PERFORMANCE OF INNOVATIVE ALTERNATIVE ONSITE SEPTIC SYSTEMS FOR THE REMOVAL OF NITROGEN IN BARNSTABLE COUNTY, MASSACHUSETTS 1999-2007

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ABSTRACT

A web-based reporting system for performance samples from innovative alternative (I/A) onsite septic systems has been implemented in Barnstable County, Massachusetts. Nitrogen removal data from a total of 557 individual systems; 487 single-family installations and 70 multi-family installations are presented. When systems having four or more samples are considered, 69% of the 297 single-family systems and 60% of the 50 multi-family I/A systems have medians that meet a regulatory discharge standard of 19 mg/L or less of total nitrogen. Results from individual technologies are presented. The difficulties in assessing the performance of I/A technologies using such data are discussed.

Disclaimer

The mention of any product or company in this paper does not constitute an endorsement by Barnstable County. Data contained herein were reported by various service providers for alternative onsite septic system components. The Barnstable County Department of Health and Environment does not guarantee the data accuracy beyond that point implied by the collection, processing and reporting practices required or implied by the system operator's Wastewater Treatment Plant Operator license.

CONTENTS

INTRODUCTION

The role of anthropogenic nitrogen in the degradation of many marine estuarine environments is now widely accepted. As recent research focuses on determining the maximum amount of nitrogen capable of being assimilated by an estuary without exhibiting detrimental environmental effects, (a concept referred to as Total Maximum Daily Load or TMDL), resource managers have sought measures to control nitrogen sources in the contributing watersheds. In many estuary watersheds on Cape Cod and elsewhere, a major contributor of nitrogen has been shown to be domestic wastewater.

The primary method of treating/disposing of wastewater in Barnstable County (Cape Cod) is the onsite septic system. Comprised of various components, the purpose of a septic system is to stabilize sanitary waste and render disease organisms harmless. The well-designed onsite septic system achieves these tasks by oxidizing many of the chemical/organic portions of the wastewater and maintaining adequate separation between sites of disposal and areas of potential human exposure.

Despite the ability of the onsite septic system to remove certain contaminants, the nitrogen portion of the wastewater is minimally treated in most cases. Derived primarily from urine, most nitrogen exiting the septic tank is present in the reduced state (ammonium or organically bound nitrogen). As it passes through the soil absorption system or leachfield, it is oxidized by specialized bacteria to form nitrate. The nitrogen process is illustrated in Figure 1. As nitrate, nitrogen travels conservatively with the groundwater to points of impact.

Beginning in the early 1990s, boards of health and other regulatory agencies in Barnstable County began investigating the feasibility of enhancing nitrogen removal in the onsite septic system. In 1991, the Waquoit Bay National Estuarine Research Reserve sponsored a workshop that featured many prospective technologies purporting to remove nitrogen. In subsequent years various demonstration projects ensued that sought to determine the efficacy of these systems. In 1995, the Massachusetts regulations relating to onsite septic systems (310 CMR 15.000, referred to as “Title 5”), were revised to allow for the approval of what are termed “innovative and alternative” or I/A systems for the treatment of various wastewater constituents. Under these revisions, over 1,100 I/A systems have been installed in Barnstable County between 1995 and 2007.

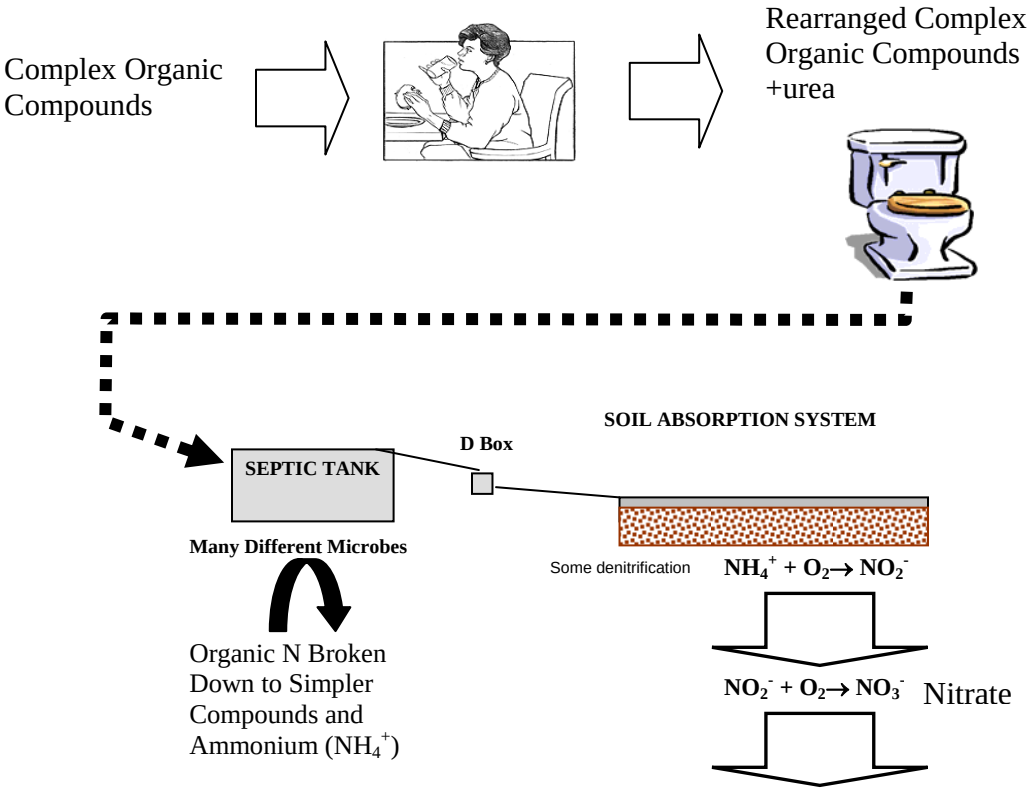

Figure 1. Schematic representation of nitrogen passage through a standard onsite septic system.

This paper describes the efforts of the Barnstable County Department of Health and Environment (BCDHE), in conjunction with the 15 Boards of Health in Barnstable County, to compile reliable information regarding the performance of I/A systems, particularly for their ability to remove nitrogen. This effort anticipates the need for information by towns engaging in Comprehensive Wastewater Management Plans (CWMPs). During the CWMP process all viable alternative strategies for treating wastewater must be identified and characterized in terms of efficacy, costs, sustainability and other factors. The mandatory monitoring programs required by both the Commonwealth and local boards of health present an unprecedented opportunity to assess the efficacy of a number of onsite alternatives to address the nitrogen issue.

DATA SOURCES

Innovative/Alternative septic system technologies in Massachusetts that purport to reduce nitrogen are approved in a progressive manner from Piloting Approval to General Use Approval in accordance with the amount of data and information that support the manufacturers' claims. Piloting Approval is granted to a system with limited supporting information from third-party testing and/or from other states. Under this approval, the manufacturer can install up to 15 systems and must monitor and report results in accordance with the Piloting Approval letter issued by the Department of Environmental Protection (DEP). Provisional Approval is granted to systems that have supporting data from a number of sites from other states. Under this approval, a manufacturer must install at least 50 systems and must monitor them for a period of three years. At least 90% of these systems must meet the criteria specified in the approval letter for the technology to be considered for General Use Approval. Under General Use Approval there are generally no restrictions on the number of systems that may be installed, and limited monitoring may be required. All monitoring results must be submitted to both DEP and the local boards of health. It bears mention here that presently there are only two I/A systems with General Use Approval in Massachusetts for nitrogen removal; these are the recirculating sand filter and the RUCK® system.

A unique set of circumstances in Barnstable County has resulted in the monitoring of an inordinate number of I/A systems. Foremost, since the contaminant of concern in Barnstable County is nitrogen, many boards of health require monitoring for nitrogen even in circumstances where DEP approvals would not require such. In addition, boards of health in Barnstable County commonly require systems to be monitored for periods beyond that required by DEP approvals.

Beginning in 2005, BCDHE encouraged towns to require the reporting of I/A system performance data to a central location. After researching a number of options for the collection and analysis of data, BCDHE developed a web-based reporting system in conjunction with Carmody™ Data Systems, Inc. Maintenance providers and system monitors in 14 of the 15 towns in Barnstable County are presently required to report all findings in accordance with maintenance and sampling schedules specified in DEP Approval Letters and/or board of health conditions. These reports must be filed electronically with BCDHE. In addition to data reports

filed since the inception of the web-based reporting system, Carmody™ Data Systems integrated all previously collected data into the overall database.

DATA CONSIDERATIONS

There are many references in this document to the regulatory limit of 19 mg/L or less Total Nitrogen (TN). This value derives from the majority of Provisional Approval Letters for nitrogen removal which commonly state "For Systems installed at residential facilities with design flows less than 2,000 gpd, TN concentration in the System effluent shall not exceed 19 mg/L." Achieving this concentration at the point where the system discharges to the soil absorption system assumes that approximately 50% of the TN is removed from the influent wastewater. ***The discharge level of 19 mg/L is generally accepted as a regulatory limit, indicating that the system is in compliance with the DEP Approval Letters***. Although this number would seem to represent a ready standard to infer whether the system is "working," it should be understood that actual nitrogen mass loading is not addressed by simple use of this standard. For instance, an I/A system with a TN concentration of 40 mg/L at discharge would be considered as not working. However, if the influent nitrogen concentration was 80 mg/L, this same system has removed 50% of the TN. The implications of this can be substantial. If, for instance, a household was served by a compliant system discharging 19 mg/L, and used 260 gallons of water per day (not unusual for a family household), they could be contributing more nitrogen to the groundwater (~15 lbs/year) than the household discharging 40 mg/L if that household practiced more frugal water use of 120 gallons per day (~14.6 lbs/year). Accordingly, effluent concentrations alone should not be the sole indicator of system function, but rather discharge volume (water use data) should ideally be integrated into conclusions regarding system performance. Unfortunately, water use data are rarely accurately maintained and reported so that the true efficacy of an I/A system can be determined. In addition, the present regulatory requirements do not allow the mass loading approach in determining compliance for onsite systems.

Another obstacle in determining the "real" performance and total nitrogen mass loading reductions achievable by the I/A system is the inability to measure influent or beginning nitrogen concentrations of the wastewater. This is because many technologies (fixed activated sludge treatment, trickling filters, and sequencing batch reactors) in most instances recycle a portion of treated wastewater back to the chamber that receives fresh wastewater. Thus, measurements taken in this primary chamber represent a mixture of the raw influent waste with some recycled

effluent resulting in an underestimation of the influent TN concentrations. Although taking a sample from the influent pipe might appear to be a solution, a representative sample from this location would not be attained. To demonstrate this point, consider the differences in nitrogen concentration of a sample that was taken just following the flush of a toilet in the house compared with one taken while laundry was being done, or while a hand washing sink was in use. Large particulate matter (feces, toilet paper) from the former influent sample would also make sample homogenization and processing difficult and inaccurate.

In summary, the present regulatory permissions leave only one standard means of determining I/A system performance – the discharge concentration limit. It should be understood, however, that regulatory standards for single-family and small systems (<10,000 gallons/day) have an underpinning of assumptions (influent concentration and per capita per day water use) which are not confirmed in most situations.

