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:	**RECIP® RTS ~ 500 SYSTEM**	
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NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of the BioConcepts Inc., ReCip® RTS ~ 500 System (ReCip®) for nitrogen removal in residential applications. This verification statement provides a summary of the test results for the ReCip®. The Barnstable County [Massachusetts] Department of Health and Environment (BCDHE) performed the verification testing.

The U.S. Environmental Protection Agency (EPA) created the ETV Program to facilitate deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and 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 ReCip® was conducted over a 12-month period at the Massachusetts Alternative Septic System Test Center (MASSTC) located on Otis Air National Guard Base in Bourne, Massachusetts. A nine-week startup period preceded the verification test to provide time for the development of an acclimated biological growth. The verification test included monthly sampling of influent and effluent wastewater, and five test sequences designed to test the unit's response to differing load conditions and power failure. The ReCip® proved capable of removing nitrogen from the wastewater. Over the verification period, the total nitrogen (TN) concentration in the influent averaged 36 mg/L and the TN in the effluent averaged 15 mg/L.

TECHNOLOGY DESCRIPTION

The following technology description is provided by the vendor and does not represent verified information.

The ReCip® uses a filter medium contained in two adjacent, equally dimensioned cells. The medium provides a surface for microbes to attach, live, and grow. Timers on each of two reciprocating pumps control the process. BioConcepts Inc. describes the basic treatment processes as follows: at the start of the cycle, the first cell of the ReCip® unit is filled nearly to the top with wastewater. The pump located in the cell then pumps the liquid into the second cell, until the first cell is nearly empty. As the liquid leaves the first cell, the void space formerly occupied by the liquid fills with air from the vent system, exposing the medium to atmospheric oxygen contained in the air. At this point, the second cell is nearly full and the first cell is nearly empty. The two cells remain in this state for a time before the second cell's pump sends the liquid back to the first cell, drawing air into the second cell. Wastewater that clings to the medium contains nutrients and organics, which are oxidized by bacteria (biofilm) that are exposed to the air. The bacteria live and grow on the medium. In the presence of oxygen, organic matter is converted to carbon dioxide and water, and ammonia nitrogen (NH_3-N) is converted to nitrate nitrogen (NO_3^-). Anaerobic decomposition of the contaminants continues in the wastewater that is not exposed to air (at the very bottom of the cells), converting the NO_3^- to nitrogen gas. The two cells continue to fill and drain, with rest periods between the cycles, until additional wastewater flows into the first cell. When the capacity of the first cell is met, its contents are pumped into the second cell. The excess volume exits the overflow of the second cell as treated effluent. As an example, if the rated capacity of the tanks is 500 gallons and one extra gallon enters the system, a gallon of treated effluent will exit cell number two.

A basic residential ReCip® wastewater treatment system includes: (1) a standard septic tank to provide solids separation and primary treatment; (2) a ReCip® unit to provide secondary and tertiary treatment for the septic tank effluent; and (3) a tile field or other system for final disposal of treated effluent.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site is located on the Otis Air National Guard Base in Bourne, Massachusetts. The site uses domestic wastewater from the base's residential housing, and sanitary wastewater from other military buildings. 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 spaced along the channel length to ensure mixing, such that the wastewater is of similar quality at all locations along the channel. Wastewater is dosed to the test unit using a pump submerged in the dosing channel. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle.

Methods and Procedures

The ReCip® was installed by a contractor, in conjunction with the BCDHE support team, in August 2002. An existing 1,500-gallon septic tank was used for the verification test. On October 29, 2002, the primary tank was filled with wastewater and the dosing sequence began. The ReCip® unit had a design capacity of 500 gallons per day. The verification test was designed to load the system at design capacity (±10 percent) for the startup period as well as the entire 12-month test, except during the low load and vacation stress tests. The system was dosed 15 times per day with approximately 33.3 gallons of wastewater per dose, receiving five doses in the morning, four doses mid-day, and six doses in the evening. The dosing volume was controlled by the dosing-pump run time for each cycle and was checked and calibrated twice weekly.

