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Environmental Technology Verification Report

Reduction of Nitrogen in Domestic Wastewater from Individual Residential Homes

Bio-Microbics, Inc.
RetroFAST® 0.375 System

Prepared by

NSF

NSF International

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

ETV ETV ETV

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:	**RETROFAST® 0.375 SYSTEM**	
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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 submerged attached-growth biological treatment system for nitrogen removal for residential applications. This verification statement provides a summary of the test results for the Bio-Microbics, Inc. RetroFAST® 0.375 System (RetroFAST®). NovaTec Consultants, Inc. (NovaTec) performed the verification testing.

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 RetroFAST® was conducted over a twelve-month period at the Mamquam Wastewater Technology Test Facility (MWTTF) located at the Mamquam Wastewater Treatment Plant (WWTP), which serves the District of Squamish, British Columbia, Canada. An eight-week startup period preceded the verification test to provide time for the development of an acclimated biological growth in the RetroFAST®. 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 RetroFAST® proved capable of removing nitrogen from the wastewater. The influent total nitrogen (TN) mean concentration was 39 mg/L, with a median of 36 mg/L. The effluent TN (total Kjeldahl nitrogen (TKN) plus nitrite/nitrate (NO_2^-/NO_3^-)) mean concentration was 19 mg/L over the verification period, with a median concentration of 18 mg/L. During the first two months of testing, an apparent upset condition occurred. During investigation of the upset, Bio-Microbics determined that the blower setting of 30 minutes on and 30 minutes off was incorrect. The blower was changed to continuous operation and the verification test continued for eleven months. The mechanical components of the RetroFAST® (blower, airlift, and optional alarm) operated properly throughout the test. No maintenance or operational changes were required during the final eleven months of the verification test.

TECHNOLOGY DESCRIPTION

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

The RetroFAST® 0.375 System is a submerged attached-growth treatment system, which is inserted as a retrofit device into the outlet side of new or existing septic tanks. The RetroFAST® has a rated capacity of 375 gallons per day (gpd), and is designed to treat wastewater from a single-family home with four to six persons. The only mechanical component is a remotely housed air blower, which provides air for oxygen supply and mixing to the aerated chamber. The media used is PVC or polyethylene cross-flow media, with a total installed packed volume of 12 cubic feet. A small control panel with an alarm designed to activate if the blower fails is available as an option.

Wastewater enters the septic tank in the primary treatment zone, which can be a separate compartment (the verification test used a two-compartment septic tank) or an area that extends from the inlet pipe to the forward bulkhead of the insert. The quiescent condition in the primary zone allows the heavy solids in the wastewater to settle to the bottom of the chamber, where they are gradually digested under anaerobic conditions. The wastewater then flows into the aerobic zone (either the second compartment or the area of the tank containing the RetroFAST® insert). The organic constituents in the wastewater serve as food for the aerobic bacteria that are attached to the honeycomb media in the RetroFAST® unit and present in the suspended solids (mixed liquor) in the liquid phase within the unit. An external blower supplies air to a draft tube located in a central chamber in the submerged media. The draft tube acts as an airlift pump to draw wastewater from below the media and distribute it over the media surface by a splash plate above the water line. The draft tube induces a circulation of wastewater down through the media and provides oxygen to the wastewater. Nitrified wastewater flows through the bottom of the central chamber into the surrounding anoxic zone, where solids settle to the bottom of the second chamber. Denitrification occurs in the anoxic zone in this chamber. The clarified effluent is discharged by gravity, flowing through an opening (notch) that separates the discharge water from the aeration zone and exiting via a discharge pipe.

VERIFICATION TESTING DESCRIPTION

Test Site

The MWTTF site is located at the wastewater treatment plant serving the District of Squamish, British Columbia, Canada. Wastewater is supplied from a sanitary sewer collection system serving a catchment consisting of primarily residential houses, with minor commercial sources. After passing through the WWTP screens and grit-removal processes, wastewater is pumped through a 2.5-inch diameter manifold pipeline to the test site, at a rate of approximately 53 gallons per minute (gpm) (3.4 liters per second [L/s]). During dosing periods, wastewater is constantly circulated through the manifold pipeline to ensure solid material contained in the wastewater does not settle. Excess flow in the manifold is discharged to the headworks of the WWTP. Dosing at each test unit is regulated by a pneumatic gate valve that is controlled by a programmable logic controller (PLC). The PLC enables operators to monitor the operating status of the test facility and the individual test units, and to change any of the dosing parameters (e.g., dosage volume, frequency of dosage, duration of dosing period, etc.).