DATA PRESENTATION AND STATISTICAL METHODS

The data presented for nitrogen removal comes from a total of 557 individual systems; 487 single-family installations and 70 multi-family installations. However, many of these systems had only a small number (≤ 3) of samples; a decision was made that this was an insufficient amount of data to be indicative of performance. For this reason, most data analysis was conducted on those systems with ≥ 4 samples. This dataset represents 297 single-family and 50 multi-family installations.

It is important to note that, even for systems with ≥ 4 samples, data for each system are characterized by high variability and a generally low sample number. For single-family installations, the highest number of samples for any system was 33; most systems analyzed had 6-8 samples. There are 60 single-family systems with ≥ 10 samples. Samples from these systems represent 864 out of a total of 2,308 samples, or roughly 37% of all data analyzed. These 60 systems are approximately 20% of the total number of single-family systems in the dataset, but represent almost 40% of the data analyzed.

Small sample size and high variability in the data present statistical challenges for data analysis. For this reason, we have chosen to use both mean and, more commonly, median values to draw conclusions about system performance, as discussed below.

In order to facilitate use of the information, data are presented and analyzed in a variety of ways. Each statistical method used has some limitation or bias. It is only by presenting a variety of methods that we can we draw meaningful conclusions regarding I/A system performance. The following methods were used to present data in this report.

Mean or Average. The mean (sometimes called the average) is perhaps the most widely used statistic. It is calculated by summing all of the values in a set of observations (like TN concentrations) and dividing by the number of observations. When viewing datasets like those presented here, the mean should be used with caution when the sample size comprising the mean is five or less. Consider two I/A systems having the following set of discharge nitrogen data:

		System 1		
48 mg/L	19 mg/L	18 mg/L	16 mg/L	19 mg/L
		System 2		
26 mg/L	22mg/L	23 mg/L	26 mg/L	23 mg/L

A simple comparison of the two means alone (System 1 = 24 mg/L, System 2 = 24 mg/L) might lead one to conclude that these systems are of comparable function. However, System 2 failed to achieve a nitrogen level below 22 mg/L on any occasion, while four of the five observations from System 1 indicated levels of 19 mg/L or less. Accordingly, when means or averages from datasets with small numbers of observations are compared, an inaccurate comparison of system performance can result if that statistic alone is used.

Median. The median is the central value of an ordered set of data. In the above example the median of System 1 is 19 mg/L (16,18,**19**,19,48) and the median of System 2 is 23 mg/L (22,23,**23**,26,26). The advantage of using a median is that it diminishes the effect of one or two outlying values such as the start up discharge levels of an I/A system, which may not represent its function under normal conditions. Some researchers consider this statistic more valid than the mean when small datasets are examined.

Ranked Medians with Ranges. These graphs are compiled by ranking the medians for the specified groups and graphing them in order, while also displaying the ranges of each system dataset (Figure 2). Each individual bar represents one system; the top and bottom of points of the bar represent the maximum and minimum values observed, while the horizontal line on the bar represents the median value for that system. These graphs assist in visually determining the percentage of systems whose medians correspond with any desired discharge limit, while preserving an indication of data variability.

Modified Box-and-whisker Plots. A box-and-whisker plot (sometimes called simply a box plot) is a histogram-like method of displaying data (Figure 3). The "box" part of the Figure contains 50% of all of the observed values, and gives a visual picture of the central tendency of the data. The line within the box is the median. The "whiskers" in this type of graph represent the ranges of values reported.

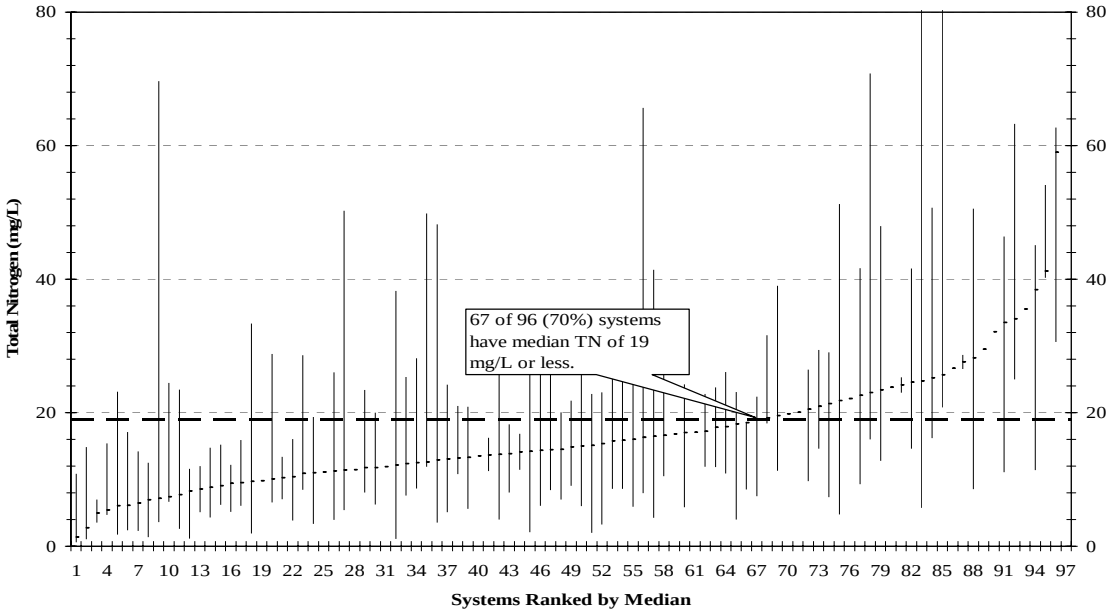

Figure 2. Sample ranked histogram showing individual observations from a number of treatment systems. Note the ability to determine the percentage of observations meeting any specified standard.

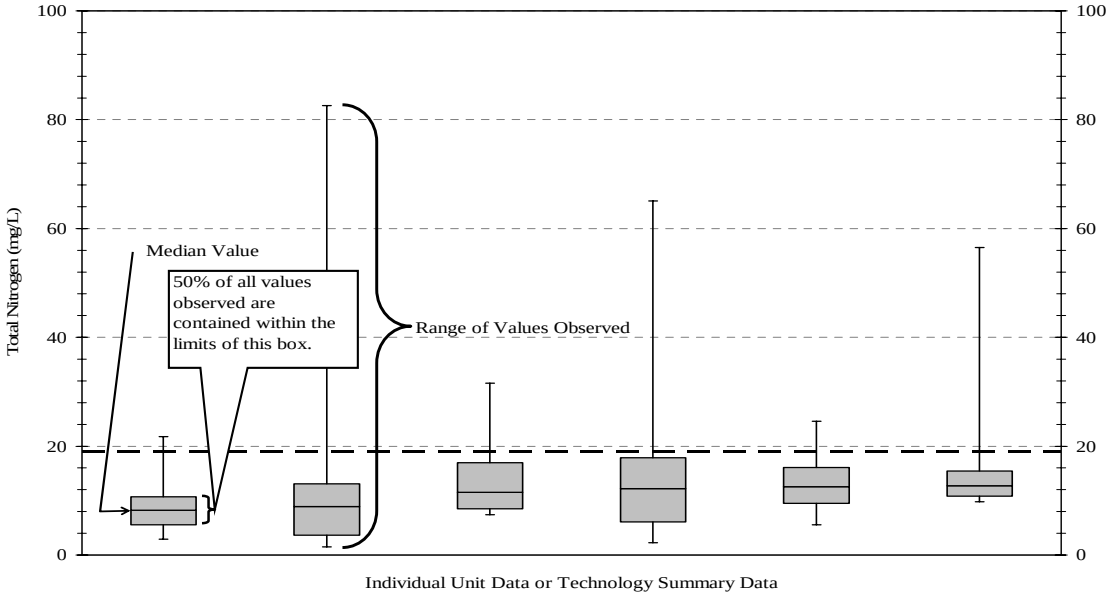

Figure 3. Sample Box-and-whisker plot for showing central tendency of data from individual treatment units or summaries of technologies.

In summary, a number of graphical representations and statistics are presented for each technology type. As with sampling of any type, the fewer the data points, the higher the probability that the statistics used will not represent the "true" assessment of overall performance. These authors recommend considering all graphs and statistics presented to determine the patterns of performance in context of the amount of data for each system.

DATA EXCLUSIONS

This report includes data from all systems reporting values for Total Nitrogen (TN) in the discharge where that total could be derived from nitrogen species assays provided. Some sampling conducted shortly after the approval of I/A systems in Massachusetts did not include assays for all species of nitrogen (Total Kjeldahl Nitrogen, nitrate-nitrite) that are necessary for determining TN. These latter data were excluded from our analyses.

Due to the complexities involved in certain commercial applications (restaurant and high-strength wastes), this report focuses on residential applications. Commercial I/A systems will be the topic of future reports. This report also does not consider discharge concentrations of Biochemical Oxygen Demand (BOD) or Total Suspended Solids (TSS). These parameters are important in the Remedial Use Approvals granted in the Commonwealth, particularly for the downsizing of soil absorption systems and the granting of a two-foot relief for distance to groundwater requirements. They do not, however, bear directly on the nitrogen issue.

RESULTS

As of January 2007, there were over 1,100 I/A systems installed in Barnstable County. The number of units reporting data (not necessarily nitrogen monitoring data) for each technology is presented in Figure 4. For various reasons, not all I/A systems installed are reporting nitrogen performance data. In most cases where there is no nitrogen data, it is because reporting for this parameter was not required. The number of systems reporting nitrogen data and sample numbers is presented in Figures 5 and 6. Because nitrogen data are reported, we have assumed for the purposes of this report that the system was designed to remove nitrogen, since nitrogen monitoring is only required where nitrogen removal is expected.

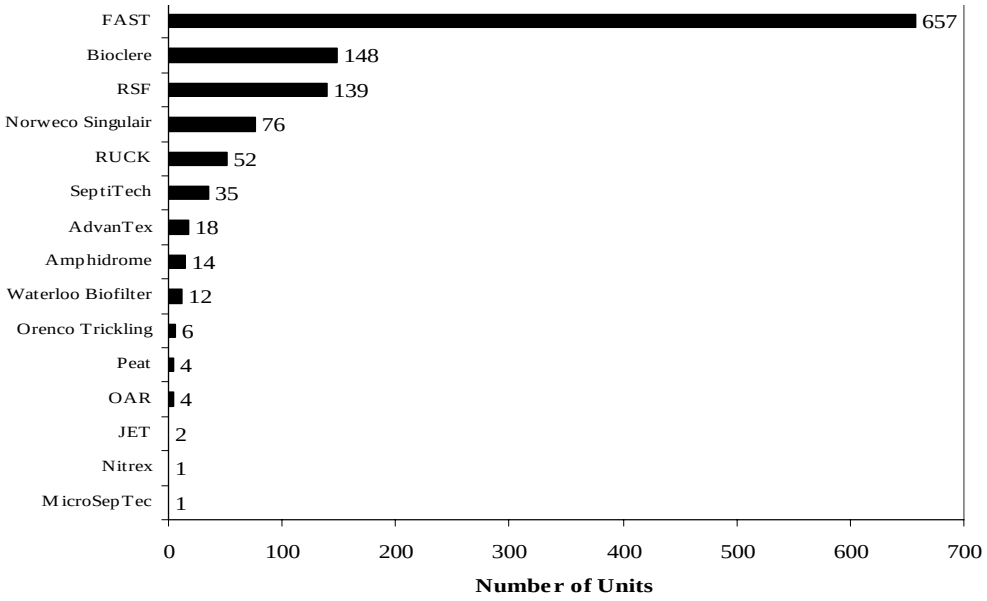

Figure 4. Summary of total number of innovative/alternative onsite septic system technologies in Barnstable County, Massachusetts as of January 2007. Not all units necessarily report nitrogen performance data.