A startup period allowed the biological community to become established and the operating conditions to be monitored. The verification test consisted of a 12-month test period, incorporating five sequences with varying stress conditions simulating real household conditions. The five stress sequences, performed at two-month intervals, included washday, working parent, low load, power/equipment failure, and vacation test sequences. Monitoring for nitrogen reduction was determined by measurement of nitrogen species [total Kjeldahl nitrogen (TKN), NH_3-N, nitrite (NO_2^-), and NO_3^-]. Biochemical and carbonaceous biochemical oxygen demand (BOD_5/$CBOD_5$) and other basic parameters [pH, alkalinity, total suspended solids (TSS), and temperature] were also monitored. Operational characteristics, such as electric use, labor to perform maintenance, maintenance tasks, durability of the hardware, and noise and odor production, were also evaluated.

Twenty-four-hour flow-weighted composite samples of the influent and effluent wastewater were collected once per month under normal operating conditions and more frequently following stress tests, as well as at the end of the verification test. Grab samples were collected each sampling day to monitor the system pH, dissolved oxygen, and temperature.

All analyses were performed in accordance with EPA-approved methods or according to the methods in *Standard Methods for the Examination of Water and Wastewater,* 19th Edition. 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 of all test procedures, analytical methods, and QA/QC procedures are provided in the verification report.

PERFORMANCE VERIFICATION

Overview

Evaluation of the ReCip® began on October 29, 2002, when the ReCip® pumps and the initial dosing cycles were activated. Five samples of influent and effluent were collected during the startup period. Verification testing began on January 1, 2003 and continued for twelve months, until December 21, 2003. During the verification test, 53 sets of samples of influent and effluent were collected to measure system performance.

Startup

The installation instructions were easy to follow, and installation proceeded without difficulty. The unit started with no mechanical difficulty. The initial timer setting was the default value of a two-hour rest period between pump cycles. Near the end of the startup, BioConcepts changed the timer setting to provide a one-hour rest period, thus increasing the number of pumping cycles per day. At the end of the nine-week start-up, effluent $CBOD_5$ was 43 mg/L and TSS was 22 mg/L. The influent TN concentration was 37 mg/L, and the effluent TN concentration was 30 mg/L.

Verification Test Results

The standard dosing sequence was performed daily from January 1, 2003 through December 21, 2003, except during certain stress periods. Following completion of the 12-month verification test, the unit continued in operation at the same dosing levels and settings for four additional months, January through April 2004. Volume per dose and total daily volume varied only slightly during the verification test. All monthly average doses and volumes met the requirement of being within ±10 percent of the target.

At the start of the verification test, the pump timer was reset to provide a two-hour rest period between pump cycles. On January 22, 2003, the rest period was changed to one hour. BioConcepts requested this change to improve system performance by introducing additional air (oxygen) to the unit by increasing the number of pump cycles between the cells. The pump timer setting of one-hour rest periods between cell wastewater transfers remained constant from January 22, 2003 to August 11, 2003. At that time, it was reset to provide a half-hour rest period, at BioConcept's request.

The TSS and BOD_5/$CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1.

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
Mean	200	28	86	130	13	90
Median	190	26	87	130	12	91
Maximum	360	67	>99	230	28	95
Minimum	98	<2	68	82	6	74
Std. Dev.	52	14	6.8	32	4.7	4.7

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 ReCip® showed a mean TN reduction of 58 percent, with a mean NH_3-N removal of 57 percent.

Table 2. Nitrogen Data Summary

	TKN (mg/L)		NH_3-N (mg/L)		TN (mg/L)		NO_3^- (mg/L)	NO_2^- (mg/L)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent
Mean	36	13	23	10	36	15	1.7	0.18
Median	36	14	23	10	36	15	1.8	0.19
Maximum	44	27	35	18	44	27	11	0.86
Minimum	24	5.4	15	3.4	24	3.0	<0.10	<0.05
Std. Dev.	4.1	4.7	3.1	4.0	4.1	4.2	2.5	0.19

Note: The TKN, effluent NH_3-N and influent TN data in Table 2 are based on 52 samples. The influent NH_3-N data are based on 51 samples. The effluent TN, NO_3^- and NO_2^- data are based on 53 samples.

Verification Test Discussion

At the beginning of the verification test, TN removal was 29 percent and NH_3-N removal was 14 percent. Following the January 22, 2003 timer change, performance began to improve. TN removal reached 50 percent by February. NH_3-N removal increased more slowly, reaching 50 percent removal in mid-April

when wastewater temperatures also increased. TN, TKN, and NH_3-N removals all improved as the test continued. NH_3-N removal reached 80 percent by November 2003, following the August 11, 2003 timer change.

