the BCDHE support team, and supported by the AQP staff. The installation was performed in June 1999 as part of an earlier test program. In order to prepare for startup of the Bioclere™ for the ETV verification, the entire Bioclere™ system was emptied of wastewater and cleaned in October 2000. Solids were removed from the primary tank and the clarifier section of the Bioclere™ filter unit. All pumps, lines, and associated equipment were cleaned. The filter media was repeatedly flushed and solids removed from the bottom of the unit. Clean water was recirculated in the unit from November through mid-December to further clean the media and lines. The entire unit was then drained and remained off until the beginning of the startup period in January.

The VTP and Protocol allow for an eight-week startup period. During the startup, the biological community is established and operating conditions are adjusted, if needed, for site condition. The startup procedures in the Technical Manual were followed as written. This included filling the primary tank and filter system with water and checking each component of the system for proper operation.

In early January fresh water was added to the unit and the system was cycled for several days to make sure the unit was operating properly, the influent dosing pump was calibrated, and the PLC was working properly. Startup of the cleaned Bioclere™ system began on January 15, 2001. The primary tank was filled approximately two thirds (2/3) full with clean water and one third (1/3) with wastewater from the dosing channel. The dosing sequence was started on January 15 with a setting of 15 doses of wastewater per day, with a target of 26.67 gallons of wastewater per dose. This dose setting provided a target total daily flow of 400 gallons per day. The pumps and timers on the unit were started using the factory default settings.

The system was monitored during the startup period of January 15 through March 11, 2001 through visual observation of the system, routine calibration of the dosing system, and the collection of influent and effluent samples. Samples for analysis were collected during weeks two, three, five, seven and eight (two sets) of the startup period. Influent samples were collected for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS analyses. The effluent was also monitored 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 of the AQP Bioclere™ treatment technology. The verification test consisted of a thirteen-month test period, incorporating five stress periods with varying stress conditions simulating real household conditions. Dosing volume was set to the design capacity of the Bioclere™ system. Monitoring for nitrogen reduction was accomplished by measurement of nitrogen species (TKN, NH_3, NO_2, NO_3). Carbonaceous oxygen demand (CBOD) 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, labor to perform maintenance, maintenance tasks, durability of the hardware, noise and odor production were also monitored.

Verification results and observations are presented in this Verification Report in Section 4.0.

3.4.2 Objectives

The objectives of the verification test were to:

- Determine nitrogen reduction performance of the Bioclere™ system;
- Monitor removal of other 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 thirteen-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. The Bioclere™ system tested had a design capacity of 400 gallons per day. The target for total daily flow to the unit was 400 gallons per day.

3.4.3.1 Influent Flow Pattern

The influent flow dosed to Bioclere™ was controlled by the use of timed pump operation. The dosing pump was set to provide 15 doses of equal volume (target - 26.7 gallons per dose) in accordance with the following schedule:

- 6 a.m. – 9 a.m. 33 percent of total daily flow in 5 doses
- 11 a.m. – 2 p.m. 27 percent of total daily flow in 4 doses
- 5 p.m. – 8 p.m. 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 influent 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 the barrel. The dosing flow volume was checked by this calibration method at least twice per week. Calibration results were recorded in the field logbook.

The total daily flow to the Bioclere™ was targeted to be 400 gallons per day (26.67 gallons per dose). After each calibration test, the measured volume was compared to this target rate. If the volume was more than 10 percent above or below the target, the influent dosing 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 plus/minus 10 percent of the rated capacity (400 gallons per day) 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 on the log.

Flow information was entered into a spreadsheet that showed each day of operation, the influent dosing 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 following every two months of operation at the normal design loading during the verification test. Five stress scenarios were run during the thirteen (13) month evaluation period. These special tests were designed to test the Bioclere™ response to differing load conditions and a power/equipment failure.

Stress testing included the following simulations:

- Wash-day stress
- Working parent stress
- Low-loading 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 was adjusted so that the total loading 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 manufacturers recommended amount.

The working parent stress simulation consisted of five (5) consecutive days when the Bioclere™ 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]. The total hydraulic loading did not exceed the design loading rate during the stress test period.

The low-loading stress simulation consisted of testing the unit at 50 percent of the design 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 is initiated. Power to the Bioclere™ 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 vacation stress was 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 Bioclere™ influent dosing pump intake, approximately four to six inches from the channel floor. 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. Influent dosing pumps for individual systems are located in-line along the dosing channel. The influent wastewater-sampling site was located close to the AQP Bioclere™ influent dosing pump to ensure a representative sample of wastewater was obtained.

3.4.3.3.2 AQP Bioclere™ Effluent Sampling Location

For the Bioclere™ effluent, the sampling site was located in the normal effluent pipe of the Bioclere™ as close to the final treatment unit as was practicable. During installation and setup of the Bioclere™, a 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.

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 volume of sample from the waste treatment stream at the same frequency, number (15), and timing as influent wastewater doses. Samples taken in this manner were therefore flow proportional. The effluent sampler timing was delayed to correspond to the passage of a flow pulse through the Bioclere™ system based on the influent dosing pump timer setting. 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 that was 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 once per month for the thirteen-month test period (March 2001 – April 2002). The initial VTP was designed for a twelve-month test program; however, the test period was extended for one additional month to provide data for the month of April when temperatures were expected to be higher.

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 loading, 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.

The decision was made to extend the test period of one additional month to monitor changes in the system that would be influenced by the temperature of the wastewater. Therefore, there was one additional set of samples (April 17, 2002) collected after the five-day sampling of the “final week.”

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 Bioclere™ System

Month/Day	Sampling Event
Jan 23 and 31, 2001	Startup – 2 sampling events
February 14 and 28, 2001	Startup – 2 sampling events
March 7 and 13, 2001	Startup – 2 sampling events
March 21, 2001	Normal monthly sample
April 18, 2001	Normal monthly sample
May 8,10, and 13-18, 2001	Wash day stress - 8 samples
June 6, 2001	Normal monthly sample
July 3, 2001	Normal monthly sample
July 10 and 13-20, 2001	Working Parent stress – 8 samples
August 1, 2001	Normal monthly sample
September 5, 2001	Normal monthly sample
September 18, 27 and October 9-14, 2001	Low Loading stress – 8 Samples
October 31, 2001	Normal monthly sample
November 28, 2001	Normal monthly sample
December 3, and 9-13, 2001	Power Failure stress – 6 samples
December 28, 2001	Normal monthly sample
January 16, 2002	Normal monthly sample
February 4 and 14-19, 2002	Vacation Stress – 7 samples
March 4-8, 2002	Final week sampling – 5 samples
April 17, 2002	Additional monthly sample

3.4.3.4 Residuals Monitoring and Sampling

Byproducts or residuals generated by the Bioclere™ system are returned to the primary tank. Solids from the incoming wastewater and the Bioclere™ system settle in the primary tank and accumulate slowly over time. Measurements of solids depth in the primary tank were made twice near the end of the testing period, in the thirteenth and fourteenth months after startup. A coring solids measurement tool (Core Pro) was used to estimate the depth of solids and the scum layer in the 1,000 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 ensure that 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 the depth of solids. The thickness of any scum layer present is measured by ruler or tape also. Three measurements of solids depth were made at each of the two access manholes. A measurement of solids depth in the Bioclere™ unit clarifier was also made in March near the end of the testing period. The solids measurement tool was inserted into the unit's central riser and a measurement of solids in the bottom of the treatment unit/process tank recorded in the Field Log.

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 and the water present in the tube. Thus, the concentration measurements for solids represent the concentration as if the entire contents of the 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 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-three (53) samples of the influent and effluent for the Bioclere™ unit were collected over the thirteen-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 #423
Temperature (^oC)	On-site	N/A	N/A	SM #2550
Dissolved Oxygen	On-site	N/A	N/A	SM #4500
Suspended Solids	BCDHE Laboratory	80-120	N/A	SM #2540 D
BOD_5/ $CBOD_5$	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 provided 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 a 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 was summarized in an Excel spreadsheet by BCDHE personnel at the test site. This data was proof read against the original laboratory reports by the site staff. The data was also checked by NSF to ensure the data was accurate. The spreadsheets included in Appendix F.

3.4.5 Operation and Maintenance Performance

Both quantitative and qualitative performance of the Bioclere™ unit was evaluated during the verification test. A field log was maintained that included all observations made during the startup of the unit. This field log was maintained throughout the verification test. Observations regarding the condition of the system, any changes in setup or operation (timer adjustments, nozzle cleaning, etc.), 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 AQP Bioclere™. The meter reading was recorded biweekly 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

For this ETV testing, the Bioclere™ did not use any process chemicals to achieve treatment.

3.4.5.3 Noise

Noise levels associated with mechanical equipment (particularly compressors and blowers) 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. 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 final eight 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, 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 compressors or blowers, mixers, and chemical and 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

Evaluation of the AQP Bioclere™ Model 16/12 at MASSTC began in January 2001. The unit was filled with a mixture of fresh water and wastewater on January 15, 2001, the pumps and timers were activated, and the initial dosing cycles activated. Flow was set at 400 gpd, resulting in 15 doses per day with a target of 26.7 gallons per dose. The startup period continued until March 13, 2001. Six samples of the influent and effluent were collected during the startup period. Verification testing began on March 13, 2001 and continued for 13 months until April 17, 2002. The extra month of dosing and sampling (13 months versus the planned 12 months) was added to the test to obtain data on the system response as the temperatures began to rise in the spring. During the verification test, 53 sets of samples of the influent and effluent were collected to determine the system performance.

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.

4.2 Startup Test Period

The startup period provided time for the Bioclere™ to develop a biological growth that was acclimated to the site-specific wastewater. The startup also provided an opportunity for the Bioclere™ 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 Bioclere™ operation and maintenance requirements. Samples were collected during weeks 2, 3, 5, 7, and 8 (two sets) of the startup period.

4.2.1 Startup Flow Conditions

The flow conditions for the Bioclere™ were established at the design capacity of 400 gallons per day. The influent dosing pump was set to deliver 15 doses per day at approximately 26.7 gallons per dose. Five (5) doses were delivered between 6 a.m. and 9 a.m., four (4) doses between 11 a.m. and 2 p.m., and six (6) doses between 5 p.m. and 8 p.m. The dosing sequence remained constant during the startup and verification tests, except during the stress test sequences described in Section 3.3.3.2. The volume of wastewater dosed to the unit during the startup remained mostly constant and only minor adjustments to the influent 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

Week	Average		Actual Daily Volume
	Doses/day	Gallons/dose	(Gallons)
Jan 15 - 20	15	26.6	399
Jan 21 - 27	15	26.8	402
Jan 28 – Feb 3	15	27.1	407
Feb 4 – 10	15	26.4	396
Feb 11 – 17	15	26.4	396
Feb 18 – 24	15	22.4	335
Feb 25 – Mar 3	15	28.6	429
Mar 4- Mar 12	15	26.9	404

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 set of samples was taken 9 days after the unit was started. The initial data showed that the unit reduced the $CBOD_5$ and TSS to 25 mg/L and 8 mg/L, respectively. The Bioclere™ was also reducing some of the total nitrogen (41 mg/L in the influent, 29 mg/L in the effluent). Overall, the system appeared to be acclimating quickly. No adjustments to the system were made. Daily observations and additional sampling to determine the condition of the unit continued for the next eight weeks.

