EXECUTIVE SUMMARY

The Ventura Regional Sanitation District (VRSD) in Ventura County, California, field-tested and evaluated six different Advanced Onsite Sanitary Systems (OSS) from four different manufacturers. The demonstration was partially funded by grant moneys from the United States Environmental Protection Agency (EPA) via the CA RWQCB. The purpose of this Septic Tank Nutrient Removal Project (STNR) was to demonstrate the typical wastewater treatment levels, and particularly the degree of nutrient removal by advanced OSS from typical household wastewater.

Results indicated that the systems provided excellent treatment beyond that of a standard septic system and comparable to Public Owned Treatment Works (POTW). All systems removed > 67 % BOD_5 and >81 % TSS from the wastewater. The following four systems consistently met biological oxygen demand (BOD_5) and total suspended solids (TSS) requirements of 30 mg/L: Fast Regular, Fast Custom, MicroSepTec, and Orenco RX. None of the systems consistently removed total nitrogen (TN) below 10 mg/L. All systems reduced TN by >50 % from the influent. The most effective TN reducing unit was Orenco RX, with a mean effluent TN concentration of 11.4 mg/L.

All units were also tested for total coliform and total phosphorus (TP). MicroSepTec was the only system capable of multi-log pathogen reduction because of its chlorinating treatment, reducing influent wastewater from >1600 mpn/100 ml to a mean concentration of 219.5 mpn/100 ml. All systems removed some TP. Percent TP reductions were not very significant, ranging from 3 % to 22 %.

The three-month STNR project demonstrated that OSS units provide significant improvement in nutrient reduction over standard septic systems. The demonstration indicates some OSS units can consistently treat wastewater to the quality typically required of POTWs with discharge by percolation.

ACKNOWLEDGEMENTS

VRSD would like to acknowledge the participation and assistance of the many agencies, businesses and individuals that contributed to the development and performances of this project.

Camrosa Water District
Bio-Microbics
Micro Sep Tec
Orenco
7H Technical
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Los Angeles Regional Water Quality Control Board
United States Environmental Protection Agency

1.0 INTRODUCTION

There are more than 1.2 million housing units, or 10% of the state of California, that rely on individual onsite sewage treatment systems. This represents more than 3.5 million persons with the systems handling an estimated 420 million gallons of wastewater per day. The proper treatment of this sewage is important as the major portion of the resulting wastewater migrates through the soil and recharges the groundwater and surface water. (2)

Water Quality Problems specific to septic systems in Southern California

- Environmental degradation caused by individual septic tanks.
- Septic tank effluent is a real concern along beach areas where there is insufficient natural treatment before the water reaches the ocean.
- Heavy reliance on septic tank systems by communities located over groundwater recharge areas.
- Differing regulators, effluent quality, domestic water quality, and weather of Southern California.
- Although many small package wastewater treatment plants have been or are being tested in Michigan, Florida, and Massachusetts, local testing in Southern California has not been done yet; and
- Expected increases in regulation of future operation and installation of septic tanks in California. (11)

Purpose of Project.

The California Regional Water Quality Control Board has determined that the effluent of simple septic systems degradation is one of the major environmental concerns in Southern California. VRSD created this project to address this problem by comparing and demonstrating the improved technology of alternative onsite sanitary systems. The project compared individual home treatment plants from several manufacturers to establish which consistently produces acceptable effluent quality. The purpose of this project was to evaluate the potential for improved nutrient removal efficiency of Advanced Onsite Sanitary Systems over conventional septic systems. There was insufficient time in this study to evaluate reliability, consistency, operation and maintenance requirements, and costs associated with On-site Sanitary Systems.

Project Scope and Objectives

The California State Water Resources Control Board (WRCB) and the Ventura Regional Sanitation District (VRSD) entered into Agreement number 0-047-254-0, on August 1, 2000. This agreement was for the evaluation of manufactured “off the shelf” advanced individual small package wastewater treatment plants appropriate for single-family residences. The project required the construction of a facility that provided side-by-side operation of six different individual disposal system nutrient and pathogen removal processes, and analysis of sewage inflow and effluent quality. The manufacturers selected for the project were those that were expected to produce effluent quality better than 30 mg/L biological oxygen demand, 30 mg/L total suspended solids, 10 mg/L total nitrogen and multi-log pathogen reduction.