Methods and Procedures

The RetroFAST® was installed by the MWWTP operators with the assistance of Bio-Microbics staff on June 6, 2001. The unit was installed in the second compartment of a two-compartment septic tank in accordance with the installation instructions supplied by Bio-Microbics. On July 6, 2001, the septic tank was filled with one-third wastewater and two-thirds potable water, and the dosing sequence began. An eight-week startup period allowed the biological community to become established and the operating conditions to be monitored. The standard dosing sequence was used for the entire startup period.

The system was monitored during the startup period, including visual observation of the system and routine calibration of the dosing system. Several influent samples were collected and analyzed for pH, alkalinity, temperature, five-day biochemical oxygen demand (BOD_5), TKN, ammonia nitrogen (NH_3-N), NO_2^-, NO_3^-, and total suspended solids (TSS). Effluent samples were analyzed for pH, alkalinity, temperature, five-day carbonaceous biochemical oxygen demand ($CBOD_5$), TKN, NH_3-N, TSS, dissolved oxygen (DO), NO_2^-, and NO_3^-.

The thirteen-month verification test period incorporated five sequences with varying stress conditions simulating real household conditions. The five stress sequences were performed at two-month intervals, and included washday, working parent, low load, power/equipment failure, and vacation test sequences. Nitrogen reduction was monitored by measuring nitrogen species (TKN, NH_3-N, NO_2^-, NO_3^-). Other basic parameters (BOD_5, $CBOD_5$, pH, alkalinity, TSS, temperature) were monitored to provide information on overall system performance. Operational characteristics, such as electric use, residuals generation, labor to perform maintenance, maintenance tasks, durability of the hardware, and noise and odor production were also monitored.

The verification test was designed to load the RetroFAST® at design capacity (375 gpd ± 10%) for the entire test, except during the low load and vacation stress tests. The RetroFAST® was dosed 100 times per day with approximately 3.7 gallons of wastewater per dose. The unit received 35 doses in the morning, 25 doses mid-day, and 40 doses in the evening. The dosing volume was controlled by the length of time the pneumatic valve was open for each cycle. Dosing volumes were verified once per week.

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 more intensely, with six to eight composite samples being collected during and after each stress test period. Five consecutive days of sampling occurred in the last month of the verification test. All composite samples were collected using automatic samplers located at the dosing manifold pump location (influent sample) and at the discharge of the unit. Grab samples at each sample location were collected on each sampling day to monitor the system pH, DO, and temperature.

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

PERFORMANCE VERIFICATION

Overview

Evaluation of the RetroFAST® began on July 6, 2001, when the septic tank was filled and the wastewater dosing started. Flow was set at 375 gpd based on delivering 80 doses per day with a target of 4.7 gallons per dose. Samples of the influent and effluent were collected during the startup period, which continued until September 4, 2001. The dosing sequence was adjusted in September to delivery 100 doses per day with a delivery of 3.7 gallons per dose. Verification testing began September 5, 2001, and continued until October 25, 2002. Sampling and equipment problems in October and November 2001 resulted in the verification test being extended to fourteen months in order to obtain a full set of valid data. During the verification test, 60 sets of samples of the influent and effluent were collected to determine the system performance.

Startup

Overall, the unit started up with no difficulty. The installation instructions were easy to follow, and installation proceeded without difficulty. No changes were made to the unit during the startup period, and no special maintenance was required.

The RetroFAST® was removing $CBOD_5$ and TSS within the first three weeks of operation. At the end of the eight-week startup, effluent $CBOD_5$ was 8 mg/L and TSS was 6 mg/L. The effluent TN concentration was 12 mg/L at the end of the startup period, ranging from 6 to 12 mg/L in the final four weeks of startup. Influent TN concentration ranged from 30 to 37 mg/L during this time. Both the nitrification and denitrification processes appeared established at the end of the startup period, as indicated by the difference between influent and effluent TN. The blower was set to operate 30 minutes on and 30 minutes off during this period.

Verification Test Results

The daily dosing schedule was adjusted slightly at the beginning of the verification test. The dose sequence was set for 100 doses of 3.7 gallons per dose to be applied every day, except during the low load (May to June 2002) and vacation stress (September 2002) periods. Volume per dose and total daily volume varied only slightly during the verification test. The daily volume, averaged on a monthly basis, ranged from 366 to 380 gpd, within the range allowed in the protocol for the 375 gpd design capacity.