As can be seen in Tables 4-2 and 4-3, the Bioclere™ system performance for $CBOD_5$, TSS, and TN remained somewhat steady throughout the startup period. The unit came on line within a few days and performance remained steady. There was some TN reduction occurring, but it did not appear that the nitrifying organisms had established themselves in the system. The temperature was considered likely to be the primary reason for the lack of a trend toward improved reduction in both $CBOD_5$ and TN. The temperature of the effluent wastewater was about 5 ^oC when the unit was started and remained in the 5 – 7 ^oC range through March 13.

Based on the stable conditions shown by the Bioclere™ system and the fact the startup had extend for eight weeks, the decision was made to end the startup period and begin the verification test with the unit operating conditions remaining the same as the initial startup.

Table 4-2. Influent Wastewater Quality - Startup Period

Date	Alkalinity (mg/L) as $CaCO_3$	BOD_5 (mg/L)	DO (mg/L)	Ammonia (mg/L)	pH (mg/L)	TKN (mg/L)	TN (mg/L)	TSS (mg/L)	Influent Temp. (^oC)
1/23/01	180	160	0.2	27	7.5	41	41	130	8.2
1/31/01	160	270	1.2	24	7.3	40	40	270	8.0
2/14/01	180	150	N/S	26	7.4	39	39	150	N/S
2/28/01	190	220	1.0	27	7.8	46	46	250	8.0
3/07/01	170	180	0.8	23	7.4	34	34	140	7.7
3/13/01	170	140	1.7	25	7.4	39	39	120	7.7

N/S – no sample

Table 4-3. Bioclere™ Effluent Quality during the Startup Period

Date	Alkalinity (mg/L) as $CaCO_3$	$CBOD_5$ (mg/L)	DO (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	pH (mg/L)	TKN (mg/L)	TN (mg/L)	TSS (mg/L)	Effluent Temp. (^oC)
1/23/01	180	25	11	23	0.8	0.12	7.9	28	29	8	5.2
1/31/01	150	22	6.6	16	0.4	0.03	7.9	27	27	18	5.0
2/14/01	190	28	8.7	24	1.0	0.18	8.0	35	36	39	5.5
2/28/01	180	51	6.7	23	<0.1	0.11	7.9	31	31	32	7.3
3/7/01	160	30	8.6	24	0.6	0.32	8.1	29	30	24	5.4
3/13/01	160	13	9.0	22	1.1	0.42	8.0	28	30	16	6.6

4.2.3 Startup Operating Conditions

The Bioclere™ system was started with the factory default settings for the media dosing pump and the treated wastewater/solids return pump. The media dosing pump was set to be on for 3 minutes and off for 5 minutes. The treated wastewater/solids return pump was set to run for 1.5 minutes every 2.5 hours. The startup instructions in the Technical manual (Appendix A) were easy to follow and provided the necessary instructions to get the unit up and operating.

No changes were made to the unit during the startup period. Daily observation showed that biological growth was established on the media. No special maintenance was required during the startup period. Overall, the unit started up with no difficulty.

4.3 Verification Test

Based on the stable operating conditions observed and monitored in the Bioclere™ system and in accordance with the startup period set forth in the VTP, the verification test was started officially on March 12-13, 2001. A final startup sample was collected on March 12-13. After that time all results were considered part of the verification test period. The data collected during startup is not included in any of the data summaries presented in the verification test sections below. As stated above, there was no change made to the basic operation of the system. All Bioclere™ operating parameters (pumps, timers, alarms, etc.) remained the same as during the initial startup period.

4.3.1 Verification Test - Flow Conditions

The daily dosing schedule during normal operations remained constant throughout the entire verification test. A daily dosing sequence of 15 doses was performed every day except during the low load (September 2001) and vacation stress (February 2002) periods. Volume per dose and total daily volume varied only slightly during the test period. Table 4-4 shows the average monthly volumes for the verification period. As this data shows, the actual wastewater volume dosed to the Bioclere™ was very close to the targeted volume of 400 gallons per day.

Table 4-4. Bioclere™ Influent Volume Summary

		Ave Monthly	
Mon/Year	Doses/day	Gallon/dose	Gallon/day
Mar-01	15	26.2	392
Apr-01	15	25.8	387
May-01	15	26.9	403
Jun-01	15	26.3	395
Jul-01	15	26.0	391
Aug-01	15	25.9	389
Sep-01	15	14.9	401(1)
Oct-01	15	26.6	400(1)
Nov-01	15	27.1	407
Dec-01	15	27.1	406(2)
Jan-02	15	26.4	395
Feb-02	15	26.5	397(3)
Mar-02	15	26.6	400
Apr-02	15	26.2	393
Average	**15**	**26.4**	**397**
Maximum		27.1	407
Minimum		25.8	387
Std. Dev.		0.4	6.2

(1) September/October 2001– Low load test; flow data only for normal flow
(2) December 2001 – Power/Equipment Failure test; average flow data does not include the days without flow
(3) February 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 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 the results with a summary of the data (average, 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 has a large number of nitrifying organisms present, which can cause nitrification to occur during the first five days of the test. The $CBOD_5$ analysis is used to inhibit nitrification during the analysis, and give 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 influent wastewater had an average BOD_5 of 210 mg/L and a median BOD_5 of 200 mg/L. The TSS in the influent averaged 160 mg/L and had a median concentration of 140 mg/L. The Bioclere™ effluent showed an average $CBOD_5$ of 14 mg/L with a median $CBOD_5$ of 10 mg/L. The average TSS in the effluent was 16 mg/L and the median TSS was 10 mg/L. The Bioclere™ system averaged 93 percent reduction of BOD_5/$CBOD_5$ with a median removal of 95 percent. TSS removal averaged 90 percent over the thirteen-month period with a median removal of 93 percent. $CBOD_5$ concentrations in the effluent typically ranged from 4 to 20 mg/L, and TSS ranged from 4 to 17 mg/L, except during an apparent upset condition that occurred in July 2001. This upset period is discussed later in this section and in the O&M section.

The verification sampling program emphasizes sampling during and following the major stress periods. This results in a large umber 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, as the median values compared to average values can help in analyzing these impacts. In the case of the Bioclere™ results, the median values are much lower than the average values due to the upset condition when the nozzles plugged during the working parent stress test.

At the end of the startup period, the Bioclere™ system was reducing TSS and $CBOD_5$, but had not yet achieved the level of performance anticipated by AQP. During the period March 13 through April 18, wastewater temperature began to increase quickly (see Figure 4-7) and the effluent concentration of TSS and $CBOD_5$ began to trend lower. By the start of the first stress test, (washday stress test, May 2001), the unit was producing effluent concentrations in the range of 13 to 26 mg/L for $CBOD_5$ and 2 to 13 mg/L for TSS. The washday stress test was started on May 8 and concluded on May 11. There was no apparent impact on the $CBOD_5$ and TSS performance during this stress period. Post stress period monitoring showed an actual improvement in performance in the week following the washday test. Both $CBOD_5$ and TSS in the effluent were 10 mg/L or less during the post stress test monitoring period.

In early July, the effluent quality began to deteriorate (July 3 results). The working parent stress test was started on July 9 and was completed on July 13. During this time, visual observation of the unit indicated that the effluent had high solids content and the dissolved oxygen content was much lower in the effluent. AQP was notified of the condition of the unit and arrived at the site on July 17. The unit was found to have two plugged nozzles. The nozzles were cleared and the system performance improved over the next two weeks. By the August 1 monthly sampling event, performance had returned to the levels achieved in late May and June. The plugged nozzles clearly had an impact on both $CBOD_5$ and TSS removal performance. The wastewater was not being recycled at the established rate and treatment of the oxygen demanding organics was reduced. The increased TSS indicated that the organisms on the media were probably stressed due to reduced and uneven recirculation flow, and began to slough. It is not clear what impact the working parent stress test had on the system performance. The deterioration of the performance prior to the stress period would suggest that the plugged nozzles were causing a problem prior to the stress test, and that the higher effluent levels were due to lack of proper wastewater circulation rather than the change in loading schedule during the working parent test. The nozzle plugging issue is discussed further in the O&M section.

For the remainder of the test, August 2001 through April 2002, the Bioclere™ performance was consistent. Data collected during the low load stress test in September-October and the power/equipment failure test in December showed no change in either $CBOD_5$ or TSS performance. The vacation stress test was performed in February 2002. There was an increase in $CBOD_5$ (11 to 22 mg/L range) in the effluent during the post stress sampling period (February 15 to 19). These results may be due to the vacation stress test or could be within the normal variation of the $CBOD_5$ measurement in the effluent.