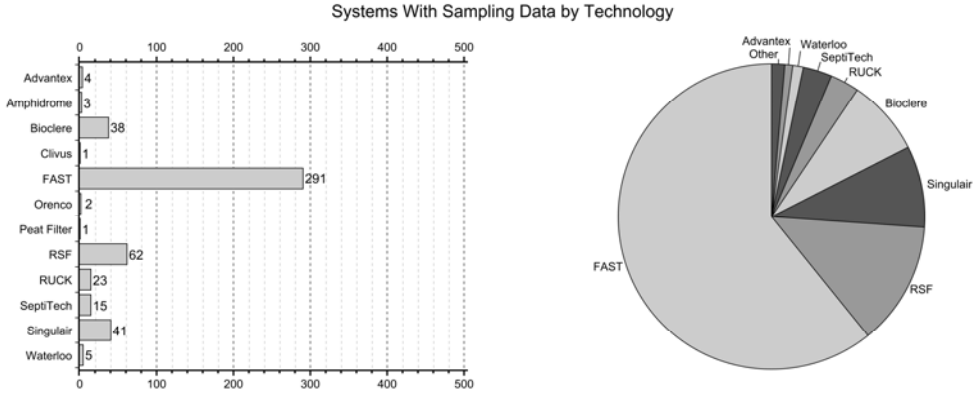

Figure 5. Total number of I/A systems by technology reporting validated sampling data for nitrogen in Barnstable County, Massachusetts as of January 2007.

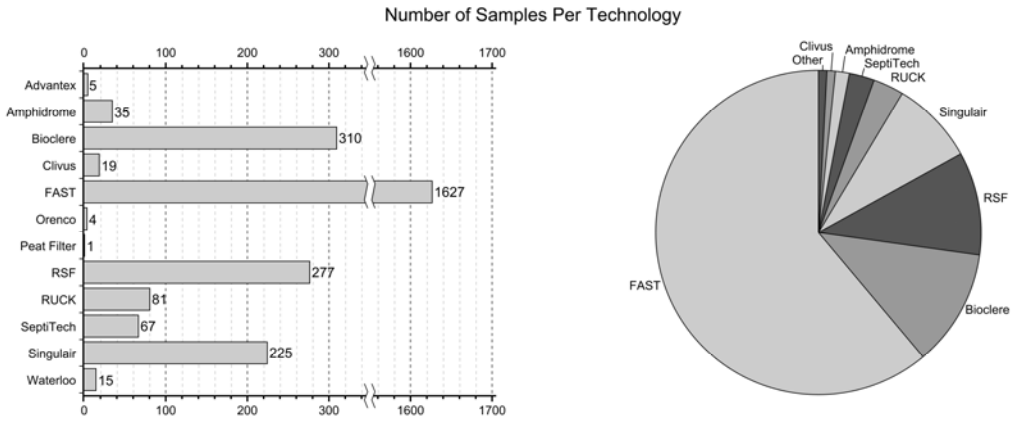

Figure 6. Total number of validated nitrogen samples by technology reported to Barnstable County Department of Health and Environment as of January 2007.

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A brief description of each technology, along with performance data are presented below. ***The reader should note that the approval status of any technology, accompanied by model numbers and descriptions can be found on the Massachusetts DEP website http://www.mass.gov/dep/water/wastewater/iatechs.htm.***

PERFORMANCE OVERVIEW – ALL TECHNOLOGIES COMBINED – SINGLE AND MULTI-FAMILY

A review of all available data shows that there is significant variability in the performance of systems within the same technology and among all tested technologies (Figures 7, 8, 9 and 10). Using data only from those systems having four or more samples, it appears that single-family units maintain an overall better performance with 69% exhibiting median TN values of 19 mg/L or less (Figure 8), compared with 60% of the multi-family units (Figure 10). This questions the common assumption that larger systems serving more than one residence perform better than single-family systems, at least for multi-family units with flows less than 10,000 gal/day.

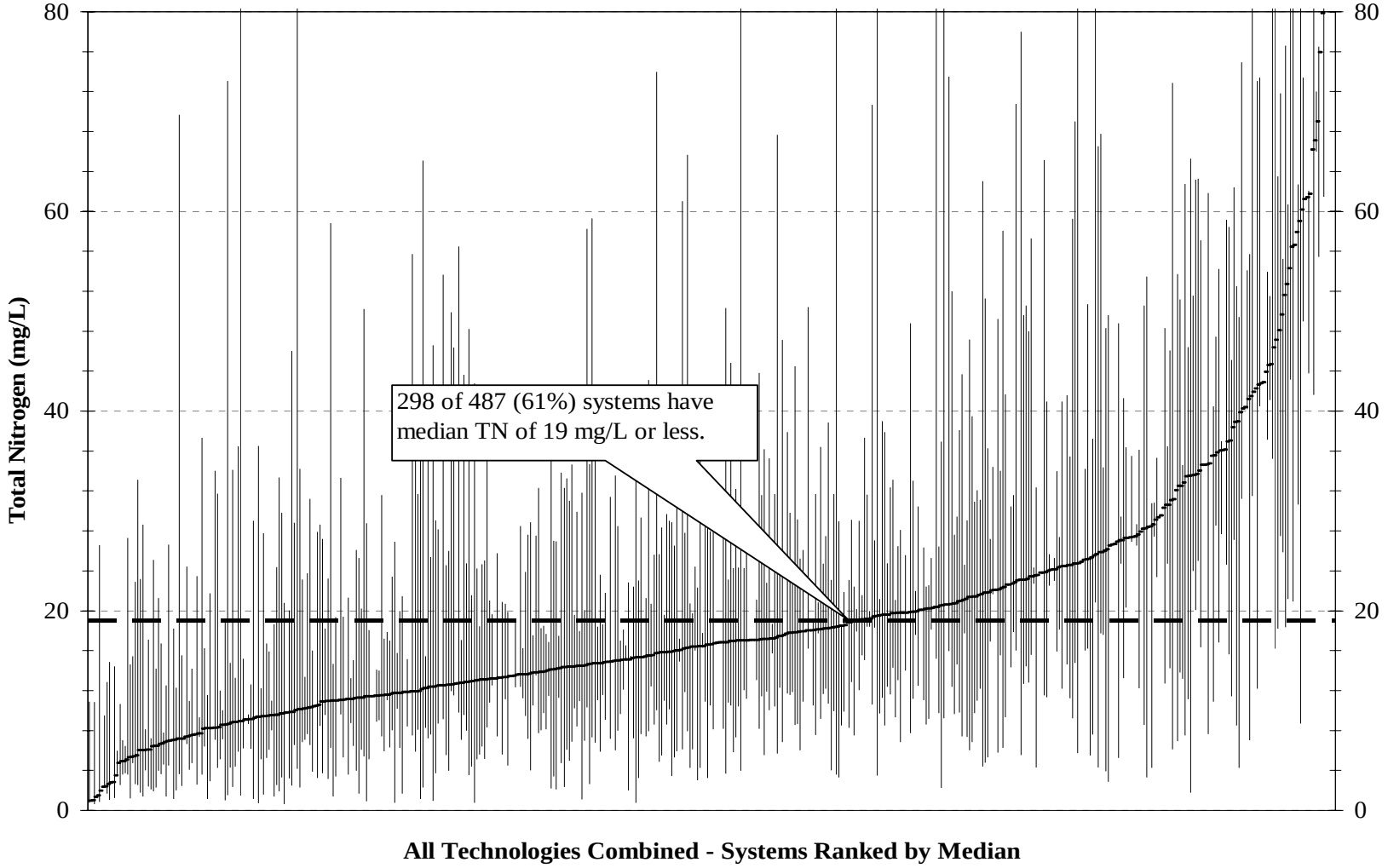

Figure 7. Ranked median total nitrogen concentrations from single-family I/A systems plotted with range values (all systems with any number of samples included). All technologies combined.

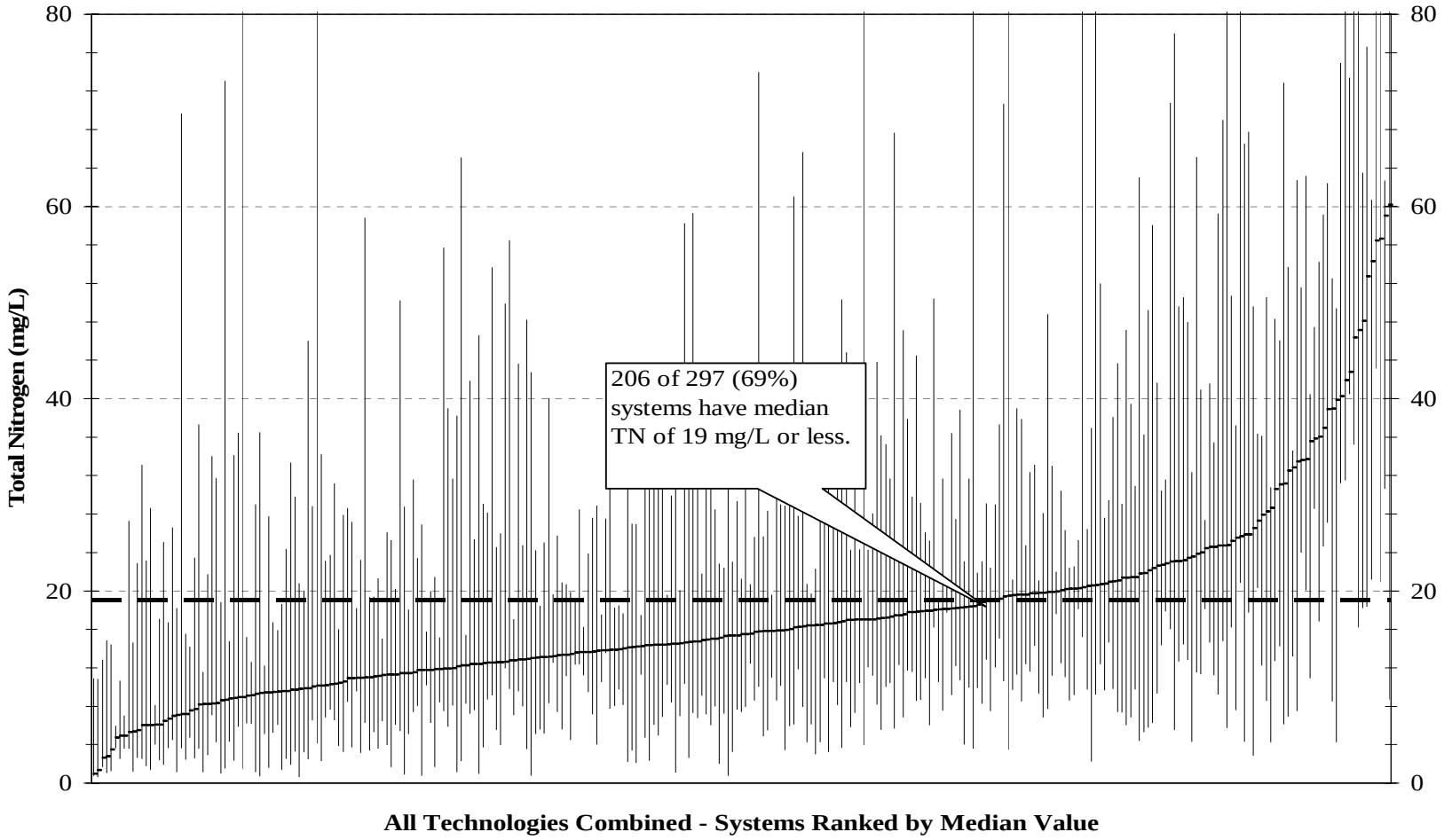

Figure 8. Ranked median total nitrogen concentrations from single family I/A systems having ≥ 4 samples plotted with range values. All technologies combined.