2.0 WASTEWATER TREATMENT PROCESSES

Processes for Onsite Wastewater Treatment

Levels of Treatment

Wastewater treatment processes include three levels of treatment. These are primary, secondary, and advanced wastewater treatment.

Primary Treatment

Primary treatment removes settleable solids from the waste flow and the majority of oils, greases, and other floatable solids. Primary treatment methods include primary clarification and primary treatment in septic tanks. As wastewater flows through a septic tank, solids are separated from settling via gravity and the scum floats to the top of the tank where both are collected and removed by mechanical equipment or pumping. Primary treatment can only provide a partially clarified effluent because it does not remove all suspended solids, dissolved organic materials, or other soluble pollutants from the wastewater stream.

Secondary Treatment

Secondary treatment processes are designed to further remove suspended solids to reduce biological oxygen demand (BOD). Typically, secondary processes remove 85% of the TSS and BOD from the wastewater. However, secondary processes provide only limited removal of nutrients phosphorus and nitrogen.

Advanced Secondary Treatment

Advance secondary treatment (AST) processes further removal of BOD and nutrients such as phosphorus and nitrogen. The most common and least expensive AST processes are biological methods utilizing microorganisms to transform solids and organic matter into carbon dioxide, biological cell mass, and nitrogen gas.

Advanced Wastewater Treatment

Advanced wastewater treatment (AWT) provides even further removal of suspended solids, BOD, and nutrients. AWT processes can reduce BOD and TSS by 95% and nitrogen and phosphorus by 90%.

Conventional verses Alternative Onsite Sewage Treatment Systems (OSTS)

Conventional systems consist of two treatment components 1) a septic tank that receives the raw sewage from the home, followed by 2) a subsurface soil absorption/dispersal area that receives the wastewater from the tank. The septic system is the most widely used onsite wastewater treatment option in the U.S.

Alternative Onsite Sewage Treatment Systems (OSTS)

Alternative OSTS are systems that replace, add to, or modify one or both of the treatment components or add additional components to the conventional system above. These systems are capable of providing improved treatment and a higher quality wastewater effluent. Alternative OSTS in many respects are variations of the conventional system because they use one or more naturally occurring biological, chemical or physical principles and processes found in the conventional system. (2). These processes include aerobic treatment units, disaffection units, nutrient removal systems, wastewater segregation and recycle systems, intermittent sand filters, various media filters of sand, peat, foam or fabric

Description of Tested Onsite Sanitation Systems (OSS) Processes and Operation

The VRSD invited manufacturers to provide their systems for full-scale model testing at the demonstration site located at the Camrosa Water District wastewater treatment plant in Camarillo California. The following OSS units were tested for three months by the STNR project:

<u>Bio-Microbics- FAST Regular and FAST Custom systems</u>

The wastewater solids and floatables stay in and are anerobically treated in the primary treatment tank. A bubble diffuser underneath fixed media further treats wastewater for secondary treatment and nutrient removal. FAST Regular has the blower on all the time. FAST Custom cycles the blower on and off for increased denitrification.

Micro Sep Tec system

The EnviroServer can be described as a hybrid fixed-film-suspended growth extended aeration system with a two-stage biological process to optimize denitrification. The treatment process is unique in that excess biomass is periodically decomposed to carbon and inert ash in a thermal processor as opposed to periodic wasting and subsequent disposal in conventional biological treatment processes. The system is controlled and monitored by an onboard computer. The computer is capable of detecting failures of electrical and mechanical components critical to the treatment processes and delivering signals both remotely via a modem and locally with a visible and audible alarm.

Orenco- AX and RX systems

The wastewater solids and floatables stay in and are anoxically treated in the primary treatment tank. A pump doses the wastewater over the textile filter where ammonia is converted to nitrates. From the textile filter, most of the wastewater reenters the anoxic tank for denitrification and recirculates back to the textile filters. The textile filters in the AX unit is draped like close packed curtains. In the RX unit, the textile is cut into coupons and randomly dispersed.

7H Technical system

This system provides an intermittent batch reactor. The unit employs an alternating batch process of aeration and anoxic treatment with two clarification stages. This system is usually installed after a conventional septic system.