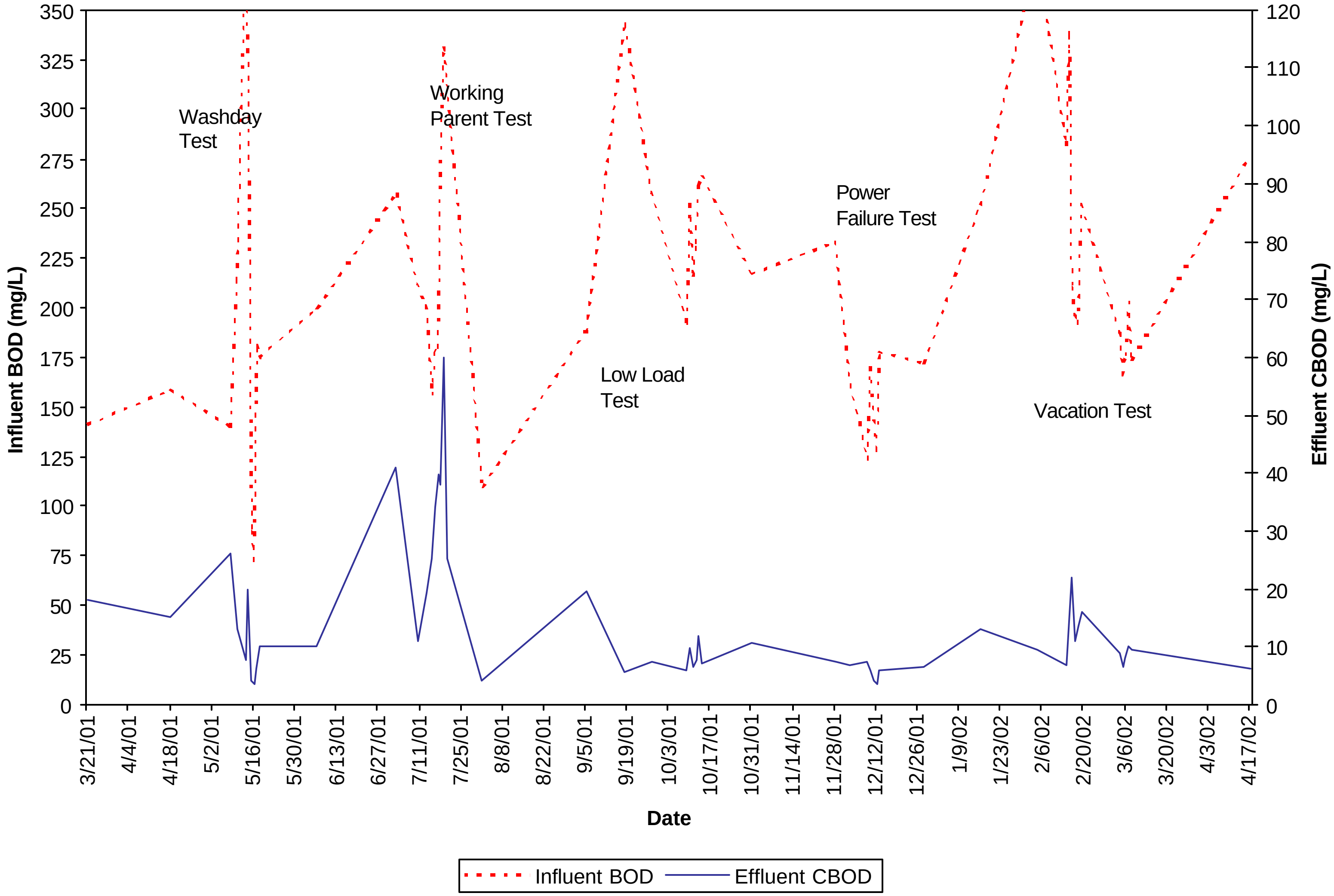

Figure 4-1. Bioclere™ BOD/CBOD Results

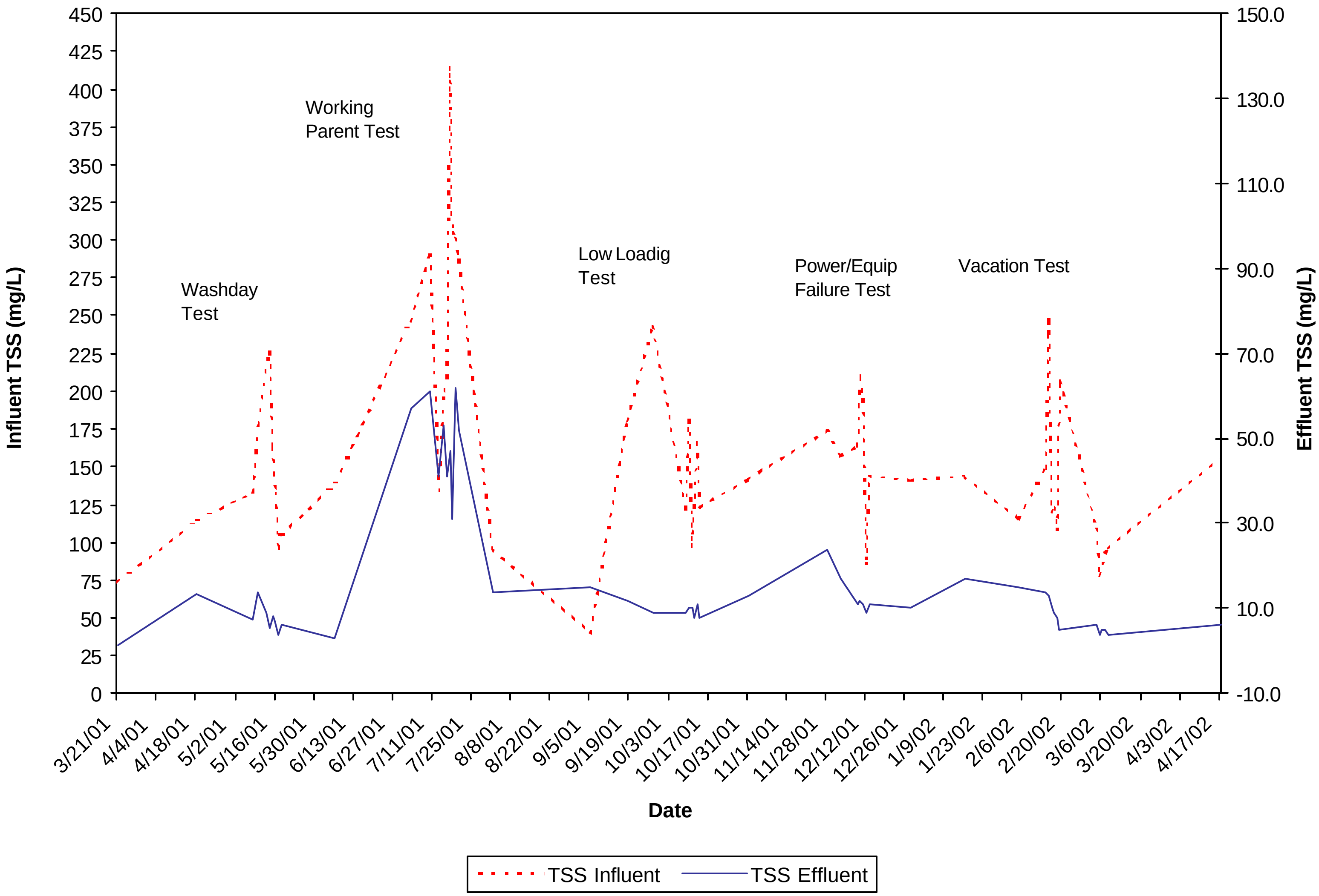

Figure 4-2. Bioclere™ Total Suspended Solids Results

Table 4-5. Bioclere™ BOD/CBOD 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
3/21/01	140	18	87	74	2	98
4/18/01	160	15	91	110	13	88
5/08/01	140	26	81	130	8	94
5/10/01	210	13	94	180	14	92
5/13/01	380	7.7	98	220	9	96
5/14/01	320	20	94	230	5	98
5/15/01	87	4.0	95	160	8	95
5/16/01	72	3.5	95	130	7	95
5/17/01	180	6.2	97	96	4	96
5/18/01	180	10	94	100	6	94
6/06/01	200	10	95	140	3	98
7/03/01	260	41	84	250	57	77
7/10/01	210	11	95	290	61	79
7/13/01	200	19	90	130	41	69
7/15/01	160	25	84	200	53	74
7/16/01	180	34	81	210	41	80
7/17/01	180	40	78	410	47	89
7/18/01	290	38	87	300	31	90
7/19/01	330	60	82	300	62	79
7/20/01	310	25	92	290	52	82
8/01/01	110	4.0	96	96	14	85
9/05/01	190	20	90	40	15	63
9/18/01	340	5.5	98	180	12	93
9/27/01	260	7.3	97	240	9	96
10/09/01	190	5.9	97	120	9	93
10/10/01	250	9.9	96	180	10	94
10/11/01	220	6.4	97	97	10	90
10/12/01	230	7.8	97	130	8	94
10/13/01	260	12	95	170	11	93
10/14/01	270	7.0	97	120	8	93

Table 4-5. Bioclere™ BOD/CBOD and TSS Results (continued)

	BOD_5	$CBOD_5$		TSS		
Date	Influent (mg/L)	Effluent (mg/L)	Removal Percent	Influent (mg/L)	Effluent (mg/L)	Removal Percent
10/31/01	220	11	95	140	13	91
11/28/01	230	7.4	97	170	24	86
12/03/01	160	6.7	96	160	17	89
12/09/01	120	7.4	94	160	11	93
12/10/01	170	5.9	97	210	12	94
12/11/01	140	4.2	97	190	11	94
12/12/01	130	3.6	97	85	9	89
12/13/01	180	6.0	97	140	11	92
12/28/01	170	6.5	96	140	10	93
1/16/02	250	13	95	140	17	88
2/04/02	380	9.4	98	120	15	87
2/14/02	280	6.8	98	150	14	91
2/15/02	340	17	95	250	13	95
2/16/02	210	22	90	120	10	92
2/17/02	200	11	94	120	9	93
2/18/02	190	14	93	110	8	93
2/19/02	250	16	94	210	5	98
3/04/02	190	8.8	95	110	6	94
3/05/02	170	6.6	96	78	4	95
3/06/02	180	7.9	96	85	5	94
3/07/02	200	10	95	93	5	95
3/08/02	170	9.5	95	96	4	96
4/17/02	280	6.1	98	160	6	
Samples	53	53	53	53	53	52
Average	210	14	93	160	16	90
Median	200	10	95	140	10	93
Max	380	60	98	410	62	98
Min	72	3.5	78	40	2	63
Std. Dev.	70	11	5	71	16	7

Samples = Number of samples used in the calculations

4.3.3 Nitrogen Reduction Performance

4.3.3.1 Results

Figures 4-3 through and 4-5 show the results for the TKN, ammonia and total nitrogen (TN) in the influent and effluent for the verification test. Figure 4-6 shows the results for nitrite and nitrate in the effluent from the Bioclere™ system. Table 4-6 presents the results with a summary of the data (average, maximum, minimum, standard deviation).

The influent wastewater had an average TKN concentration of 37 mg/L, with a median value of 38 mg/L, and an average ammonia nitrogen concentration of 23 mg/L, with a median of 23 mg/L. Average TN concentration in the influent was 37 mg/L (median of 38 mg/L), based on the assumption that the nitrite and nitrate concentration in the influent was negligible. The Bioclere™ effluent had an average TKN concentration of 10 mg/L and a median concentration of 6.3 mg/L. The average NH_3-N concentration in the effluent was 6.2 mg/L and the median value was 2.8 mg/L. The nitrite concentration in the effluent was low averaging 0.45 mg/L. Nitrate concentrations averaged 5.3 mg/L, with a median of 4.4 mg/L. Total nitrogen was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), nitrite and nitrate. Average TN in the Bioclere™ effluent was 16 mg/L (median 14 mg/L) for the thirteen months verification period. The Bioclere™ system averaged a 57 percent reduction of TN for the entire test period, with a median removal was 64 percent.