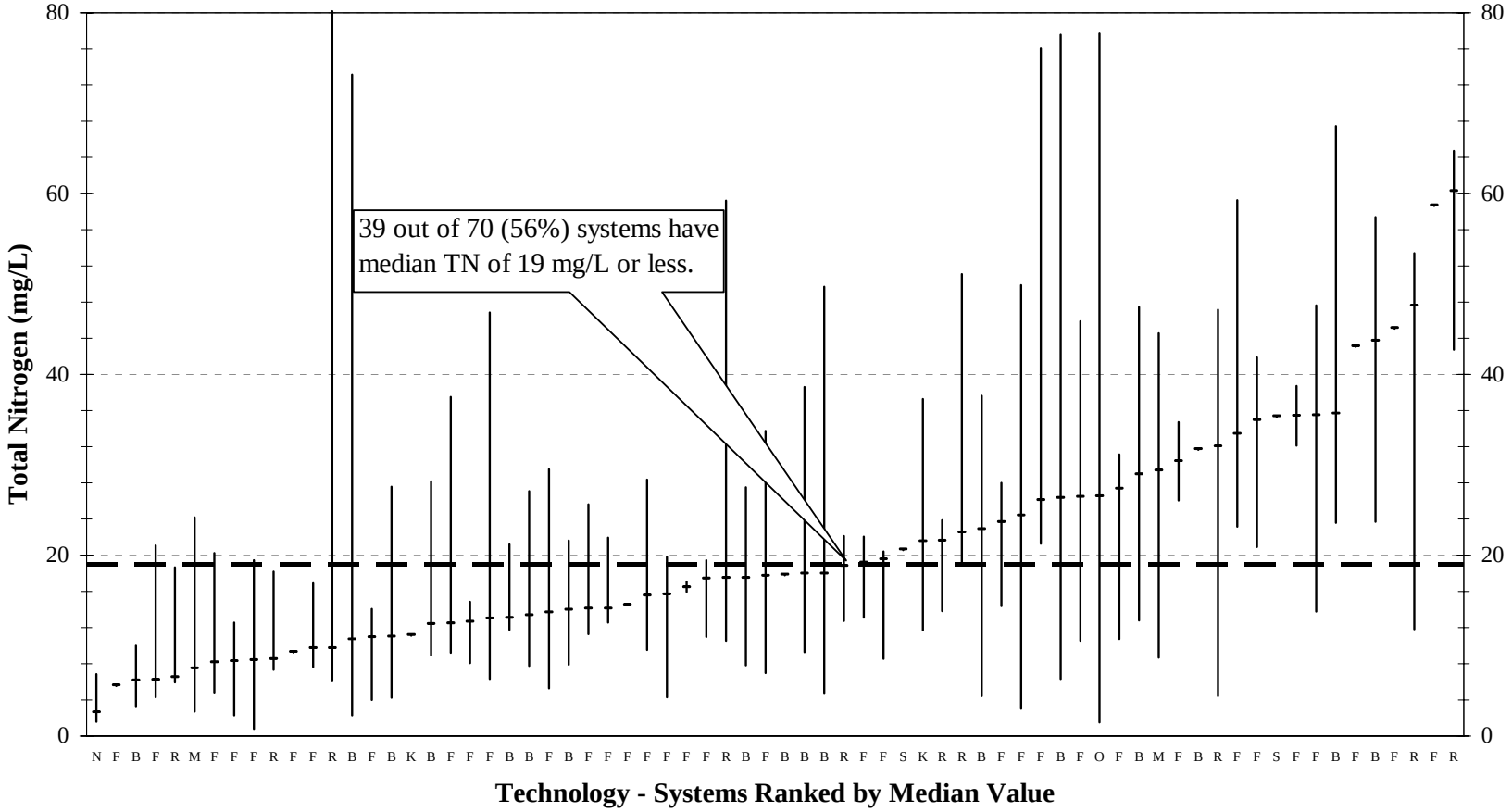

Figure 9. Ranked median total nitrogen concentrations from multi-family I/A system technologies plotted with range values (all systems with any number of samples included). B=Bioclere®, F= FAST®, R= Recirculating Sand Filter, K=RUCK®, N=Nitrex®, S= Singulair®, M= Modular FAST, O= Bioren. Systems with single sample only represented by median bar at that single value.

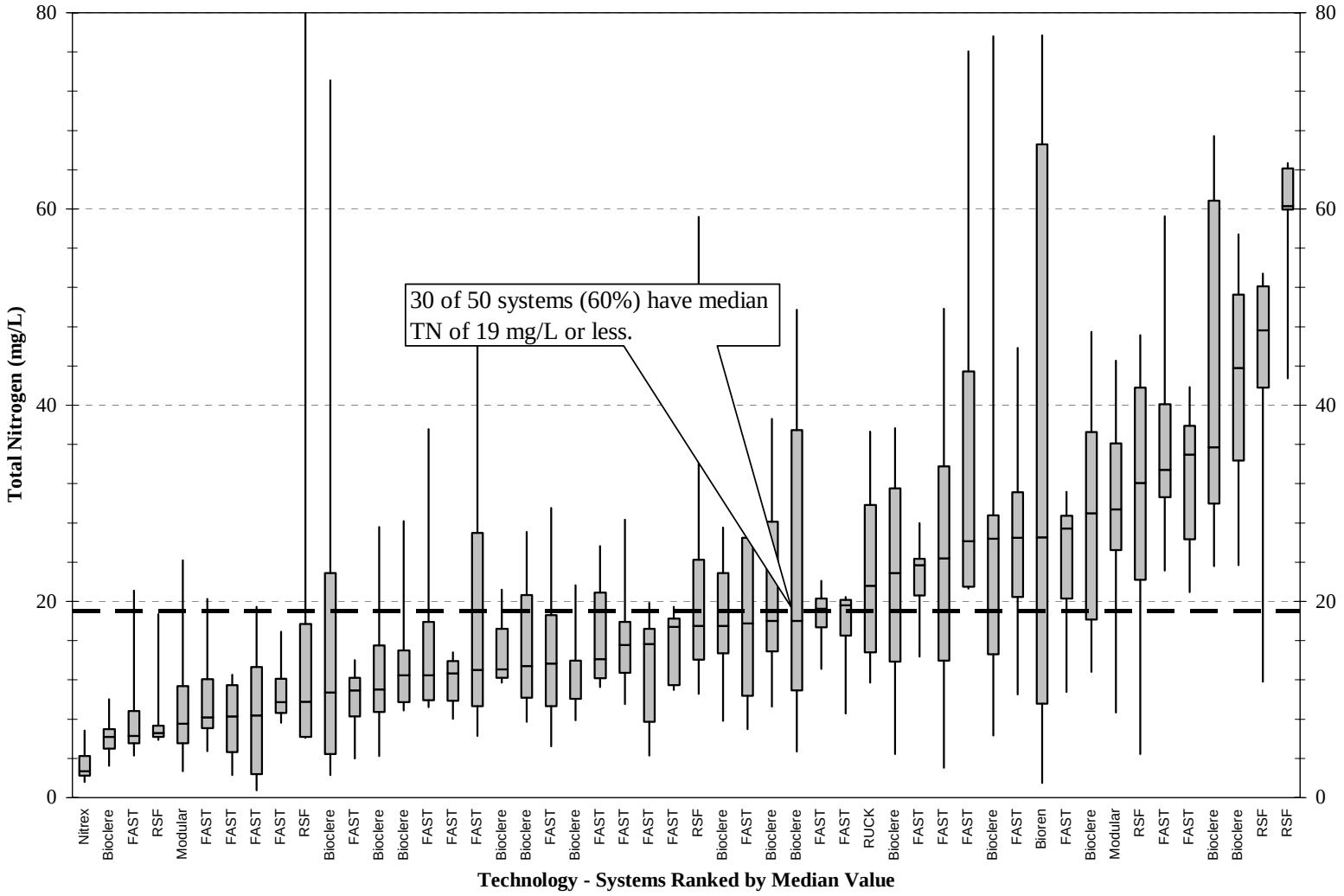

Figure 10. Ranked median total nitrogen concentrations from multi-family I/A systems plotted with range values (only systems with ≥4 samples included). Modular= Modular FAST, RSF= Recirculating Sand Filter.

Fixed Activated Sludge Treatment (FAST®)

Fixed Activated Sludge Treatment systems comprise the majority of treatment systems installed in Barnstable County. They are sold in various sizes and models including MicroFAST 3.0, 4.5 and 9.0; High Strength FAST Treatment System Models High Strength FAST 3.0, 4.5 and 9.0 and NitriFAST Treatment System Models NitriFAST 3.0, 4.5 and 9.0 Units for facilities with design flows of 2,000 gpd to less than 10,000 gpd (Bio-Microbics, Inc., 8450 Cole Parkway, Shawnee, KS 66227 - www.biomicrobics.com/). Specializing in units with flows from 2000 gpd to less than 10,000 gpd, Smith & Loveless Modular FAST is sold by Smith & Loveless, Inc., 14040 Santa Fe Trail Drive, Lenexa, KS 66215 (www.smithandloveless.com/). The systems have Provisional Use Approval for nitrogen removal in the Commonwealth and General Use Approval where nitrogen removal is not required. Data analyses below include all models combined. The prevalence of this technology compared with other I/A systems allows a more in depth analysis of their performance. Figure 11 presents data from all single-family FAST systems having any number of samples. Sixty-nine percent of the units demonstrated a median less than 19 mg/L or less.