3.0 CAMROSA TEST FACILITY DESIGN AND STUDY METHODOLOGY

The Ventura Regional Sanitation District (VRSD) in Ventura County, California, designed the Septic Tank Nutrient Removal Project (STNR) to evaluate the potential for advanced individual treatment systems to reduce organic, solids, and nutrient loading from wastewater. The Camrosa Water District hosted the test by providing space, wastewater, water and electric power at their wastewater treatment plant. The plant is located on Camarillo Road, which is within 200 yards of the intersection of Lewis Road and Potrero Road a few miles south of the City of Camarillo, California.

Test Facility Design, Construction, and Operation

Four manufacturers with a total of six different models furnished systems that were installed side-by-side at the Camrosa Water District, along with a standard septic system as a “control”, for comparison. The systems were stationed in the following order: standard septic system (control), Fast Regular, Fast Custom, Orenco AX, MicroSepTec, Orenco RX, and 7H.

Wastewater Hydraulic Loading

Wastewater influent to the Camrosa Treatment Plant was diverted to each system in doses approximating that received by an individual home treatment plant, 300 gallons per day. Electrical instrumentation automatically controlled uniform wastewater loading to seven wastewater treatment systems and logged the events and the volume. The loading schedule was programmed to simulate the diural wastewater flow characteristics of a single-family residence, with peaks in the morning and early evening hours (1). VRSD installed a pump in the Camrosa influent meter vault that pumped typical municipal wastewater to each disposal system. As the wastewater was pumped, time splitter valves directed the wastewater to each tank.

The pump and the timed valves were programmed to supply 1 to 20 gallon discrete doses of the wastewater. Most of the doses arrived between 6 a.m. and 8:30 a.m.; lessor dosing was done during the day and more again between 6 p.m. and 10 p.m.

Stress Loading Methodology and Procedure

During the testing period, all onsite sanitary systems were stressed under heavy load conditions and vacation conditions. Stress loading conditions were designed to evaluate the treatment performance under non-ideal conditions.

Heavy Load Conditions

Heavy load conditions involved an increased influent volume to simulate heavy wash days and/or party days. A heavy load day was an additional 200 gallons between 12:15 p.m. to 4:30 p.m. on top of the normal 300 gpd. Each disposal system received heavy load doses of 500 gpd for one week during the testing period.

Vacation Stress

A vacation is no flow for one week followed by 300 gpd. Each disposal system was cycled through a vacation week during the testing period. Sampling was resumed on the week following the vacation.

Investigative Materials and Methods

Weather Monitoring

VRSD maintained a field logbook for the purpose of recording weather conditions. Air temperature was recorded biweekly on a max-min thermometer. General weather conditions: cloudy, rainy, clear, windy, dry were observed and recorded biweekly.

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Field Testing and Observations

Influent temperature was recorded twice a week on a max-min thermometer positioned on the influent pipe before flow splits to the various treatment units. Effluent temperature was recorded on a max-min thermometer positioned on the effluent pipe after all the effluent pipes join. The MicroSepTech was the only system that used chlorinating treatment, therefore it was field tested biweekly for chlorine residual. Total daily flows through the Camrosa Wastewater Treatment Plant were electronically measured and recorded. The comparison test site was checked frequently to ensure proper maintenance and operation. On a weekly basis, a project operator verified flows and checked for process disruptions, such as, inoperative pumps, plugged lines, power failures, flow volume treated, and process disruptions.

Wastewater and Effluent Sampling

VRSD finished installing the disposal systems at the Camrosa Water District in late September 2000. Start-up sampling and analysis began on October 3, 1999 and continued until the biologic treatment processes stabilized and the Tytronics Sentinels arrived and were operational on December 7, 1999. The start up period involved grab sample analysis and onsite continuous measurements of nitrate and ammonia nitrogen from the Tytronics sentinels. After all the systems under went continuous testing for a week, each system was given a week vacation followed by continuous sensing until the system had returned to its previous steady state effluent quality. Official sampling and analysis began on December 14, 2000 and ended on March 8, 2000.

Influent Sampling

The influent samples were taken with a composite sampler and collected biweekly. A refrigerated composite sampler accumulated a sample from the influent pipe before the flow split to the various treatment units. Each influent sample was regularly analyzed for pH, BOD, TSS, T-P, ammonia-N, and TKN.