The verification test program emphasizes sampling during and following the major stress periods. This results in a large number of samples being clustered during five periods with the remaining samples spread over the remaining months (monthly sampling). Therefore, impacts of 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 as the median values compared to average values can help in analyzing these impacts. In the case of the Bioclere™ results, the median concentrations are lower than the average concentrations due to the upset condition when the nozzles plugged during the working parent stress test.

Alkalinity, pH, dissolved oxygen (DO), and temperature were measured during the verification test. These parameters can impact total nitrogen removal, and their measurement can provide insight into the condition of the system. 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 7.2 to 7.6. The effluent from the Bioclere™ showed a slight increase in pH, consistently remaining in the pH 7.5 to 7.9 range. The alkalinity of the influent averaged 180 mg/L as $CaCO_3$ with a maximum concentration of 210 mg/L and minimum of 160 mg/L. The effluent alkalinity was consistently lower than the influent (as expected when nitrification/denitrification is occurring), with an average concentration of 110 mg/L as $CaCO_3$. The only time the effluent alkalinity did not decrease by at least 25 percent was during the upset period in July when the system performance for nitrogen removal was severely impacted.

The Dissolved Oxygen in the influent domestic wastewater was low, as would be expected. The average DO in the influent was 0.4 mg/L and was less than 1.0 mg/L on all but one day of testing. The Bioclere™ system is designed to operate as an aerobic system with the fan on the top of the unit moving air through the media and aerating the wastewater. The DO in the effluent from the Bioclere™ was normally above 5 mg/L, and averaged 6.3 mg/L over the thirteen months of verification testing. The dissolved oxygen was significantly lower during the upset period in July when two nozzles were plugged on the unit. DO in the first eighteen days of July was in the 0.6 to 2.8 mg/L range. Once the nozzles were repaired, the DO immediately increased to 5 mg/L.

4.3.3.2 Discussion

As discussed earlier in the startup section, at the end of the startup period (January 15- March 12, 2001), the Bioclere™ effluent was showing some reduction of total nitrogen, but only in the 25 percent to 30 percent range. Wastewater temperatures were still in the 5 -7 ^{o}C range. As shown in Table 4-7, beginning in late March and earlier April, the temperatures began to increase and the TN concentration in the effluent began to decrease. The nitrifying population clearly became established in this period, as indicated by the decrease in the TKN and NH_3 concentrations in the effluent. Nitrate concentrations increased somewhat in this same period, but the data show that denitrification was also occurring. During May and June, the TN reduction was typically above 70 percent. The Washday stress test in May 2001 did not have any negative impact on nitrogen reduction.

In early July 2001, the data show that there was loss of the nitrifying population in the unit. In addition, the effluent concentrations of $CBOD_5$ and TSS increased indicating the system was under stress. As discussed in Section 4.2.2, visual observation of the effluent before and during the Working Parent stress test showed that solids were being lost and the effluent was very cloudy. Two of the nozzles on the Bioclere™ unit were clogged. Within two to three weeks after the nozzles were repaired, nitrogen removal increased to 69 percent (August 1, 2001), similar to the period before the problem occurred. The $CBOD_5$ and TSS levels in the effluent also decreased, returning to the levels measured before the nozzle plugging occurred. The data would suggest that loss of nitrogen and $CBOD_5$ removal efficiency was due to the nozzle plugging problem rather than the stress of the working parent dose sequence. Loss of nitrogen removal occurred before the start of the stress test. The dissolved oxygen in the effluent had decreased to less than 1 mg/L a week before the stress test, and was in the 2 to 3 mg/L range during the stress test period. After the nozzles were repaired, dissolved oxygen immediately jumped to 5 mg/L, similar to the levels measured in May and June.

Once the nitrifying population was reestablished (by August 1, 2001), the Bioclere™ system continued to reduce the total nitrogen concentration on a steady basis (60-80 percent reduction) until December. The low load stress test, performed in September, did not have any impact on treatment performance. The temperature of the wastewater began to decrease in October as would be expected. While the trend was not clear, the late November sample indicated a lower removal of nitrogen was occurring as compared to September and October. The power failure stress test was started on December 3, 2001. Power was off for 48 hours. Sample results for the post stress period showed total nitrogen removal had decreased to the low 50 percent range. Subsequent monitoring over the next few weeks showed a continued slight increase in total nitrogen in the effluent. The lower nitrogen removal efficiencies in the December to February period correspond to lower temperatures in the wastewater. The power failure stress test may have contributed to the change in efficiency by stressing the nitrifying population. The lower temperatures in the wastewater appeared to have slowed the total nitrogen removal and possibly the re-establishment of the nitrifying population.

In mid February, the data showed a slight decrease in the total nitrogen concentration in the effluent. The effluent then remained steady in TN levels through early March. The vacation stress test in February had no noticeable impact on the system performance for nitrogen removal. The last scheduled samples for total nitrogen in the first week of March showed that the Bioclere™ system was removing TN in the 60 to 66 percent range. This was somewhat lower than the earlier efficiencies of the previous summer and fall. The temperature of the wastewater appeared to have an effect on the nitrogen reduction levels based on both the startup data and on the December 2001 to February 2002. The test period was extended one additional month to determine if removal would improve as the wastewater temperature increased. The final sample (April 17) showed a steep decrease in TN from 16 mg/L (March 8) to 8 mg/L and removal efficiency increased to 80 percent. The temperature of the water increased to 14.3 ^{o}C from 9.2 ^{o}C.

The dissolved oxygen levels in the effluent may also impact the total nitrogen removal, particularly the removal of nitrate in the primary tank. A portion of the effluent (approximately 50 to 60 percent of the daily wastewater loading) is recycled to the primary tank where the removal of nitrate occurs under anoxic conditions. If the DO in the recycled effluent increases the DO in the primary tank, it can result in a decrease in nitrate removal. The best nitrate removal occurred when the system was in normal flow mode and the DO in the system effluent was typically 5 to 7 mg/L. During the late fall and winter months, the DO in the effluent increased to typically 7 to 9 mg/L or even higher. The nitrate concentration increased in the effluent during this period, which also corresponded to the decreasing temperatures described above. The influence of the recycled effluent on primary tank dissolved oxygen levels would be greater during the vacation stress period (February, 2002) as there was no influent flow during this time. Thus, while temperature of the wastewater may be the primary influence on the nitrifying population on the media, higher dissolved oxygen may also have contributed to a decrease in nitrate removal in the primary tank.

The alkalinity results collected during the test can be used as a check on system conditions as well. The nitrification process consumes alkalinity as ammonia is converted to nitrite and nitrate. Thus, the alkalinity will decrease when the nitrifying population is very active. The denitrification process produces alkalinity as nitrate is converted to nitrogen. An examination of the alkalinity data shows that the results follow the expected pattern. The nitrification process will consume approximately 7.1 mg of alkalinity per mg of nitrogen converted to nitrate, and the denitrification process will produce 3.6 mg of alkalinity per mg of nitrate converted to nitrogen. The overall net effect is that 3.5 mg/L of alkalinity will be consumed for each 1 mg/L of total nitrogen removed. The average TN removal was 21 mg/L and the average alkalinity consumed was 74 mg/L, yielding a ratio of 3.52 mg/L of alkalinity consumed per mg of total nitrogen removed.

The verification test provided a long enough test period to collect data that included both a long run of steady performance by the Bioclere™ and a period of upset conditions due to the nozzle plugging issue. The alkalinity and DO data followed an expected pattern during the test. When the system experienced the nozzle problems, the DO dropped from the typical 5 mg/L or higher level to less than 3 mg/L. System performance deteriorated and nitrogen reduction efficiency dropped to less than 10 percent. This would be expected, as the nitrifying organisms do not survive well at low DO. At the same time that the system performance decreased, the alkalinity of the effluent, which had been consistently lower than the influent, increased. During the July upset period, the alkalinity of the influent and effluent were essentially the same. These two parameters, dissolved oxygen and alkalinity, appear to provide good indicator parameters for the condition and performance of the system for nitrogen reduction. Both of these parameters can be measured in the field using quick and simple procedures. It would appear that these simple field checks could be used to provide a fast indicator if the system is experiencing an upset condition.

Overall, the TN reduction averaged 57 percent, with a median removal of 64 percent. As would be expected, removals were higher in the warmer period and somewhat lower during cold temperature months. Total nitrogen reduction ranged from a low of 50 percent to a high of 85 percent during normal operating periods (excludes the upset July 2001 and the first day after startup ended March 21, 2001).