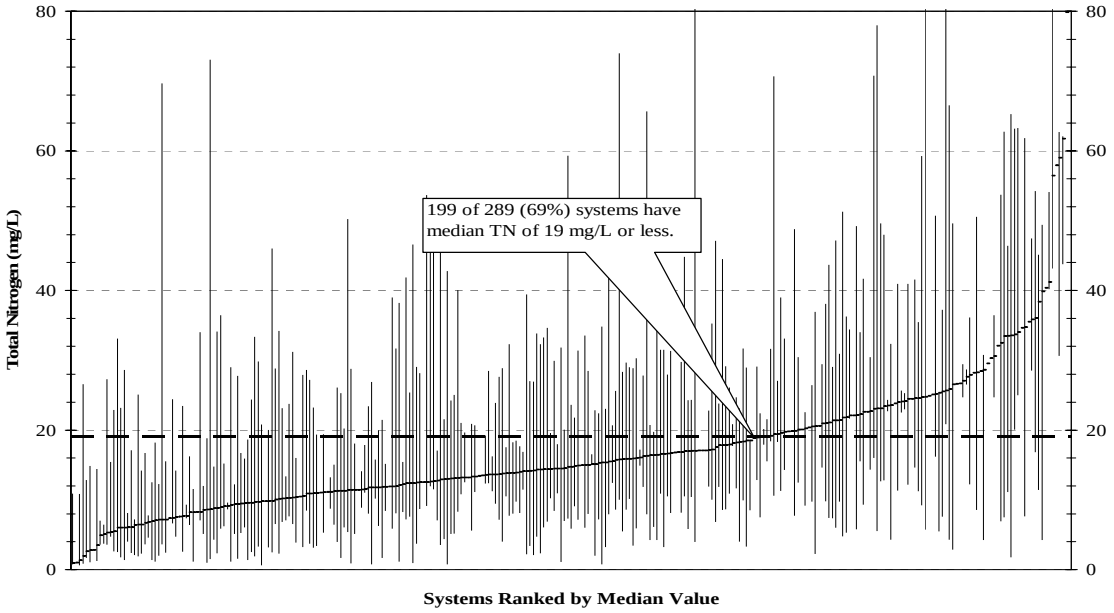

Figure 11. Ranked median total nitrogen concentrations from single-family FAST systems plotted with range values. All systems with any number of samples plotted.

When only those units for which eight or more samples were collected are plotted (Figure 12), 78% of those units demonstrated medians of less than 19 mg/L TN.

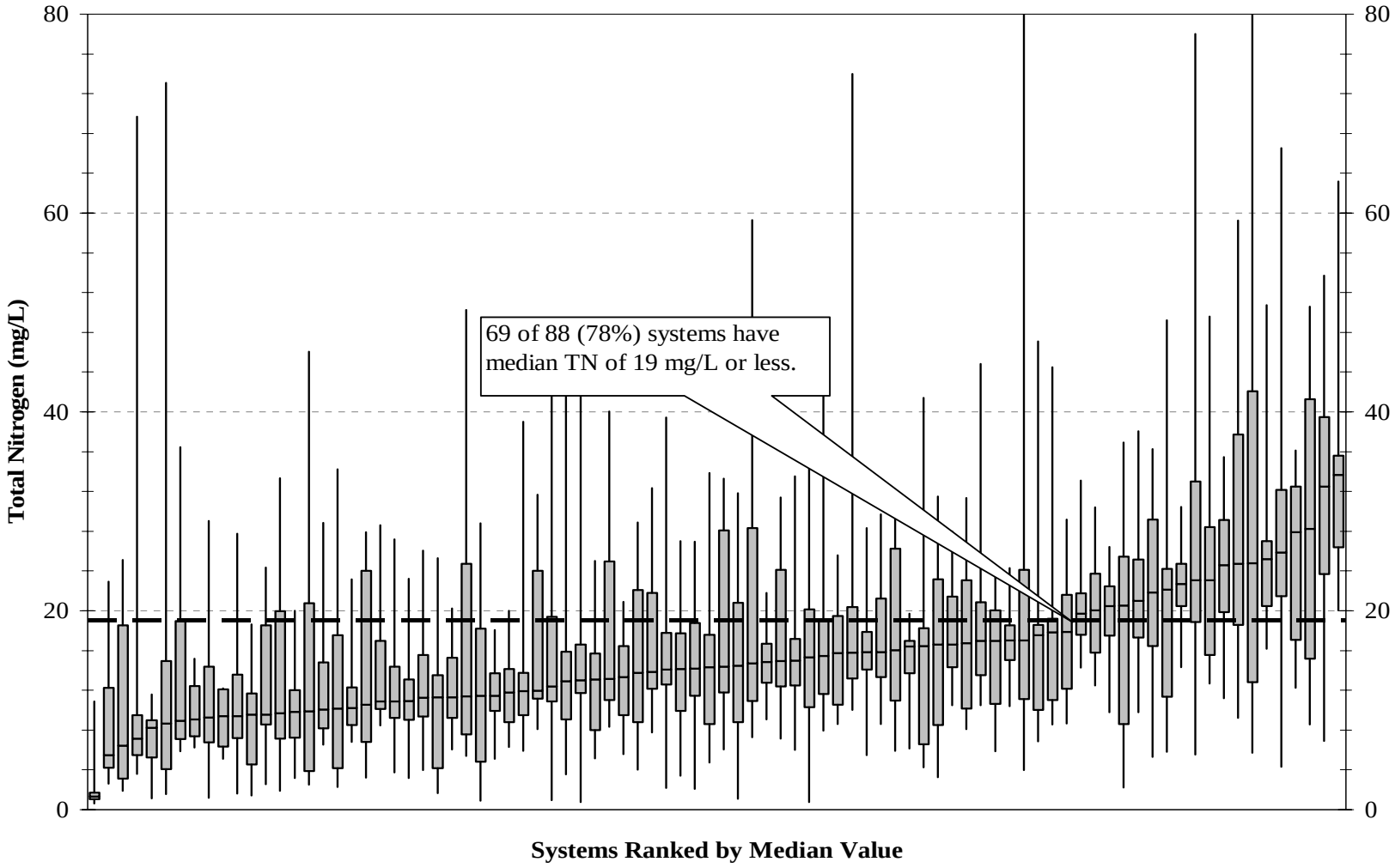

Figure 12. Ranked median total nitrogen concentrations from single-family FAST systems plotted with range values (only systems with ≥8 samples included).

Bioclere®

The second most common unit in Barnstable County is the Bioclere, marketed in this area by Aquapoint, Inc., 241 Douchaine Boulevard, New Bedford, MA 02745 (http://www.aquapoint.com/bioclere.html). The technology class is trickling filter, and various models have Provisional Use Approval for nitrogen removal and General Use Approval where nitrogen removal is not required. Using the most comprehensive set of data from 31 single-family installations with four or more samples, we observed that 71% of the systems had medians of 19 mg/L or less (Figures 13 and 14).

Recirculating Sand Filters

Recirculating sand filters (RSFs) are non-proprietary systems having various designs, usually in accordance with the Massachusetts Department of Environmental Protection (DEP) Guidelines. These guidelines provide some latitude for designers and there are no strict regulations governing their design. One company, OMNI Environmental Systems, Inc. (P.O. Box 128, 465 East Falmouth Hwy, East Falmouth, MA 02536 - www. omnirsf.com), has developed and markets a proprietary RSF which has sought Piloting Approval for the demonstration of nitrogen removal to levels below 19 mg/L. This exceeds the General Use Approval level of 25 mg/L presently approved for this technology. The data from OMNI RSFs are designated separately below (Figures 15 and 16). The 19 mg/L standard is presented on the chart, because OMNI purports the ability to comply with this lower standard.

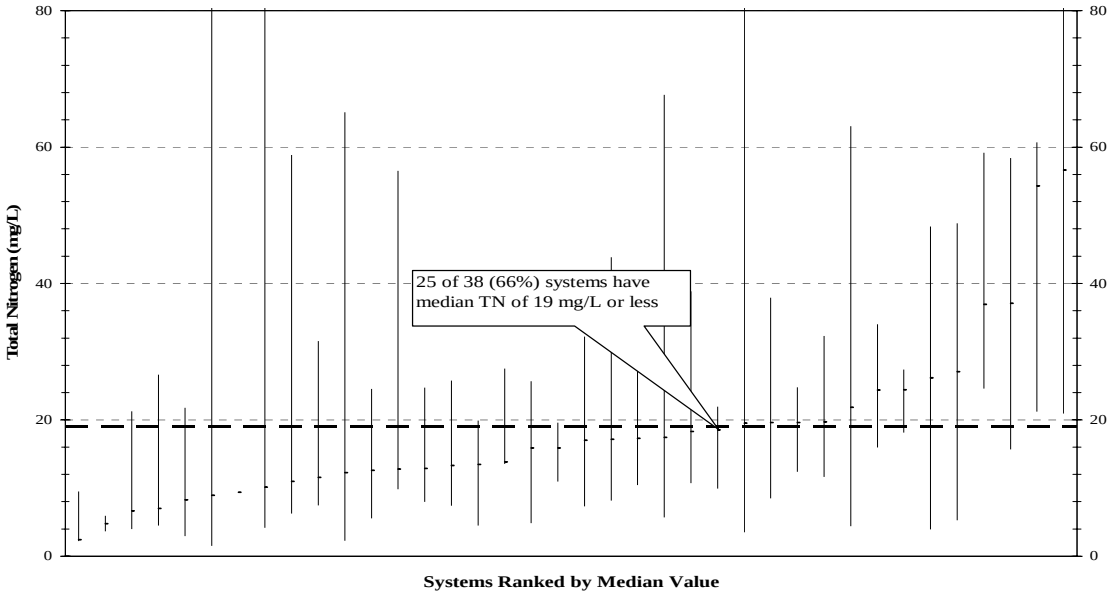

Figure 13. Ranked median total nitrogen concentrations from single-family Bioclere systems plotted with range values. All systems with any number of samples plotted.