The sampling program emphasized sampling during and after the major stress periods. This resulted in a large number of samples being clustered during five periods, with the remaining monthly samples spread over the remaining months. Both mean and median results were calculated, because comparing median values to mean values can help evaluate the impacts of the stress periods. The RetroFAST® results showed median concentrations for NH_3-N that were somewhat lower than the mean concentrations due to reduced nitrification efficiency in the December 2001 to January 2002 and July to August 2002 periods, which impacted the mean concentration.

The TSS and BOD_5/$CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1. The influent wastewater had a mean BOD_5 of 150 mg/L and a median BOD_5 of 150 mg/L. The TSS in the influent had a mean concentration of 180 mg/L and a median concentration of 170 mg/L. The RetroFAST® effluent showed a mean $CBOD_5$ of 12 mg/L with a median $CBOD_5$ of 12 mg/L. The mean TSS in the effluent was 28 mg/L and the median TSS was 24 mg/L.

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

	BOD_5 Influent (mg/L)	$CBOD_5$ Effluent (mg/L)	Percent Removal	TSS Influent (mg/L)	TSS Effluent (mg/L)	Percent Removal
Mean	150	12	91	180	28	84
Median	150	12	92	170	24	88
Maximum	210	28	98	440	170	98
Minimum	65	2	79	110	3	14
Std. Dev.	30	5.9	4.4	56	25	15

Note: Data in Table 1 are based on 60 samples.

The nitrogen results for the verification test, including all stress test periods, are shown in Table 2. The influent wastewater had a mean TKN concentration of 39 mg/L, with a median value of 36 mg/L, and a mean NH_3-N concentration of 28 mg/L, with a median of 28 mg/L. The mean TN concentration in the influent was 39 mg/L (median of 36 mg/L). The RetroFAST® effluent had a mean TKN concentration of 11 mg/L and a median concentration of 6.2 mg/L. The mean ammonia concentration in the effluent was 5.9 mg/L and the median value was 3.4 mg/L. The nitrite concentration in the effluent was low, averaging 0.46 mg/L. The mean effluent nitrate concentration was 8.0 mg/L with a median of 9.1 mg/L. Total nitrogen was determined by adding the daily concentrations of the TKN (organic plus ammonia nitrogen), nitrite, and nitrate. The mean TN in the RetroFAST® effluent was 19 mg/L (median 18 mg/L) for the verification period. The RetroFAST® showed a mean TN reduction of 51%, with a median removal of 50%.

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
Mean	39	11	28	5.9	39	19	8.0	0.46	12.8
Median	36	6.2	28	3.4	36	18	9.1	0.46	14.5
Maximum	64	44	42	30	64	44	18	1.2	20.2
Minimum	28	1.7	19	0.15	28	6.4	0.06	0.04	4.90
Std. Dev.	9.0	10	3.9	7.0	9.0	7.5	5.0	0.31	4.75

Note: The data in Table 2 are based on 60 samples, except for nitrite and nitrate, which are based on 58 samples.

Verification Test Discussion

During the first two months of the verification test, September and October 2001, the nitrification and denitrification processes, which had been established during startup, were upset, and only small amounts of ammonia or TN were removed by the RetroFAST® system. TSS levels in the effluent were variable ranging from 8 to 59 mg/L. The ETV test team investigated possible causes for the upset condition despite no apparent changes in the influent wastewater quality. On November 14 during a system check by Bio-Microbics, it was determined that the blower setting of 30 minutes on and 30 minutes off was not correct for the system. On November 14, Bio-Microbics changed the blower setting to operate continuously, after which the RetroFAST® began to recover. Due to some difficulties at the test site and sampling problems during the first stress test in November, it was agreed that the verification stress test sequence would be restarted in December, and that the November data would be reported but excluded from the verification test data summaries.

The NH_3-N concentration in the effluent began to decrease at the end of November and nitrate concentrations increased. TN removal approached 50%. The washday stress test was performed from December 24 to December 28, 2001. The NH_3-N and TKN began to rise at the end of the stress test, and nitrate decreased. By the end of the post-stress test monitoring on January 3, 2002, the data showed no removal of TN by the system. The washday stress test appears to have upset the system. It should be noted that the temperature of the wastewater was also decreasing during this time, and there was a one-day spike in influent TSS near the end of the monitoring period. These factors may have contributed to the system performance.