Effluent Sampling

Grab samples were taken approximately twice a week from the control and the six demonstration disposal systems, except for systems on vacation schedule. The grab samples were collected in sample bottles by turning a petcock positioned in the effluent pipe for each system. The petcocks were sprayed with alcohol and wiped with a clean paper towel to decontaminate them prior to sampling.

Water Quality Analysis

Water quality samples were collected on a biweekly basis from the STNR project site. Laboratory measurements included pH, biological oxygen demand, total suspended solids, nitrite, nitrate, ammonia, total kjeldhal nitrogen, phosphorus, and fecal coliform. The system performance samples collected were analyzed for some or all of the parameters listed in Table 1.

Table 1. Analytical Constituent, Method of Analysis, and Detection Limits

Analytical Constituent	Method of Analysis	Laboratory Detection Limit (mg/L)
Ammonia Nitrogen (NH_3-N)	EPA 350.1	1
Biological Oxygen Demand (BOD_5)	EPA 405.1	2
Coliform Total/Fecal	SM9221B	<2 mpn/100 ml
Nitrate (NO_3-N)	EPA 300	0.4
Nitrite (NO_2-N)	EPA 300	0.3
pH	EPA 150.1	0.05
Total Kjeldhal Nitrogen (TKN)	EPA 351.2	1
Total Phosphate	EPA 365.2	0.1
Total Suspended Solids (TSS)	EPA 160.2	5
Turbidity		

Sentinels Ammonia and Nitrate Nitrogen

Sampling Quality Assurance/Quality Control (QA/QC)

The VRSD Laboratory Quality Assurance/Quality Control Manual, Appendix A, details protocols for collection of wastewater samples, field sampling records, sample handling and shipping, sample preservation, laboratory records, data handling records, chain of custody procedures. It also details the complete procedure of quality control standards, blanks, spikes, duplicates, and detection limits for all lab analysis performed.

The VRSD Laboratory is certified under the Environmental Laboratory Accreditation Program (ELAP) by the California Department of Health Services, certification number 1633.

As part of the water quality sampling QA/QC procedure, quality control checks were performed on a routine basis. These QA/QC checks were obtained in order to gauge the consistency and accuracy of the laboratory analysis of the samples as well as a check on field procedures. The quality controlled checks included equipment blanks, duplicate samples, split sample, and spiked samples.

Method blanks and/or reagent blanks were analyzed for each matrix and every batch. The method blank was taken through the whole analytical processes in equal volume or weight of the sample.

Standards are prepared by an outside source and are N.B.S. or EPA traceable. These standards are used to evaluate and insure accuracy of the methodology and or instrumentation.

Duplicate samples were split from the same container at the very first stage of the analytical process. Water samples are mixed by shaking the sample container and measuring out equal aliquots.

Spiking involved adding a known amount of a standard spiking solution to an aliquot of the previously analyzed sample. Spiked samples are used to validate the accuracy of the laboratory. The amount selected should approach the original concentration.

For further quality control checks, split samples were collected to determine the accuracy and variability between laboratories. Split samples were collected as grab samples from the same disposal system and split into two containers. The split sample results were then analyzed and compared.

All field and laboratory instruments were calibrated prior to use. Calibration involved using solutions of known value to adjust the accuracy of the instruments.

4.0 SYSTEMS MONITORING RESULTS AND DATA

Wastewater Treatment Performance

Water quality samples were collected on a biweekly basis from the STNR project site. Laboratory measurements included pH, biological oxygen demand, total suspended solids, nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen, total kjeldhal nitrogen, total phosphorus, and total and fecal coliform. The system performance samples collected were analyzed for some or all of the parameters listed in Table 1. Results of the water quality analyses for all the testing parameters for the influent, control, and all of the treatment units are provided as the calculated means in Table 2.

The data was analyzed based on the STNR effluent performance standards to see if any of the advanced onsite disposal units could produce effluent of better quality than 30 mg/L biochemical oxygen demand (BOD_5), 30 mg/L total suspended solids (TSS), 10 mg/L total nitrogen (TN), and multi-log pathogen reduction. A treatment unit will qualify if 90 % of its effluent flow volume is less then 27 mg/L BOD_5, 27 mg/L TSS, and 9 mg/L TN.