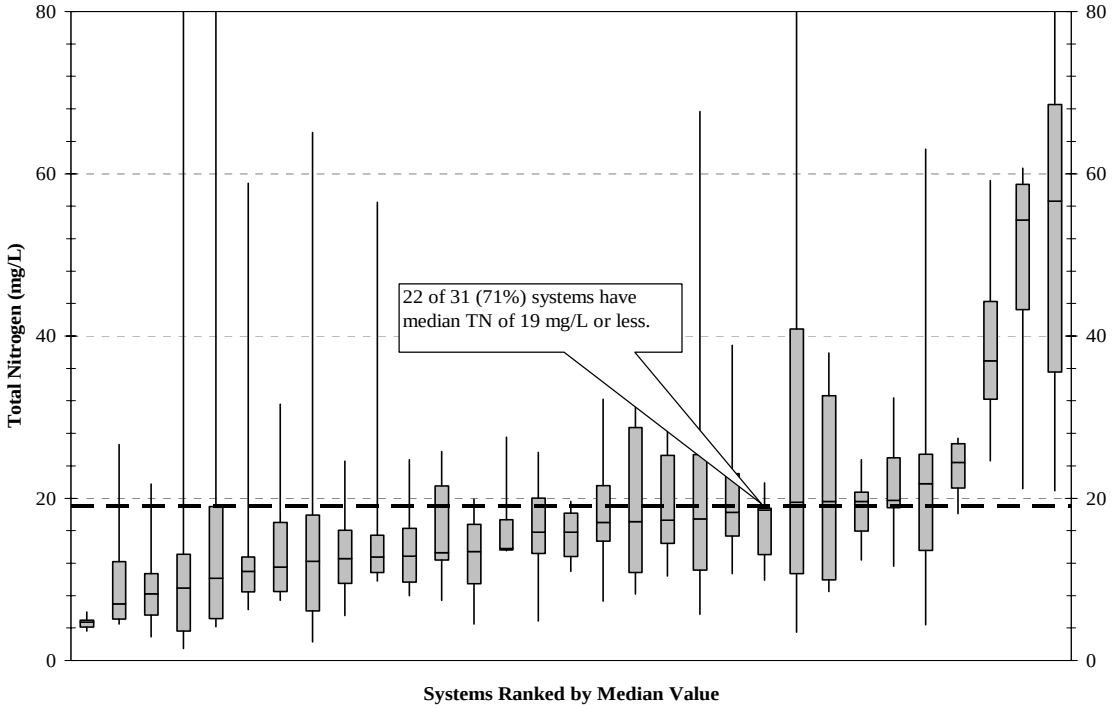

Figure 14. Ranked median total nitrogen concentrations from single-family Bioclere systems plotted with range values (only systems with ≥4 samples included).

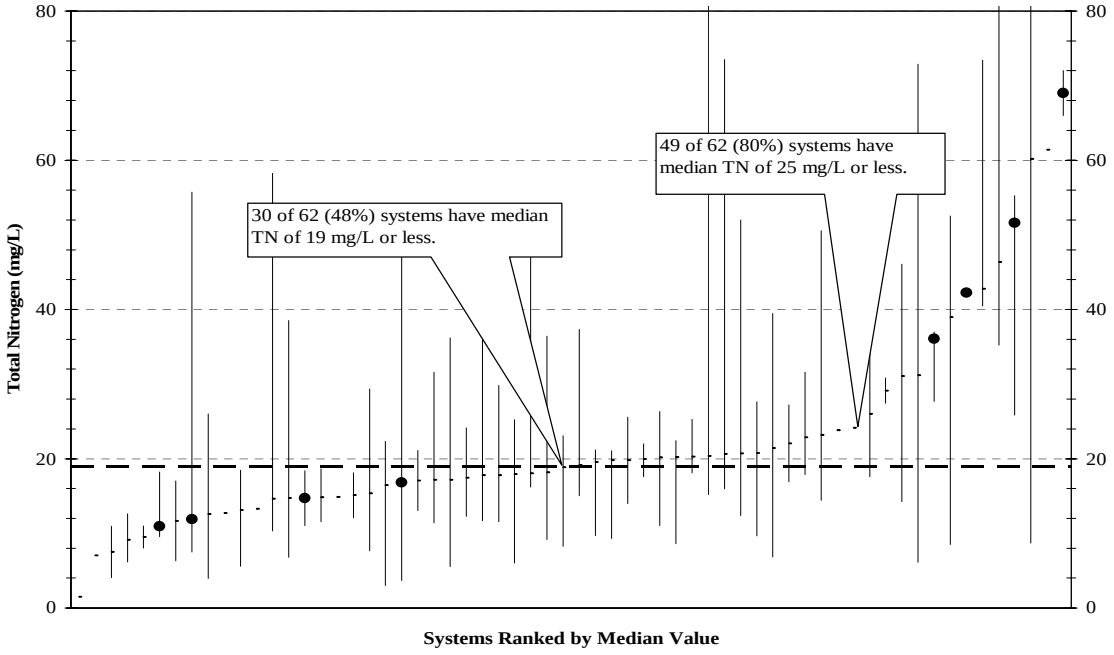

Figure 15. Ranked median total nitrogen concentrations from single-family recirculating sand filters plotted with range values. All systems with any number of samples included. Darkened medians (●) correspond to systems *not* designed by OMNI Environmental.

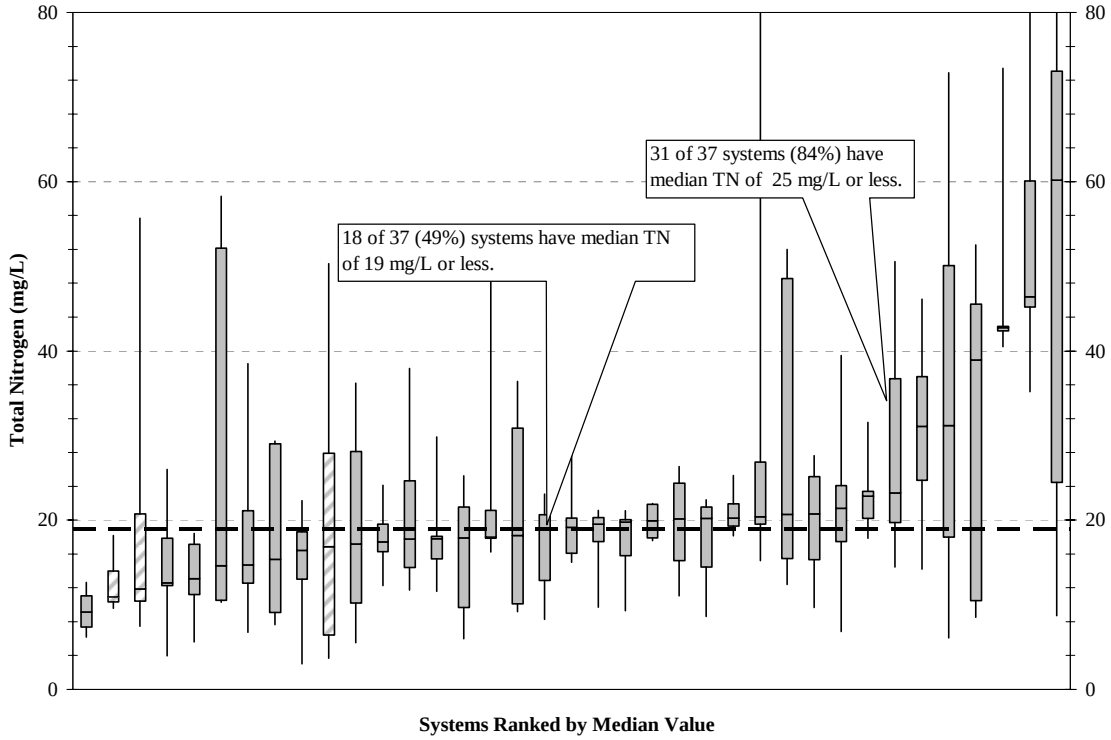

Figure 16. Ranked median total nitrogen concentrations from single-family RSF systems plotted with range values (only systems with ≥4 samples included). Hatched boxes correspond to systems *not* designed by OMNI Environmental.

Singulair®

The Singulair is a three-compartment extended aeration wastewater treatment system contained in a concrete tank. It is manufactured by NORWECO, Inc., 220 Republic Street, Norwalk, OH 44857 (website http://www.norweco.com/html/products/singulair.htm). The system is distributed locally by Siegmund Environmental Services, Inc., 49 Pavilion Avenue, Providence, RI 02905 (website http://www.siegmundgroup.com/siegmund_ses.asp). The system has Provisional Use Approval for nitrogen removal and General Use Approval where nitrogen removal is not required. Figures 17 and 18 represent the data from single-family installations.

An inspection of the more comprehensive dataset indicates that nine of the fourteen installations (64%) where four or more samples were taken exhibited TN of 19 mg/L or less (Figure 18).

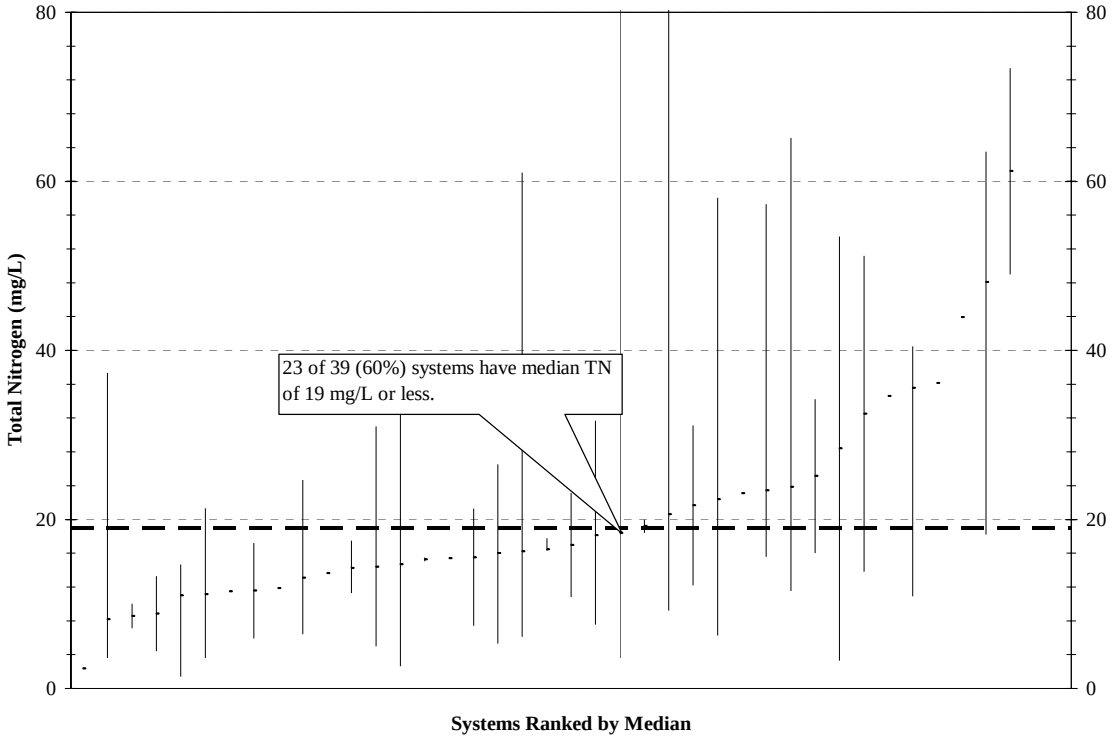

Figure 17. Ranked median total nitrogen concentrations from single-family Singulair systems plotted with range values. All systems with any number of samples plotted.