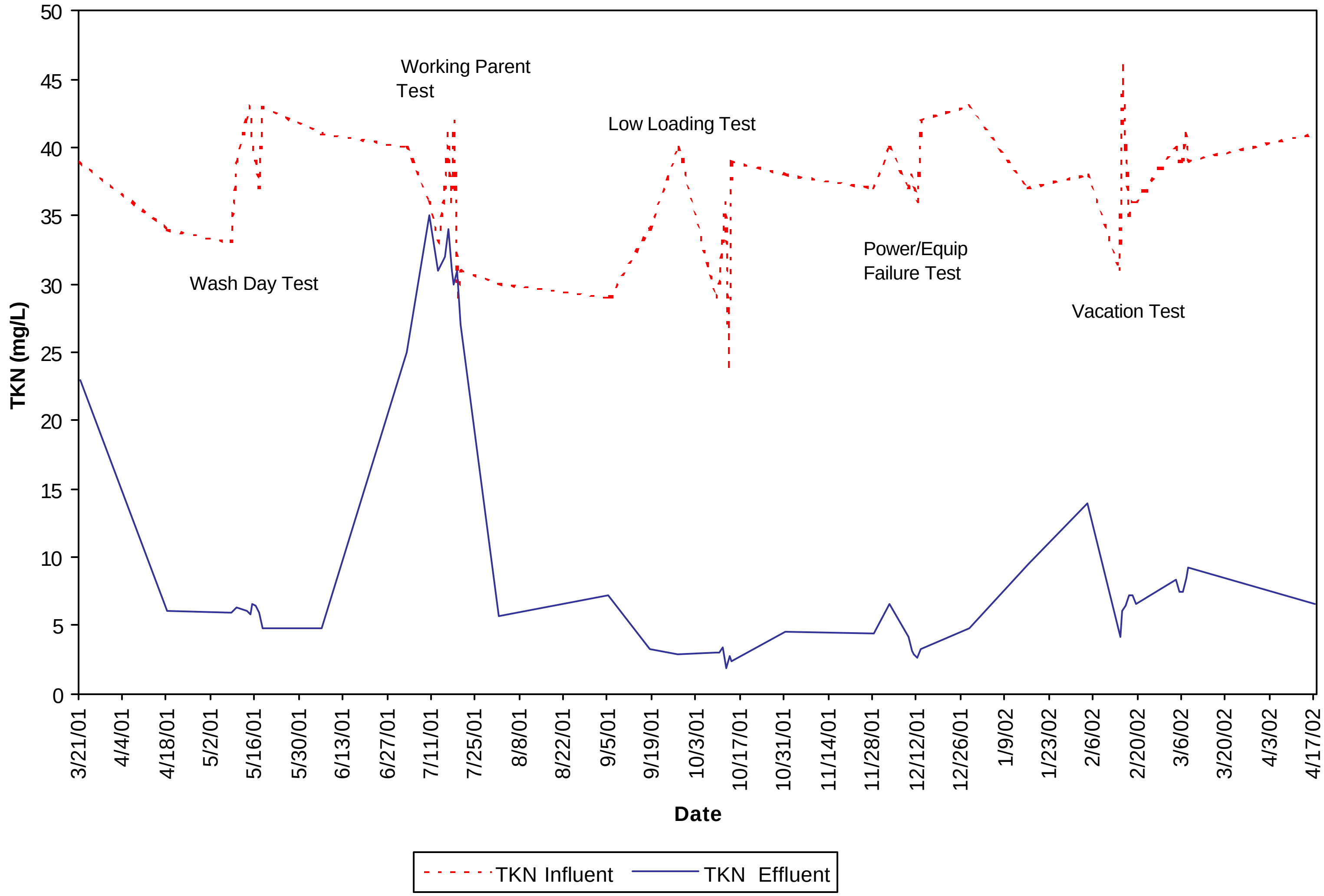

Figure 4-3. Bioclere™ Total Kjeldahl Nitrogen Results

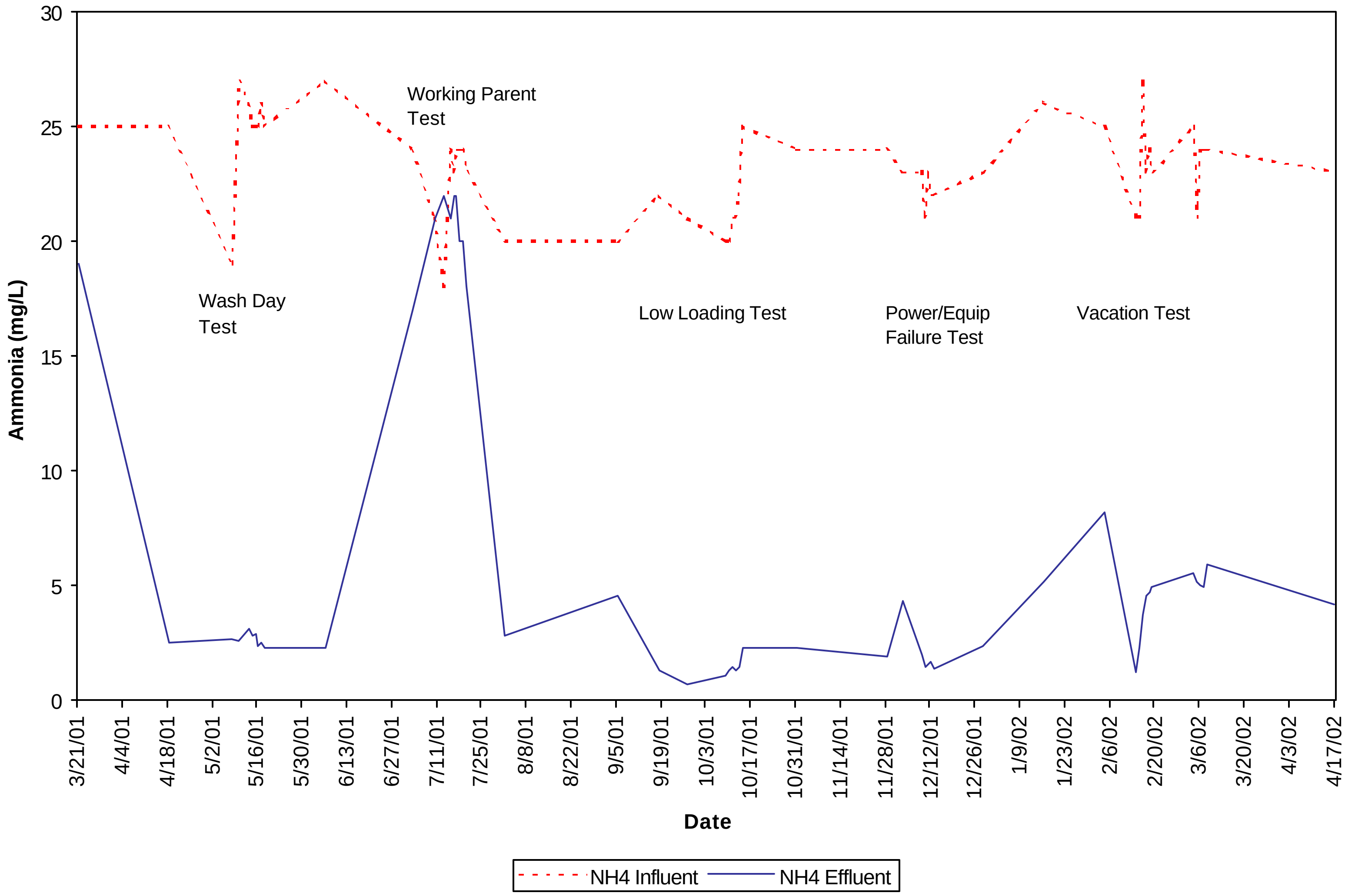

Figure 4-4. Bioclere™ Ammonia Nitrogen Results

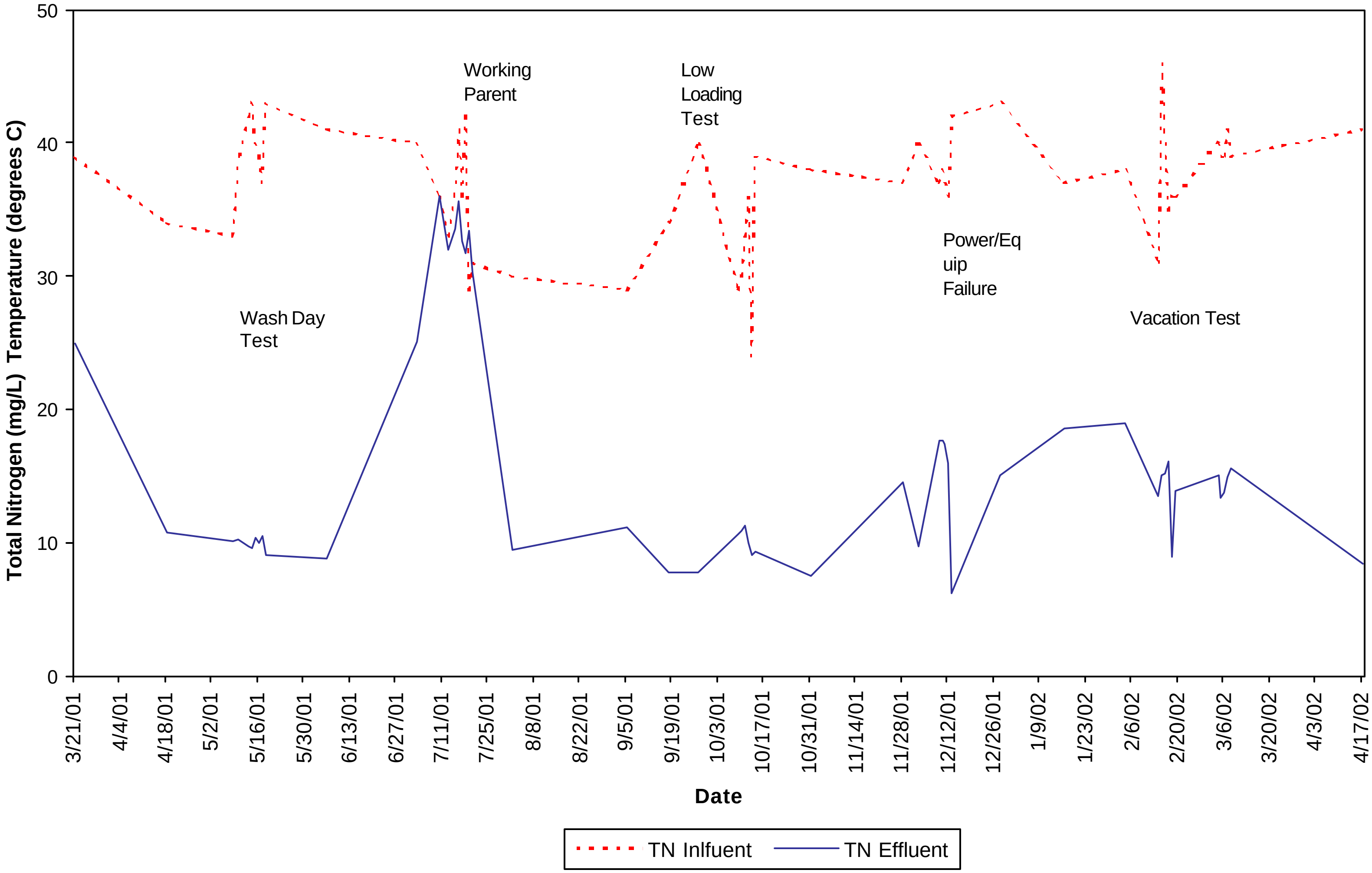

Figure 4-5. Bioclere™ Total Nitrogen Results

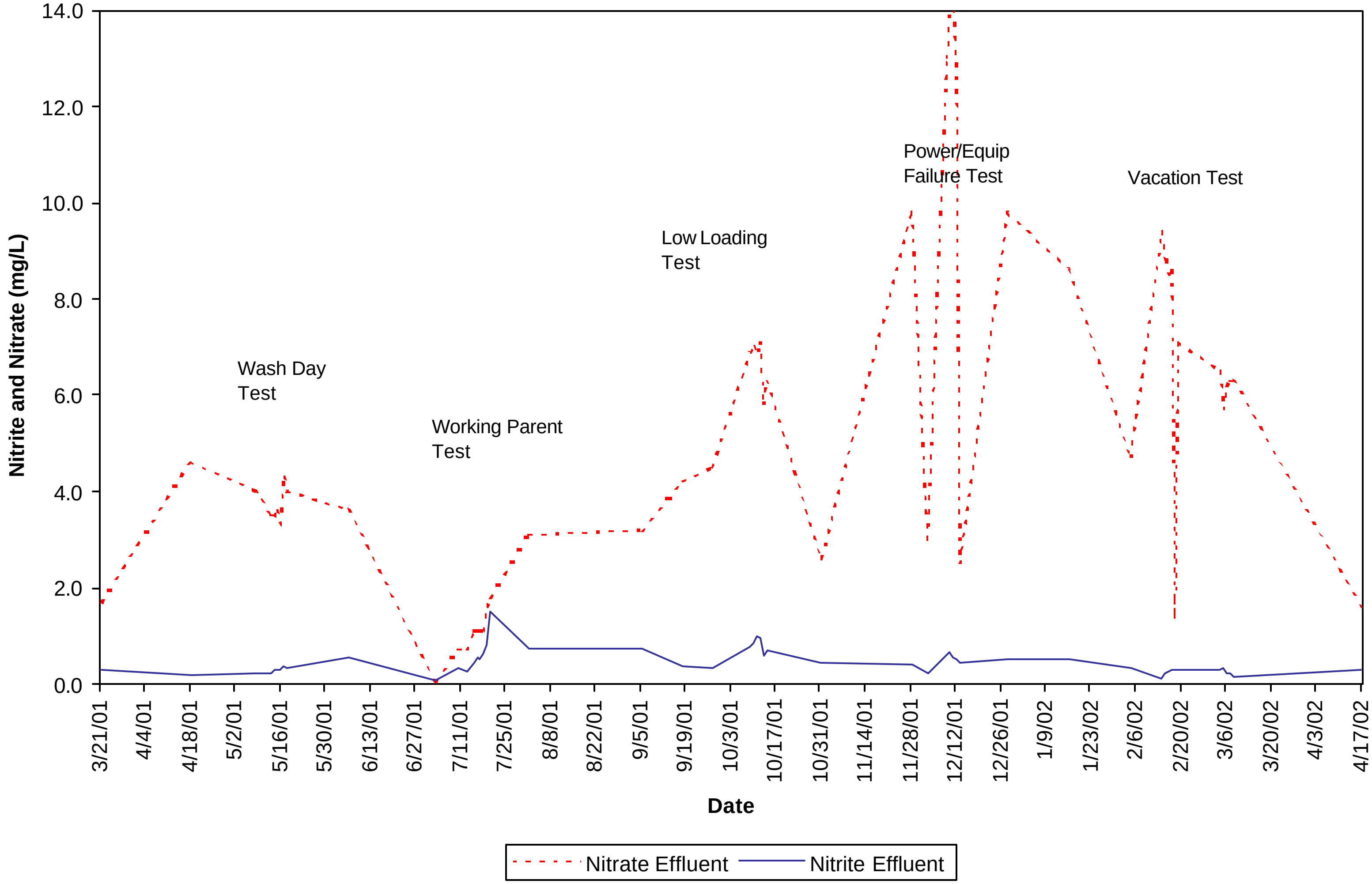

Figure 4-6. Bioclere™ Nitrite and Nitrate Effluent Concentrations

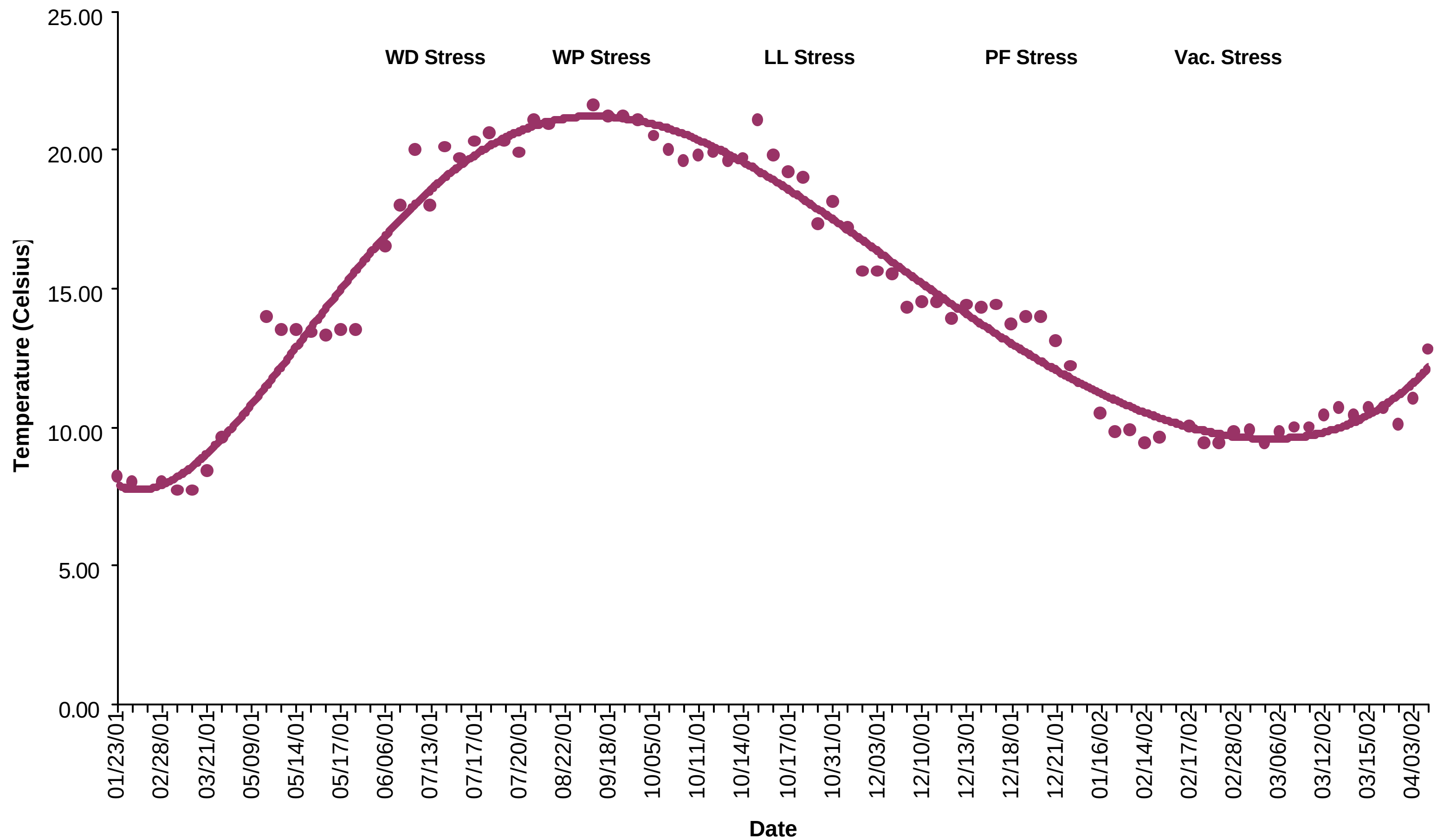

Figure 4-7. Bioclere™ Influent Temperature

Table 4-6. Bioclere™ Nitrogen Data for Influent and Effluent

Date	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)			Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Removal	Effluent	Effluent	Effluent
3/21/01	39	23	25	19	39	25	36	1.7	0.30	7.4
4/18/01	34	6.0	25	2.5	34	11	68	4.6	0.18	9.5
5/8/01	33	5.9	19	2.7	33	10	69	4.0	0.22	
5/10/01	39	6.3	27	2.6	39	10	73	3.8	0.24	14
5/13/01	42	6.0	26	3.1	42	10	77	3.5	0.23	16
5/14/01	43	5.8	25	2.8	43	10	78	3.5	0.31	15