Results of the water quality analyses for testing parameters for the influent, control, and all of the treatment units are provided as the calculated means in Table 2. The influent wastewater was within the range of that reported in the literature for typical untreated domestic wastewater (Metcalf and Eddy, 1991) with mean BOD_5, TSS, TN (inorganic and organic N), and TP values of 177.9 mg/L, 225 mg/L, 38.6 mg/L, and 3.2 mg/L, respectively. The treatment efficiency was significantly improved over a standard septic system for all the treatment systems.

Table 2. Summary of Mean Water Quality Data for All Advanced Onsite Systems

Parameter	Units	Influent	Control	F. Regular	F. Custom	Orenco AX	M.SepTec	Orenco RX	7H
BOD	mg/L	177.9	157.8	13.2	15.8	57.7	4.6	10.3	27.4
TSS	mg/L	225.1	58.1	5.9	8.4	28.6	9.9	1.9	42.4
NH_3-N	mg/L	18.6	27.7	1.2	13.9	11.1	1	1	1.3
NO_2-N	mg/L	1.6	0.2	0.7	0.2	0.4	0.2	0.2	1.1
NO_3-N	mg/L	7.2	0.2	14.9	1.1	3	10.3	9.1	10.4
TKN	mg/L	29.8	31.5	3.9	16	16.1	5.4	2.1	4.5
Organic N	mg/L	11.6	3.6	3.4	3	5.1	5.4	2.1	3.6
Inorganic N	mg/L	27.4	28.1	16.8	15.2	14.5	11.3	10.3	12.8
Inorganic and organic N	mg/L	38.6	31.9	19.5	17.3	19.5	15.9	11.4	16
Total PO_4-P	mg/L	3.2	2.9	2.7	2.6	2.5	3.1	2.8	2.6
Fecal coliform	mpn/100mL	>1600	>1600	>1600	>1600	>1600	219.5	>1600	>1600
Total coliform	mpn/100mL	>1600	>1600	>1600	>1600	>1600	357.1	>1600	>1600

Mean and Range of Data

Significant variations occurred about the calculated mean values for most of the parameters for each unit. This is typical of domestic wastewater from individual homes since wastewater loading is not always consistent as a Public Owned Treatment Works (POTW). The discussion of this study is based on the calculated mean values and the range. The range is important because field sampling and analysis of onsite sanitary systems is typically infrequent, if performed at all. While field sampling and analysis at a POTW is more frequent and required. Therefore, at any given sampling date a measurement may vary significantly from its calculated mean value. Only the systems that had range values that remained below the STNR effluent performance standard were considered reliable to meet the standard consistently with infrequent sampling.

BOD and TSS Reductions

The mean influent BOD_5 concentration of 177.9 mg/L was reduced below the required STNR effluent performance standard of 30 mg/L by all the onsite sanitary systems, except for Orenco AX (Figure 1). The mean effluent BOD_5 ranged from 4.6 mg/L for the MicroSepTec to 57.7 mg/L for the Orenco AX.

Figure 1 indicates variability of the BOD_5 concentration over the study period by showing the range for each unit. The only two systems that consistently met the STNR performance standards were MicroSepTec and Orenco RX because their maximum BOD_5 never exceeded 30 mg/L.

The conventional septic tank only reduced the BOD_5 by 20.1 mg/L; the mean control effluent BOD_5 was 157.8 mg/L. All the systems significantly reduced the BOD_5 concentrations below that of a standard septic system.

The mean influent total suspended solids (TSS) concentration of 225.1 mg/L was reduced effectively below the STNR standard effluent standard 30 mg/L by all the systems, except for 7H (Figure 2). The mean effluent concentrations of TSS ranged from 1.9 mg/L for Orenco RX to 42.4 mg/L for the 7H.

Figure 2 indicates variability of the TSS concentration over the study period by showing the range for each unit. The four systems that consistently met the STNR performance standards were Fast Regular, Fast Custom, MicroSepTec and Orenco RX because their maximum TSS never exceeded 30 mg/L.

The conventional septic tank mean TSS concentration was 58.1 mg/L, it reduced the TSS concentration by 167 mg/L from the influent. All the systems reduced the TSS concentrations below that of a standard septic system.