The washday (February 18 to 22) and working parent (April 22 to 26) stress tests did not negatively impact nitrogen removal. In fact, NH_3-N removal and TN removal improved in the post-stress-test monitoring periods. The low load stress test, during which the hydraulic loading (250 gpd) of the ReCip® was half of design loading, began on July 2 and ended on July 22. NH_3-N, TKN, and TN removal all decreased during the post-low-load stress test monitoring, but the ReCip® recovered within the following three weeks. Performance returned to pre-low-load stress test levels, and removal percentages for NH_3-N and TN were consistently higher during September 2003 compared to previous periods of the test. The power/equipment failure stress test was conducted from September 16 to 18, and showed no impact on the unit.

The vacation stress test was started on November 18 and continued until November 27. During this period, there was no influent flow to the system for eight days. Lower NH_3-N and TKN removals were observed during the last days of the post-stress-test monitoring period. However, performance improved within two weeks. On the first day of post-stress-test monitoring the NO_3^- level in the effluent increased to 11 mg/L, the highest level found during the entire verification test, then steadily decreased over the next several days. It is apparent from the increase in NO_3^- and corresponding decrease in alkalinity (denitrification produces alkalinity) that something upset the denitrification process. Flow to the unit had returned to normal for nine days following the stress test, so it is not clear if the vacation stress test had a direct impact on the denitrification process. It is more likely that something else caused the decrease in denitrification.

The system performance returned to the same general levels achieved in September and October during the final week of sampling in December 2003, with effluent NH_3-N and TKN concentrations of less than 10 mg/L (in the 3.8 to 5.1 mg/L and 7.6 to 9.2 mg/L ranges, respectively). After a peak of 11 mg/L on November 30, 2003, the NO_3^- levels improved to between 3.0 and 4.1 mg/L in late December.

Operation and Maintenance Results

Noise levels associated with pumps were measured once during the verification period using a decibel meter. Measurements were made one meter from the unit and one and one-half meters above the ground, at 90° intervals in four directions. The noise levels ranged from 78 to 97 decibels with a background noise level of 85 decibels.

Qualitative odor observations based on odor strength (intensity) and type (attribute) were made 13 times during the verification test. Observations were made during periods of low wind velocity (<10 knots), at a distance of three feet from the treatment unit, and recorded at 90° intervals in four directions. There were no discernible odors during the observation periods.

A dedicated electric meter serving the ReCip® was used to monitor electrical use. The average electrical use was 2.7 kilowatts (kW) per day. Electrical use increased or decreased depending on the number of pump cycles per day, as would be expected. The ReCip® did not require or use any chemical addition during normal operation.

The only maintenance performed during the test was cleaning the floats on the pump in cell one. On two occasions, March 1 and August 2, 2003, the pump did not cycle properly. This was caused by the low water shutoff float becoming stuck, preventing the pump from operating. The pump was pulled using the

procedures described in the O&M manual. The float was cleaned and the pump was reinstalled. This solved the problem in both cases.

The ReCip® appeared to be of durable design and proved to be durable during the test. The piping and construction materials used in the system meet the application needs. Although pump life is difficult to estimate, the equipment used operated continuously for 17 months.

Quality Assurance/Quality Control

NSF International completed QA audits of MASSTC and the BCDHE laboratory during testing. NSF personnel completed a technical systems audit to assure the testing was in compliance with the test plan; a performance evaluation audit to assure that the measurement systems employed by MASSTC and the BCDHE laboratory were adequate to produce reliable data; and a data quality audit of at least 10 percent of the test data to assure that the reported data represented the data generated during 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.

Original signed by Sally Gutierrez for Lawrence W. Reiter, Ph.D.	*09/30/04*	*Original signed by Gordon E. Bellen*	*10/20/04*
Lawrence W. Reiter, Ph.D. Acting Director National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency	Date	Gordon E. Bellen Vice President Research NSF International	Date

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

Availability of Supporting Documents

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

1.ETV Water Quality Protection Center Manager (order hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140
2.NSF web site: http://www.nsf.org/etv (electronic copy)
3.EPA web site: http://www.epa.gov/etv (electronic copy)

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

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

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