5/15/01	40	6.5	25	2.9	40	10	74	3.6	0.31	15
5/16/01	39	6.4	25	2.4	39	10	74	3.3	0.31	15
5/17/01	37	5.9	26	2.5	37	11	71	4.3	0.37	14
5/18/01	43	4.7	25	2.3	43	9.0	79	4.0	0.33	14
6/6/01	41	4.7	27	2.3	41	8.8	78	3.6	0.54	18
7/3/01	40	25	24	17	40	25	37	<0.1	0.07	20
7/10/01	36	35	21	21	36	36	0	0.70	0.34	21
7/13/01	33	31	18	22	33	32	3	0.70	0.27	20
7/15/01	37	32	24	21	37	34	9	1.1	0.44	22
7/16/01	41	34	23	22	41	36	13	1.1	0.55	22
7/17/01	36	31	24	22	36	33	9	1.1	0.50	22
7/18/01	42	30	24	20	42	32	24	1.1	0.63	22
7/19/01	29	31	24	20	29	33	-15	1.6	0.82	21
7/20/01	31	27	23	18	31	30	2	1.8	1.5	21
8/1/01	30	5.6	20	2.8	30	9.4	69	3.1	0.75	22
9/5/01	29	7.2	20	4.6	29	11	62	3.2	0.72	23
9/18/01	34	3.3	22	1.3	34	7.8	77	4.2	0.35	21
9/27/01	40	2.9	21	0.70	40	7.7	81	4.5	0.33	20
10/9/01	29	3.0	20	1.1	29	11	63	6.9	0.78	18
10/10/01	30	3.0	20	1.3	30	11	64	7.0	0.86	18
10/11/01	33	3.4	21	1.5	33	11	66	6.9	1.0	18
10/12/01	36	1.9	21	1.3	36	10	72	7.1	0.95	18
10/13/01	24	2.7	22	1.5	24	9.1	62	5.8	0.59	19