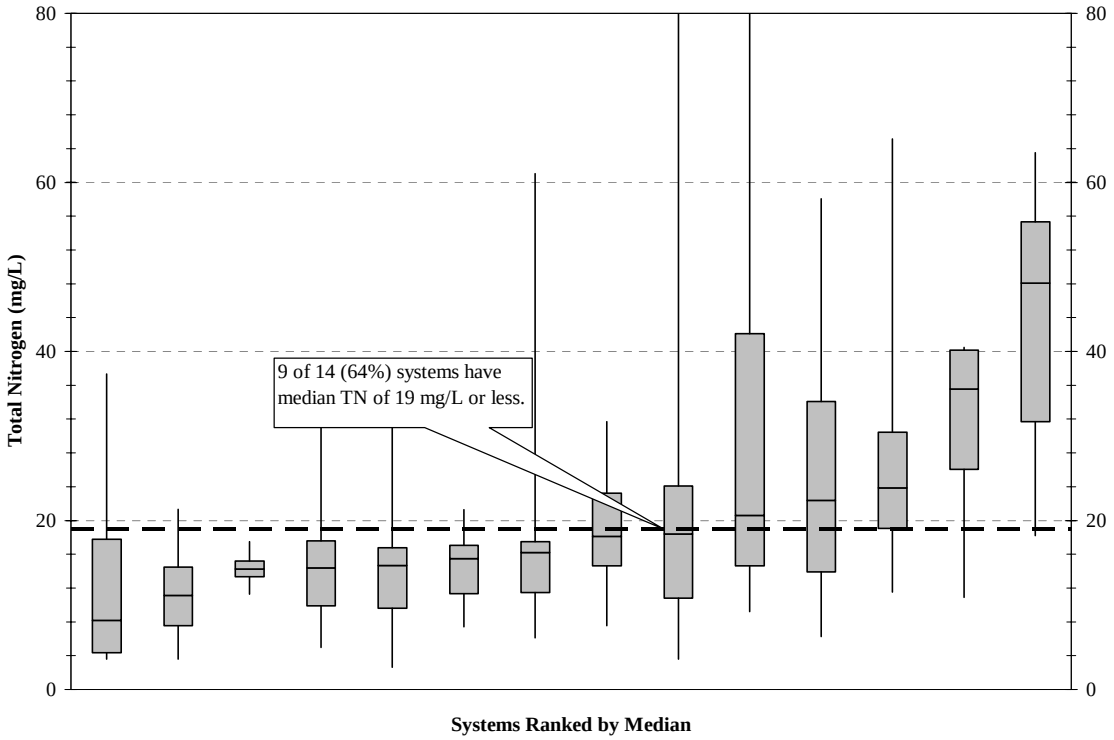

Figure 18. Ranked median total nitrogen concentrations from single-family Singulair systems plotted with range values (only systems with ≥4 samples included).

RUCK®

RUCK is a stratified filter which directs filtered blackwater percolate into a chamber receiving greywater from the building served. The system has been frequently designed to achieve denitrification. RUCK was one of the earliest systems to gain approval following the changes to Massachusetts septic system regulations in 1995 and Barnstable County has the largest number of installations in the Commonwealth. The system is marketed and designed by Innovative RUCK Systems, Inc. 362 Gifford Street, Falmouth, MA 02540 (website http://www.irucks.com/). As of July, 2007 RUCK remains the only proprietary denitrification technology certified for General Use Approval for 19 mg/L TN or less in the Commonwealth of Massachusetts. Results from single family units are presented in Figures 19 and 20. The data show that where there were four or more samples taken, four out of ten systems (40%) have TN levels of 19 mg/L or less (Figure 20). The General Use Approval for nitrogen removal for this technology explains, in part, the dearth of monitoring, since the requirement was reduced by DEP in some cases.

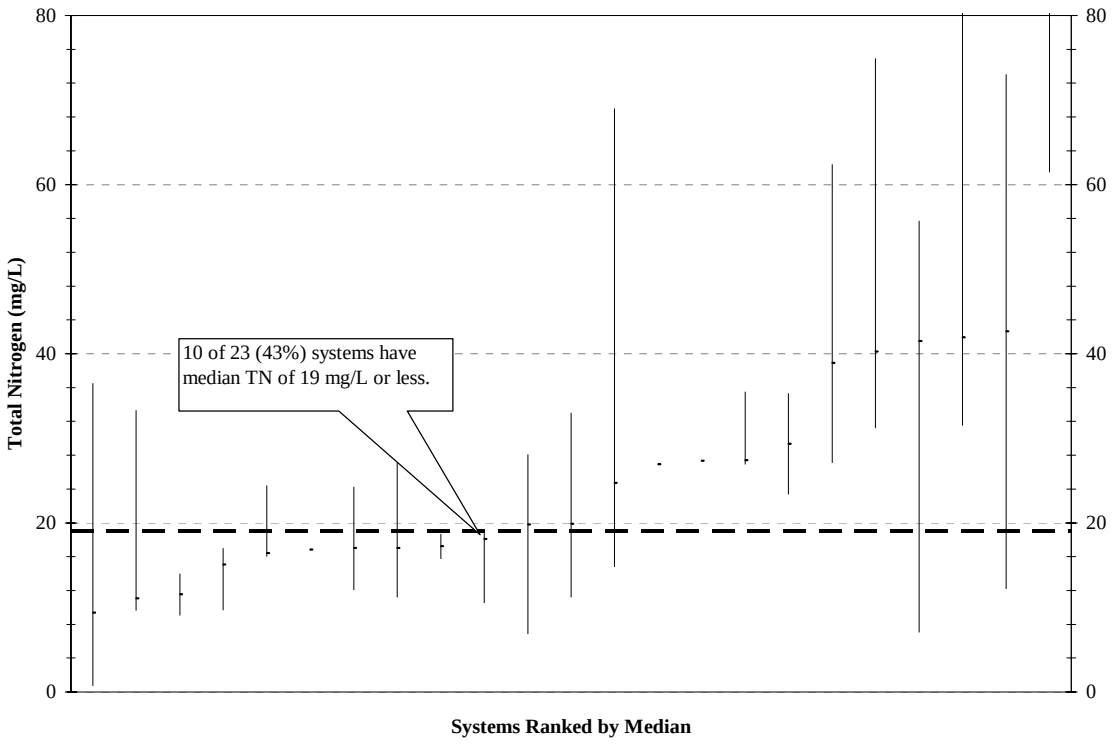

Figure 19. Ranked median total nitrogen concentrations from single-family RUCK systems plotted with range values. All systems with any number of samples plotted.

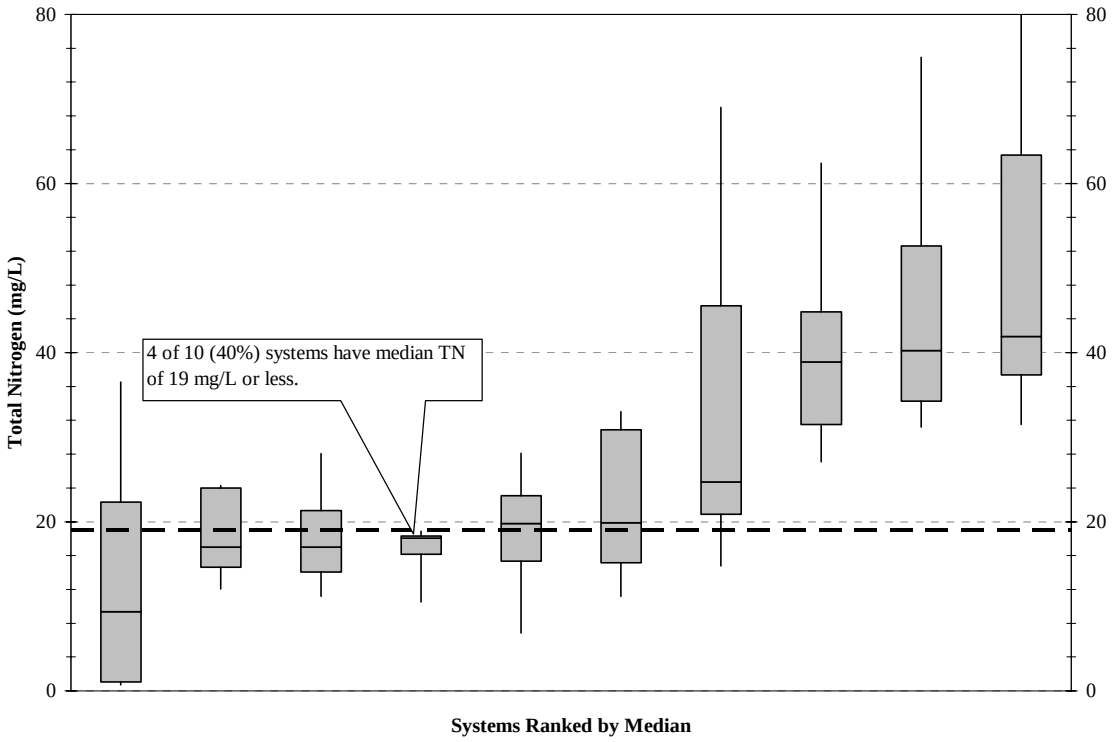

Figure 20. Ranked median total nitrogen concentrations from single-family RUCK systems plotted with range values (only systems with ≥4 samples included).

SeptiTech®

SeptiTech is a trickling filter technology that uses a proprietary media. It is distributed by SeptiTech, Inc., 220 Lewiston Road, Gray, ME 04039 (website http://www.septitech.com). It is variously sized depending on design flow and is controlled by a programmable logic controller (PLC) that has a capability for remote access to treatment parameter settings. The system has Provisional Use Approval for nitrogen removal and General Use Approval where nitrogen removal is not required. Results from units where four or more samples were taken indicate that two of the eight units (25%) met the 19 mg/L standard (Figures 21 and 22).

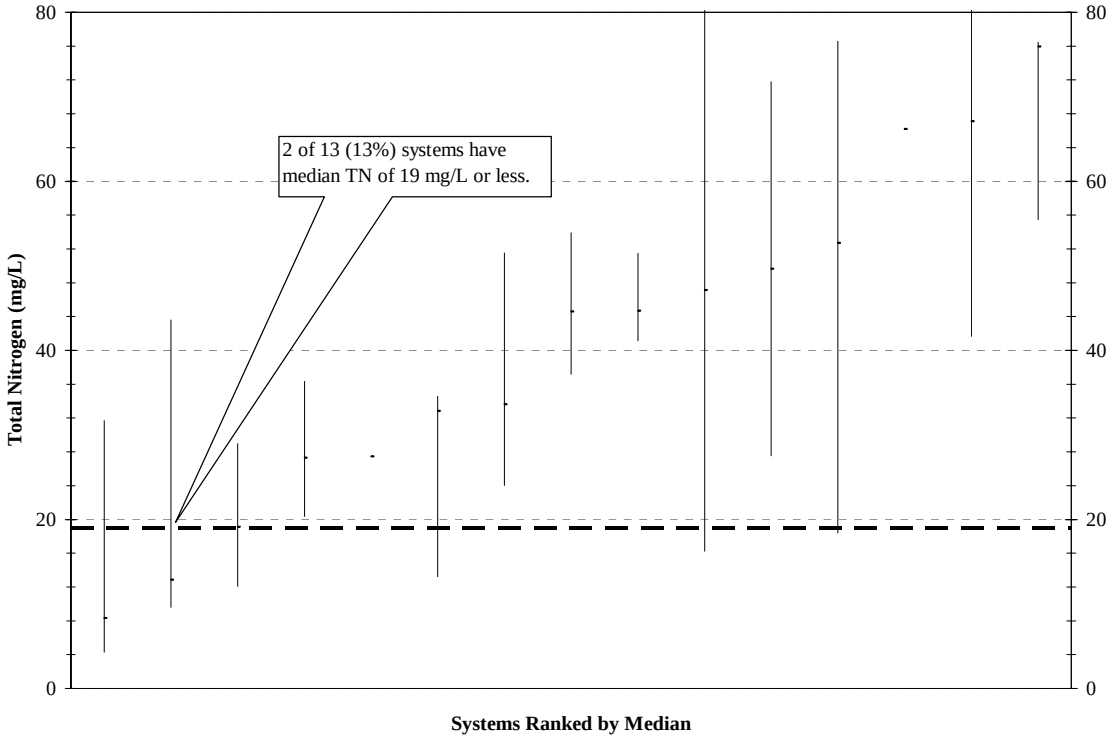

Figure 21. Ranked median total nitrogen concentrations from single-family SeptiTech systems plotted with range values. All systems with any number of samples plotted.