During the next six weeks, the RetroFAST® system re-established the nitrifying population. Effluent TN concentration dropped to 13 mg/L and ammonia nitrogen to 0.3 mg/L. The working parent stress test was performed from February 25 through March 1, 2002. The NH_3-N concentration in the effluent increased during the stress period (4.8 mg/L), but was lower at the end of the stress period and during the post-stress monitoring. Nitrate levels, however, remained in the 13 to 15 mg/L range. TN removal was above 50% for most days, with concentrations ranging from 19 to 22 mg/L in the post-stress monitoring period. The working parent stress test did not appear to have a major impact on the nitrification process. During the next two months, the data show that more than 80% of the ammonia was being removed. However, nitrate levels increased to 17 to 18 mg/L, indicating the denitrification process was not able to convert all of the additional nitrate to nitrogen gas. The DO level in the effluent was in the 9.5 to 11 mg/L during this time.

The low load stress test began on May 6 and continued until May 26, 2002. Both the nitrification and denitrification processes appeared to improve during and after this stress test. Ammonia concentrations dropped below 1 mg/L, nitrate levels decreased to the 9 to 11 mg/L range, and TN nitrogen removal was 46 to 61% after the first ten days of the stress test. The lower daily volume of wastewater (50% of the rated capacity) being processed through the unit may be a factor in the improved performance of the unit.

During the June and July test period, which included the power failure test on July 22, the effluent TN concentration ranged from 11 to 17 mg/L. Ammonia concentrations increased each day during the post-stress test monitoring and reached a maximum of 12 mg/L on August 1. At the same time, the nitrate concentrations decreased, although the actual removal of nitrate by the system (assuming all ammonia removed is converted to nitrate) remained in the 14 to 19 mg/L range. It does appear that the power failure stress test had an impact on the system, which might be expected because the nitrification system is dependent on oxygen supplied by the blower. Late in the post-stress test monitoring period, ammonia removal performance began to deteriorate and did not appear to recover until September.

The vacation stress test started on September 23 and ended on October 2, 2002. During this period, there was no influent flow to the system. Following the resumption of flow on October 2, ammonia concentrations in the effluent were generally less than 1 mg/L, similar to the levels found during the low load test. Nitrate levels increased, but denitrification continued to remove 14 to 20 mg/L of nitrate from the system. The vacation stress test did not appear to have a negative impact on the system.

The system performance remained consistent for the duration of the verification test. The TKN and NH_3-N effluent concentrations were low and similar to the data from the period after the low load stress test. The nitrate levels remained in the 10 to 13 mg/L range, and the TN concentration from 15 to 18 mg/L, representing 49 to 61% removal.

The RetroFAST® system showed variable results during the verification test, with TN removal varying from zero to 86% removal. There were at least two apparent upset periods, one at the start of the verification test (possibly caused by the blower setting) and another during the washday stress test. A smaller upset in the nitrification process may have occurred at the end of the power failure post-stress-monitoring period in July 2002. During the last six months of the verification test, the system appeared more stable and performance was more consistent. During these last six months of operation, the TN concentration in the effluent had a mean concentration of 15 mg/L (range of 6 to 21 mg/L).

Operation and Maintenance Results

Noise levels associated with blower system and airlift were measured twice 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 90θ intervals in four directions. The noise levels ranged from 58 to 64 decibels.

Qualitative odor observations based on odor strength (intensity) and type (attribute) were made six 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 90θ intervals in four directions. There were no discernible odors during five of the six observation periods. On the final observation, the odor was logged as a barely discernable musty odor.

A dedicated electric meter, serving the RetroFAST®, was used to monitor electrical use for the period of continuous blower operation. The average electrical use was 2.1 kilowatts (kW) per day. This usage rate appears low for a one-fourth horsepower blower operating continuously, but was consistent during the verification test and checked with a second meter. The RetroFAST® did not require or use any chemical addition during normal operation.

During the test, the system experienced no mechanical problems. The only change made to the system was to alter the blower operation from an on/off cycle to continuous operation on November 14, 2001. No maintenance or cleaning was performed during the verification test.

The treatment unit 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 blower life is difficult to estimate, the equipment used operated continuously for eleven months with no downtime.

Quality Assurance/Quality Control

During testing, NSF completed a QA/QC audit of the MWTTF site and CanTest Laboratories Ltd. (CanTest), the analytical laboratory. This audit included: (a) a technical systems audit to assure the testing was in compliance with the test plan, (b) a performance evaluation audit to assure that the measurement systems employed by MWTTF and CanTest were adequate to produce reliable data, and (c) 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. EPA QA personnel also conducted a quality systems audit of NSF's QA Management Program.

Original signed by *Lee A. Mulkey*	*09/30/03*		*Original signed by* *Gordon E. Bellen*	*10/02/03*
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Availability of Supporting Documents

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

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

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

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

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