Table 4-6. Bioclere™ Nitrogen Data for Influent and Effluent (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	Removal	Effluent	Effluent	Effluent
10/14/01	39	2.4	25	2.3	39	9.4	76	6.3	0.68	18
10/31/01	38	4.5	24	2.3	38	7.5	80	2.6	0.45	15
11/28/01	37	4.4	24	1.9	37	15	61	9.8	0.41	15
12/3/01	40	6.5	23	4.3	40	10	76	3.0	0.23	14
12/9/01	37	4.1	23	2.0	37	18	52	13	0.63	14
12/10/01	38	3.1	21	1.5	38	18	53	14	0.67	13
12/11/01	37	2.9	23	1.6	37	17	53	14	0.54	13
12/12/01	36	2.6	22	1.7	36	16	55	13	0.52	12
12/13/01	42	3.3	22	1.4	42	6.2	85	2.5	0.43	13
12/28/01	43	4.7	23	2.4	43	15	65	9.8	0.53	9.4
1/16/02	37	9.5	26	5.2	37	19	50	8.6	0.53	8.5
2/4/02	38	14	25	8.2	38	19	50	4.7	0.34	8.7
2/14/02	31	4.1	21	1.2	31	14	56	9.4	0.10	10
2/15/02	46	6.0	21	2.3	46	15	67	8.8	0.24	7.9
2/16/02	40	6.4	27	3.7	40	15	62	8.5	0.27	
2/17/02	35	7.2	23	4.6	35	16	54	8.6	0.30	8.0
2/18/02	36	7.2	24	4.7	36	8.9	75	1.4	0.31	8.0
2/19/02	36	6.5	23	4.9	36	14	61	7.1	0.30	7.6
3/4/02	40	8.3	25	5.6	40	15	62	6.5	0.31	9.5
3/5/02	39	7.4	21	5.2	39	13	66	5.7	0.32	8.7
3/6/02	39	7.4	24	5.0	39	14	65	6.2	0.24	8.7
3/7/02	41	8.4	24	4.9	41	15	64	6.3	0.21	9.2
3/8/02	39	9.2	24	5.9	39	16	60	6.3	0.16	9.2
4/17/02	41	6.5	23	4.2	41	8	80	1.6	0.30	14
Samples	53	53	53	53	53	53	53	53	53	51
Average	37	10	23	6.2	37	16	57	5.2	0.45	15
Median	38	6.3	23	2.8	38	14	64	4.4	0.34	15
Maximum	46	35	27	22	46	36	85	14	1.5	23
Minimum	24	1.9	18	0.70	24	6.2	-15	<0.1	0.07	7.4
Std. Dev.	4.4	10	2.1	7.0	4.4	8.4	24	3.5	0.26	4.9

Samples = Number of samples used in the calculations

Table 4-7. Bioclere™ Alkalinity, pH, and Dissolved Oxygen Results

	Alkalinity (mg/L as $CaCO_3$)		Dissolved Oxygen (mg/L)		pH (s.u.)	
Date	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
3/21/01	200	150	0.4	9.9	7.6	7.9
4/18/01	200	84	1.9	7.8	7.6	7.8
5/08/01	170	100	n/s	n/s	7.4	7.7
5/10/01	190	120	0.6	6.0	7.4	7.8
5/13/01	190	120	0.4	5.2	7.5	7.5
5/14/01	170	110	0.6	4.6	7.5	7.9
5/15/01	170	120	0.5	5.7	7.4	7.7
5/16/01	190	190	0.4	6.2	7.4	7.7
5/17/01	180	94	0.5	7.5	7.5	7.8
5/18/01	180	80	0.5	7.5	7.6	7.8
6/06/01	180	86	0.3	5.8	7.4	7.8
7/03/01	190	160	0.4	0.6	7.4	7.5
7/10/01	180	180	0.8	2.5	7.5	7.8
7/13/01	170	190	0.8	2.8	7.5	7.9
7/15/01	200	190	0.1	2.5	7.5	7.8
7/16/01	200	190	0.1	0.9	7.6	7.9
7/17/01	200	190	0.2	2.4	7.4	7.7
7/18/01	190	190	0.2	1.8	7.3	7.6
7/19/01	200	180	0.2	5.0	7.2	7.7
7/20/01	190	170	0.2	5.2	7.4	7.8
8/01/01	180	110	0.2	5.5	7.4	7.7
9/05/01	170	120	0.2	2.9	7.3	7.7
9/18/01	180	110	0.2	3.3	7.3	7.8
9/27/01	200	100	0.1	4.2	7.3	7.7
10/09/01	180	94	0.1	6.6	7.4	7.8
10/10/01	180	94	0.1	7.5	7.3	7.6
10/11/01	190	86	0.1	6.9	7.3	7.8
10/12/01	180	88	0.1	7.0	7.2	7.8
10/13/01	170	90	0.1	6.8	7.3	7.7
10/14/01	180	86	0.1	6.7	7.4	7.8

n/s – no sample

Table 4-7. Bioclere™ Alkalinity, pH, and Dissolved Oxygen Results (continued)

	Alkalinity (mg/L as $CaCO_3$)		Dissolved Oxygen (mg/L)		pH (s.u.)	
Date	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
10/31/01	190	76	0.3	7.3	7.3	7.6
11/28/01	190	82	0.4	7.7	7.4	7.6
12/03/01	170	92	0.1	5.9	7.3	7.6
12/09/01	200	74	0.2	7.0	7.4	7.6
12/10/01	180	68	0.2	7.7	7.5	7.5
12/11/01	180	60	0.2	7.7	7.3	7.5
12/12/01	180	58	0.4	8.3	7.4	7.5
12/13/01	190	58	0.2	7.9	7.5	7.6
12/28/01	200	76	0.3	7.8	7.5	7.6
1/16/02	190	90	0.3	9.3	7.6	7.9
2/04/02	170	110	0.5	7.9	7.4	7.7
2/14/02	170	80	0.2	9.8	7.4	7.6
2/15/02	210	98	0.6	9.7	7.3	7.7
2/16/02	190	94	0.3	8.9	7.4	7.8
2/17/02	190	92	0.1	8.6	7.5	7.7
2/18/02	190	90	0.2	7.2	7.5	7.7
2/19/02	180	110	0.3	7.0	7.4	7.7
3/04/02	170	90	0.9	6.2	7.4	7.6
3/05/02	160	88	0.8	9.7	7.4	7.5
3/06/02	170	88	0.8	5.8	7.4	7.5
3/07/02	180	87	0.3	7.6	7.4	7.6
3/08/02	180	90	0.6	7.8	7.4	7.6
4/17/02	190	120	0.1	5.3	7.4	7.7
Samples	53	53	52	52	53	53
Average	180	110	0.4	6.3	n/c	n/c
Median	180	94	0.3	6.9	7.4	7.7
Maximum	210	190	1.9	9.9	7.6	7.9
Minimum	160	58	0.1	0.6	7.2	7.5
Std. Dev.	10	40	0.3	2.3	n/c	n/c

n/c – not calculated
Samples = Number of samples used in the calculations

4.3.4 Residuals Results

During the treatment of wastewater in the Bioclere™ system, solids will accumulate in the primary tank and to some degree in the clarifier section in the bottom of the trickling filter unit. Inert solids will be removed in the primary tank system just as in a normal septic system. Biological solids will also accumulate both from influent wastewater solids and from the recycling of solids generated by the trickling filter during periods when solids slough from the media. Eventually, a buildup of solids will reduce the capacity of the primary tank and the solids will need to be removed.

The approximate quantity of residuals that accumulated in the system was estimated by measuring the depth of solids in the primary tank and in the Bioclere™ clarifier. Measurement of solids depth is 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 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 measured with a ruler. The column was mixed and sent to the laboratory for analysis. The measurements were made twice near the end of the test, in February 2002 and in March 2002. The results are presented in Table 4-8. The solids depth was measured in the Bioclere™ clarifier in March. The depth of solids was 12 inches.

Table 4-8. Solids/Scum Depth Measurement

	Primary Tank Solids/Scum Depth in Inches			
Manway Location	East	Middle	West	Average
February 4, 2002 Septic Tank Inlet End	10	17	24	17
February 4, 2002 Septic Tank Outlet End	13	10	25	16
February 4, 2002 Scum Depth Inlet End	0	0	0	0
February 4, 2002 Scum Depth Outlet End	0	0	0	0
March 8, 2002 Septic Tank Inlet End	25	13	5	14
March 8, 2002 Septic Tank Outlet End	23	19	14	19
March 8, 2002 Scum Depth Inlet End	0	0	0	0
March 8, 2002 Scum Depth Outlet End	0	0	0	0

Note: Measurement is estimated solids depth in the Primary Tank.

In order to characterize the solids in the primary tank, total suspended solids and volatile suspended solids were measured in the samples collected in March. These data are presented in Table 4-9. These concentrations represent the solids concentration in the total sample collected, which includes the solids and water present in the sample tube. Based on an average of 16 inches of solids present in the tube and an additional 32 inches of water (depth in the septic tank), the concentration of solids needs to be multiplied by a factor of 3.0 to estimate the actual solids concentration in the settled solids layer.

Table 4-9. TSS and VSS Results for Bioclere™ Solids Samples

Date	Location	TSS (mg/L)	VSS (mg/L)
3/8/02	Primary Tank	7300	1300
3/8/02	Clarifier Section	4500	730

The mass of solids present in the septic tank can be estimated from these data. The average concentration of solids in the septic tank, 7,300 mg/L multiplied by the tank total volume of 1,000 gallons shows that the solids accumulated during the test was approximately 61 pounds.

The solids in the clarifier section, 4,500 mg/L and a volume of 350 gallons, shows an additional solids load of 13 pounds. The solids in the clarifier appeared to be in equilibrium as solids were pumped out of the unit to the primary tank. Thus, the solids level should remain steady in the conical section of the clarifier.

The total mass of solids can also be estimated using the settled solids concentration and the tank dimensions. The primary tank holds a volume of approximately 21 gallons per inch of depth. Therefore, the solids volume, based on an average 16 inches depth, was about 350 gallons. The settled solids concentration is estimated to be 2.2 percent (22,000 mg/L) using the ratio of total depth to solids depth described above (factor of 3.0). Based on a settled solids concentration of 22,000 mg/L, the weight of dry solids accumulated was approximately 64 pounds. The volatile solids represented 18 percent of the solids in the tank.

4.4 Operations and Maintenance

Operation and maintenance performance of the Bioclere™ unit 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 Bioclere™, any changes in setup or operation (timer adjustments, nozzle cleaning, etc.) or any problems that required resolution. A complete set of field logs is included in Appendix G.

4.4.1 Electric Use

Electrical use was monitored by a dedicated electric meter serving the Bioclere™ 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 4.5 kilowatts per day based on the entire data set. There was one set of data for the August 29 to 31, 2001 period that showed an average daily use of 49.5 kW/day. It is not known why this anomaly in the data occurred. If this one reading, representing a two-day period, is removed from the database, the average electrical use was 4.2 kW/day with a maximum of 10 kW/day. The Bioclere system has a fixed pump cycle time that should result in steady reproducible power use. This was case for most of the test period. There were no alarms on the two days with abnormally high electrical use. Most likely, these readings are in error and the average of 4.2 kW/day is most likely the most representative data for the Bioclere unit.

Table 4-10. Summary of Bioclere™ Electrical Usage

	kW/day	kW/day(1)
Count	195	193
Average	4.50	4.24
Maximum	49.5	9.50
Minimum	0.00	0.00
Std. Dev.	3.52	1.32

(1) Electrical meter reading on Aug 31, 2001 indicated a use of 99 kilowatts over a two-day period. This gave an average of 49.5 kW/day for the period. This data is not included in this summary, as it appears to be incorrect data.