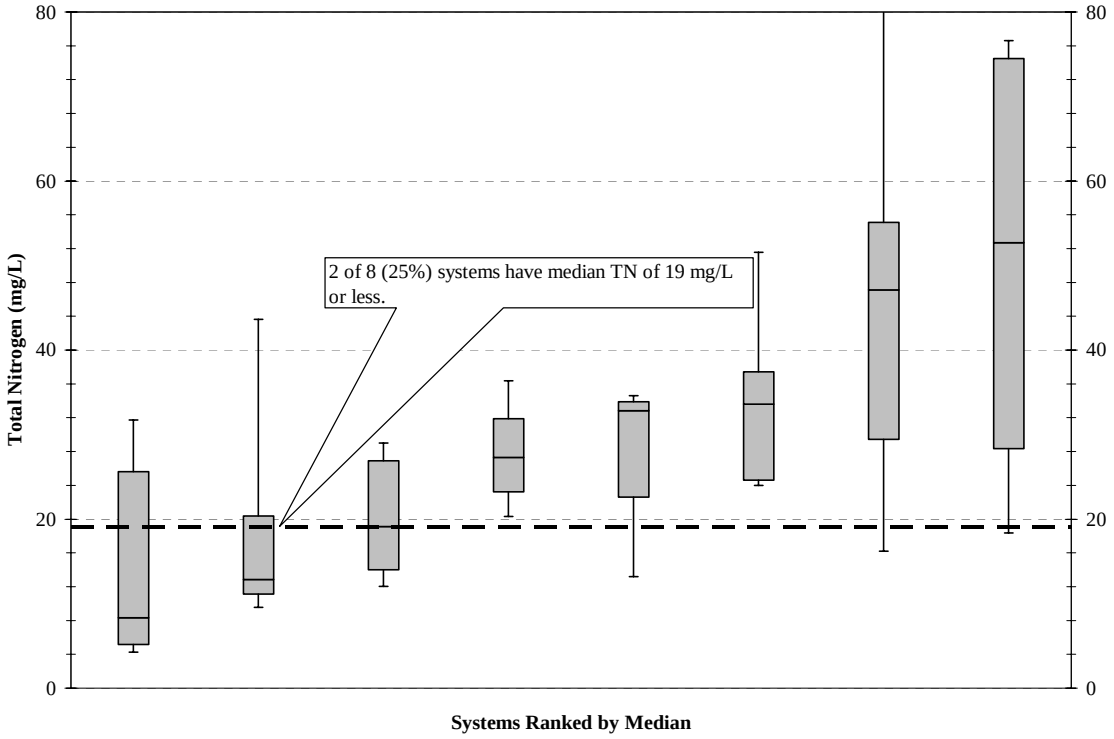

Figure 22. Ranked median total nitrogen concentrations from single-family SeptiTech systems plotted with range values (only systems with ≥4 samples included).

Advantex®

The Advantex® is a multi-pass, packed bed aerobic wastewater treatment system (DEP Provisional Use Approval Letter, 2005). In Massachusetts it must be installed in conjunction with the Vericomm™ or TCOM control panel, which is attached to an Internet interface.

During early development of the technology, a number of variant design Orenco trickling filters were installed in Barnstable County. These authors believe that most of these have been replaced by the Advantex. The system is manufactured by Orenco Systems, Inc., 814 Airway Avenue, Sutherlin, OR 97479 (website www.orenco.com), and has Provisional Use Approval for nitrogen removal and General Use Approval where nitrogen removal is not required. Table 1 presents results from four sites.

	Site 1	Site 2	Site 3	Site 4
Mean TN (mg/L)	21.6			
Median				
Std.Dev.				
Maximum	32.1	17.7	9.1	18.0
Minimum	11.0	17.7	9.1	18.0
Number of Samples	2	1	1	1

Table 1. Summary of TN (mg/L) results from single-family residential Orenco trickling filter systems and Advantex installed in Barnstable County.

Amphidrome®

Amphidrome (F.R. Mahony & Associates, 273 Weymouth Street, Rockland, MA 02370 -website www.frmahony.com/products.htm) is a sequencing batch reactor with various components. It has Provisional Use Approval for the removal of nitrogen and General Use Approval where nitrogen removal is not required. Three installations contributed 35 datapoints to this analysis (Table 2).

	Site 1	Site 2	Site 3
Mean TN (mg/L)	6.3	34.3	
Median	5.4	25.9	
Std.Dev.	3.5	22.9	
Maximum	14.6	67.8	18.0
Minimum	1.2	17.8	18.0
Number of Samples	30	4	1

Table 2. Summary of TN (mg/L) results from single-family residential Amphidrome Systems installed in Barnstable County.

Waterloo Biofilter®

Waterloo Biofilter is a class of trickling filters that use proprietary absorbent foam as a media. They are manufactured by Waterloo Biofilter Systems Inc., 143 Dennis Street, PO Box 400, Rockwood, Ontario NOB 2KO (website http://www.waterloo-biofilter.com/). It has Provisional Use Approval for the removal of nitrogen and General Use Approval where nitrogen removal is not required. Waterloo Biofilter has been used as a pretreatment for the sole Nitrex system reporting to our database. Results from five single-family installations are presented in Table 3.

	Site 1	Site 2	Site 3	Site 4	Site 5
Mean TN (mg/L)	18.8	30.5			
Median	18.2	30.6			
Std.Dev.	6.1	15.3			
Maximum	27.5	48.3	41.3	26.5	24.6
Minimum	12.2	12.7	13.2	13.1	17.7
Number of Samples	5	4	2	2	2

Table 3. Summary of TN (mg/L) results from single-family residential Waterloo Biofilter systems installed in Barnstable County.

Nitrex®

Nitrex is an upflow filter containing carbonaceous material. It is installed in conjunction with a nitrifying (or denitrifying) technology. The nitrogen influent to the filter must be oxidized for the Nitrex to be effective. The product is marketed by Lombardo Associates, Inc., 49 Edge Hill Road, Newton, MA 02467 (website http://www.lombardoassociates.com/nitrex.shtml).

To date only one system (outside of a test center venue) is reporting to the data system. The system serves a residential/light commercial complex in Mashpee and is installed in conjunction

with a Waterloo Biofilter system as pretreatment (Table 4). The present total flows to the system are less than 3000 gallons per day.

The results from May 2006-May 2007 are as follows:

	Influent	Effluent
Mean	51.5	3.5
Median	51.0	2.7
Std. Dev.	15.5	1.6
Maximum	75.6	6.9
Minimum	14.0	1.6
Number of Samples	13	13

Table 4. Summary of TN (mg/L) results from a multi-family (with some light commercial) Nitrex unit.

COMPOSTING TOILETS

One composting toilet installed in the Town of Eastham was installed in conjunction with a recirculating sand filter for disposal of graywater. This installation offers a unique, albeit limited, opportunity to see the nitrogen reduction achieved by this coupling of technologies. Nineteen samples were taken during 2005-2006 (Table 5).

	Effluent
Mean TN (mg/L)	5.4
Median	4.9
Std.Dev.	2.2
Maximum	10.6
Minimum	2.6
Number of Samples	19

Table 5. Summary of TN (mg/L) results from a recirculating sand filter graywater-only effluent, where the toilet waste was diverted to a composting toilet manufactured by Clivus New England.

The results suggest that avoiding the mingling of toilet waste with graywater can achieve overall reductions in nitrogen that yield discharge concentrations of a recirculating sand filter of <10 mg/L. The overall effect of this diversion on the groundwater in any situation however, would depend on the ultimate disposition of the waste from the composting toilet, which includes sawdust mixed with composted urine, fecal matter and toilet paper.

DISCUSSION

The management of wastewater-derived nitrogen in watersheds presents a significant financial and practical challenge to marine coastal communities. In order to comprehensively investigate all feasible management options, communities must be able to project nitrogen loads under a variety of scenarios ranging from centralized treatment to decentralized treatment options, including the use of advanced denitrifying onsite septic system technologies. Traditionally, nitrogen reductions achievable in centralized municipal treatment facilities are readily available and thus easily incorporated into watershed modeling scenarios. Conversely however, examples of I/A system use for watershed nitrogen management are less common and "standard" nitrogen reduction assumptions are not available.

The difficulty in deriving a standard set of assumptions for watersheds where I/A systems might be proposed becomes obvious when data are examined. While some of the technologies reported on herein demonstrate consistent performance in a test-center venue where full design loads are consistently applied, these same technologies serving actual residences demonstrated considerable variability both between sites and within measurements taken at the same unit. The possible reasons for the observed variability have been discussed and include the plausibility that water usage and other factors obscure the true nitrogen reduction performance of I/A systems, particularly between sites. Whatever the cause, our data suggest that the incorporation of individual onsite denitrifying technologies into watershed modeling scenarios should be done with caution and consider the variability reported here.

In order to refine the estimate of nitrogen reductions achievable by I/A systems in real situations, over the coming months we will attempt to "normalize" performance data by procuring occupancy and water use information for selected systems and relating these data to system expectations under the regulatory assumptions (influent nitrogen of 40 mg/L and 55 gallons of water use per person per day). This process may change the conclusions regarding performance of systems that indicated, by their discharge total nitrogen concentrations, a particular status in relation to the regulatory limit of 19 mg/L total nitrogen. In addition, we hope to be able to provide realistic assumptions for towns that incorporate I/A systems in their watershed nitrogen management strategies.

The Barnstable County Department of Health and Environment presently serves as oversight for I/A system performance and maintenance in 14 towns in Barnstable County. In that role, it ensures compliance by supplementing the regulatory activities of the boards of health with enforcement communications, providing public information and reporting performance to local boards of health. Towns that contemplate the wide-scale use of I/A systems to address nutrient issues should understand that the oversight of operation and maintenance of I/A systems is an essential part of ensuring a level of success. Quite simply, I/A systems that are not regularly inspected and occasionally monitored will not achieve treatment objectives. For various models on how this management could take place, the reader is directed to the publication "Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems – An Introduction to Management Tools and Information for Implementing EPA's Management Guidelines" (EPA Number 832-B-05-001), which is available as a free download from the EPA website www.epa.gov/owm/septic/pubs/onsite_handbook.pdf.