4.4.2 Chemical Use

The Bioclere™ 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 (particularly compressors and blowers) 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. Bioclere™ Noise Measurements

Location	**First Reading (decibels)**	**Second Reading (decibels)**	**Average**
Background	37.5	38.0	37.7
Bioclere™			
East	47.3	47.2	47.2
South	46.3	45.5	45.9
West	52.8	52.6	52.7
North	52.5	52.6	52.6

Decibel is a log scale so averages are calculated on a log basis.

4.4.4 Odor Observations

Odor observations were made monthly for the last eight 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. Table 4-12 summarizes the results for the odor observations. As can be seen, there were no discernible odors found during any of the observation periods.

Table 4-12. Odor Observations

Date	Number of Points observed	Observation
9/10/01	8	No discernable odor
10/20/01	8	No discernable odor
11/22/01	8	No discernable odor
12/09/01	8	No discernable odor
1/27/02	8	No discernable odor
2/17/02	8	No discernable odor
3/02/02	8	No discernable odor
3/31/02	8	No discernable odor

4.4.5 Operation and Maintenance Observations

The Bioclere™ is a trickling filter that uses proprietary hollow cylindrical corrugated plastic media for the growth of bacteria for treatment combined with bacteria resident in the septic tank. The system in total is generally comprised of a single compartment septic tank and the filter material enclosed in a more-or-less cylindrical container with a conical bottom. Beneath the media is a timed media dosing pump that circulates effluent over the media bed. A pump situated at the bottom of a conical collection area beneath the filter returns treated wastewater and collected solids to the septic tank on a timed cycle. The effluent rate from the system is determined somewhat by the influent supply rate; however, it was noted that due to the volume of effluent recirculating over the media during a timed-dose, the effluent discharge is delayed if the influent pulse is coincident with a recirculation cycle.

During the test, very few problems were encountered with the operation of the system. The effluent distribution nozzles were initially helical spray nozzles. These nozzles plugged in early July after five and a half months of operation. The plugging problem was discovered when the effluent's visual characteristic changed and had notably more suspended solids. In addition, during the nozzle plugging, the noise level of the spray hitting the inside of the media containment structure was slightly louder, signaling higher flow through one of the nozzles and overloading of a portion of the media bed. AQP was called to report the problem and they responded with a visit to the site. The nozzles were cleaned and the system placed back into service. Once the nozzles were cleaned, the clarity of the effluent returned within one week. The nozzles were cleaned again in the fall by AQP in accordance with the quarterly maintenance check that is recommended in the O&M manual. Based on the inspections of the nozzles by AQP in the MASSTC service application, a new set of helical nozzles was installed in January 2002. These nozzles needed no additional cleaning through the remaining period of the test.

Proper operation of the nozzles is important to the performance of the unit. Periodic checks of the nozzles are recommended as part of the quarterly maintenance program. AQP believes that the nozzle plugging problem was a unique occurrence as this type of unit had been operated at MASSTC and many other locations without a problem. They have added a statement regarding the nozzle issue at the end of this report (Section 4.4).

In general, the liquid effluent can be described as clear, occasionally having a slight cloudy appearance. Any more extreme cloudiness signaled a problem, such as was observed when the nozzles were clogged.

No other problems were encountered during the test period. No particular design considerations are necessary relative to placement, as the unit makes very little noise. Since approximately two feet of the system protrudes out of the ground, some siting considerations based on this feature may be desired.

The routine operation and maintenance of the system was straightforward with the exception of the nozzle plugging problem described above. The discovery of the nozzle problem was based on simple observation of the clarity of the effluent and on the change in sound coming from the unit. This problem could be easily found by an observant homeowner or during regular quarterly maintenance. Based on observations of the unit for a 15 month period, it estimated that the routine quarterly maintenance, as recommended in the O&M manual, will require one to two hours of time by a person knowledgeable of the treatment system. The skill level needed is estimated to be typical of a Class II Massachusetts treatment plant operator.

The maintenance, provided by a qualified service provider, should involve checking the two pumps (media dosing pump and treated wastewater/solids return pump), the fan, and cleaning the distribution manifold and nozzles. The maintenance check should also include measurement of the solids depth in the primary tank, observation of the condition of the media, and a visual inspection of the effluent. Pump cycle times should be verified and alarms checked.

Homeowner participation should be limited to an occasional check that the fan is operating (can check by placing hand on housing top and feeling vibration) and listening for the periodic operation of the media dosing pump sending water through the spray nozzles. The spray nozzle and pump sound can be easily heard within a few feet of the unit. If there is an alarm, the owner should call the maintenance number shown on the front panel of the unit.

The primary tank should be checked 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. In a typical or standard residential septic tank system pumping can be expected to occur every 3 to 5 years. More frequent pumping of solids from the septic tank can be expected based on the additional solids load generated by the Bioclere™ System. The regular maintenance checks should include measurement of solids level in the primary tank. When the level of solids buildup to 30 to 36 inches (48 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 thirteen months, which provided sufficient time to evaluate the overall performance of the System. However, a much longer period (several years) would be needed to evaluate the life cycle for the equipment, pumps, floats, filter and distribution assembly, etc. The basic components of the System should perform well under typical home wastewater conditions. The treatment unit itself proved durable for the duration of the test and appears to generally be a durable fiberglass design. The piping is standard PVC that is appropriate for the applications. Pump and level switch life is always difficult to estimate, but the equipment used is made for wastewater applications and is from a reputable and known manufacturer.

A final observation/recommendation is that the O&M manual, while well documented, should be changed to remove the "if necessary" comments in the routine check list for cleaning the nozzles. Cleaning and inspecting the condition of the distribution manifold and the nozzles should be required.

4.5 Aquapoint, Inc. – Discussion of Test Results

Aquapoint, Inc. has reviewed this report and has prepared the discussion and comments in the two subsections below.

4.5.1 Nozzle Clogging Problem

A period of upset occurred during the "working parent" stress testing in July 2001. As stated in this report, the reduction in treatment efficiency was most likely a direct result of the two nozzles that were completely plugged. This greatly reduced the amount of wastewater that was distributed over the media bed, minimizing contact with the biofilm. The corkscrew nozzles were cleaned and the treatment performance improved rapidly. The Bioclere nozzles were cleaned periodically from August 2001 through January 2002, as needed. On January 30, 2002, the standard corkscrew nozzles were removed and replaced with the raindrop type nozzles.

This same Bioclere unit underwent NSF Standard 40 testing over a 6-month period (October 2000) at MASSTC. The nozzles did not experience any plugging over the 6-month period and did not require any cleaning or maintenance. It should also be noted that this type of plugging has not been experienced in over 100 field installations.

During the ETV testing, the Bioclere operated for approximately 4 months without any nozzle cleaning or maintenance. Shortly thereafter, two of the three nozzles became completely plugged with debris around the time of the working parent stress testing. After this occurrence, it was determined that the nozzles were repeatedly plugged with medicine capsules commonly found in the waste stream. The medicine capsules may be unique to the waste stream generated at the Air Force Base.

In the future, the nozzle plugging problem experienced at the test center may be overcome by: 1) installing the rain drop type of nozzles with a 3/8" diameter opening in the Bioclere unit, 2) installing a 1500 gallon two compartment primary tank or 3) installing a septic tank effluent screen.

4.5.2 Data Presentation

The ETV protocol is based on monthly sampling during normal operation and intensive daily sampling following stress tests. Therefore, any upset or unique conditions occurring during the stress test (even if not caused by the stress test) may impact the calculation of average values for the entire test period. The nozzle-clogging problem described above occurred at the same time as the working parent stress test. The effluent was tested eight times during and following this stress-testing period. These eight samples represent 15 percent of the total samples collected (8 out of 53) during the yearlong ETV test. The overall average effluent pollutant concentrations were increased by the overweighing of data from this upset. If the upset period from July 3 through July 20, 2001 is not used in the calculations, the average total nitrogen concentration decreases from 16 mg/L to 12mg/L, with the average removal increasing from 57 percent to 72 percent. $CBOD_5$ and TSS performance calculations are also impacted by including the data from the upset period. The $CBOD_5$ average concentration drops from 14 mg/L to 10 mg/L, with the removal improving from 93 percent to 95 percent, if the data from July 3 through July 20 is not included in the average calculations. The average TSS concentration decreases from 16 mg/L to 10 mg/L with an increase in removal efficiency increasing from 90 percent to 94 percent.

4.6 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.

4.6.1 Audits

Two (2) 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 that were 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.

4.6.2 Precision

Precision measurements were performed throughout the verification test by the 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 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 4-13. 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

Number = Number of analyses used in the calculations

Table 4-14. 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

Number = Number of analyses used in the calculations

Table 4-15. Duplicate Field Sample Summary – pH, Dissolved Oxygen

Statistics	pH (S.U.)			Dissolved Oxygen (mg/L)		
	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		

Number = Number of analyses used in the calculations

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 about 1 mg/L. TSS is 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 significantly 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 very tight target of 10 percent RPD. Nitrate results showed 14 out 211 values exceeded the 10 percent RPD target, but only 1 result out 211 exceeded a 20 percent difference.

The $CBOD_5$ and TSS precision was generally within the target objective of 20 percent RPD, except when the concentrations were low. As discussed above, 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, which would account for the difference. The data for all analyses was judged acceptable and useable for evaluating the treatment efficiency.

Table 4-16. Laboratory Precision Data – Nitrogen Compounds

Statistics	Relative Percent Difference (RPD)			
	TKN	Ammonia	Nitrite	Nitrate
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

Number = Number of analyses used in the calculations

Table 4-17. Laboratory Precision Data – CBOD, BOD, Alkalinity, TSS

Statistics	$CBOD_5$ (mg/L)			BOD_5 (mg/L)		
	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

Number = Number of analyses used in the calculations

4.6.3 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 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 4-18. Accuracy Results – Nitrogen Analyses

Statistics	TKN (% Recovery)		Ammonia (% Recovery)	
	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
Statistics	Nitrite (% Recovery)		Nitrate (% Recovery)	
	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

Number = Number of analyses used in the calculations

Table 4-19. Accuracy Results – CBOD, BOD, Alkalinity

Statistics	$CBOD_5$ (% Recovery)	BOD_5 (% Recovery)	Alkalinity (% Recovery)
	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

Number = Number of analyses used in the calculations

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 an 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.

4.6.4 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 was 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.

4.6.5 Completeness

The VTP set a series of goal for completeness. During the startup and verification test, flow data was collected for each day and the influent 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, and two readings were suspect. Out of 195 readings, three were incomplete giving a completeness of 98 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 GAL. 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

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5.2 Additional Background References

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