Percent reductions of effluent BOD_5 and TSS concentration from the influent are provided in Table 3. For most of the advanced treatment systems, there was a high correlation between percent reduction of BOD_5 and TSS. All systems reduce BOD_5 and TSS concentrations from the influent by greater than 91 %, except for Orenco AX and 7H. The standard septic system was effective at removing suspended solids by 74 %, however it removed only 11 % of the BOD_5.

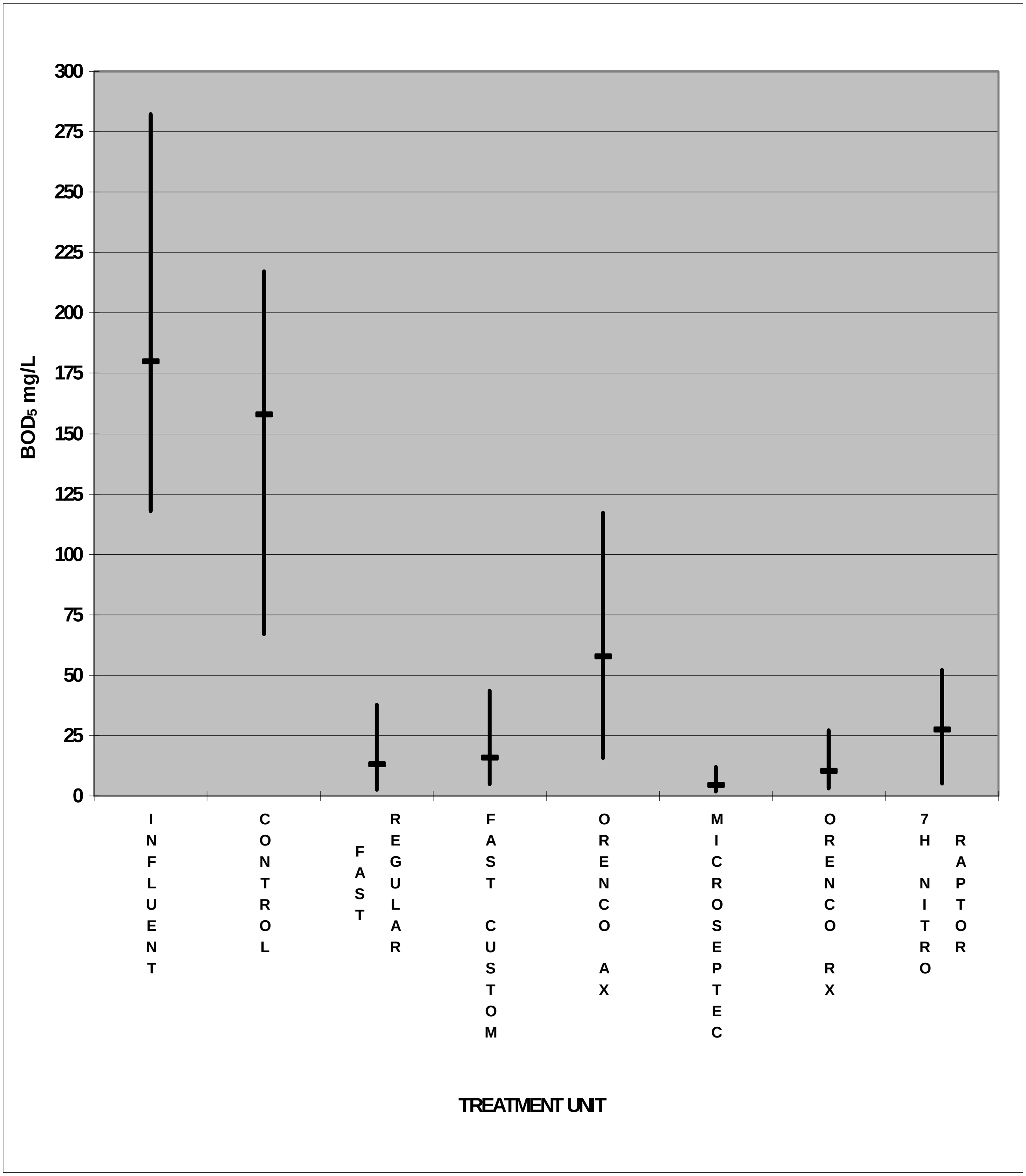

Figure 1. Biological Oxygen Demand Concentrations; Mean and Range.

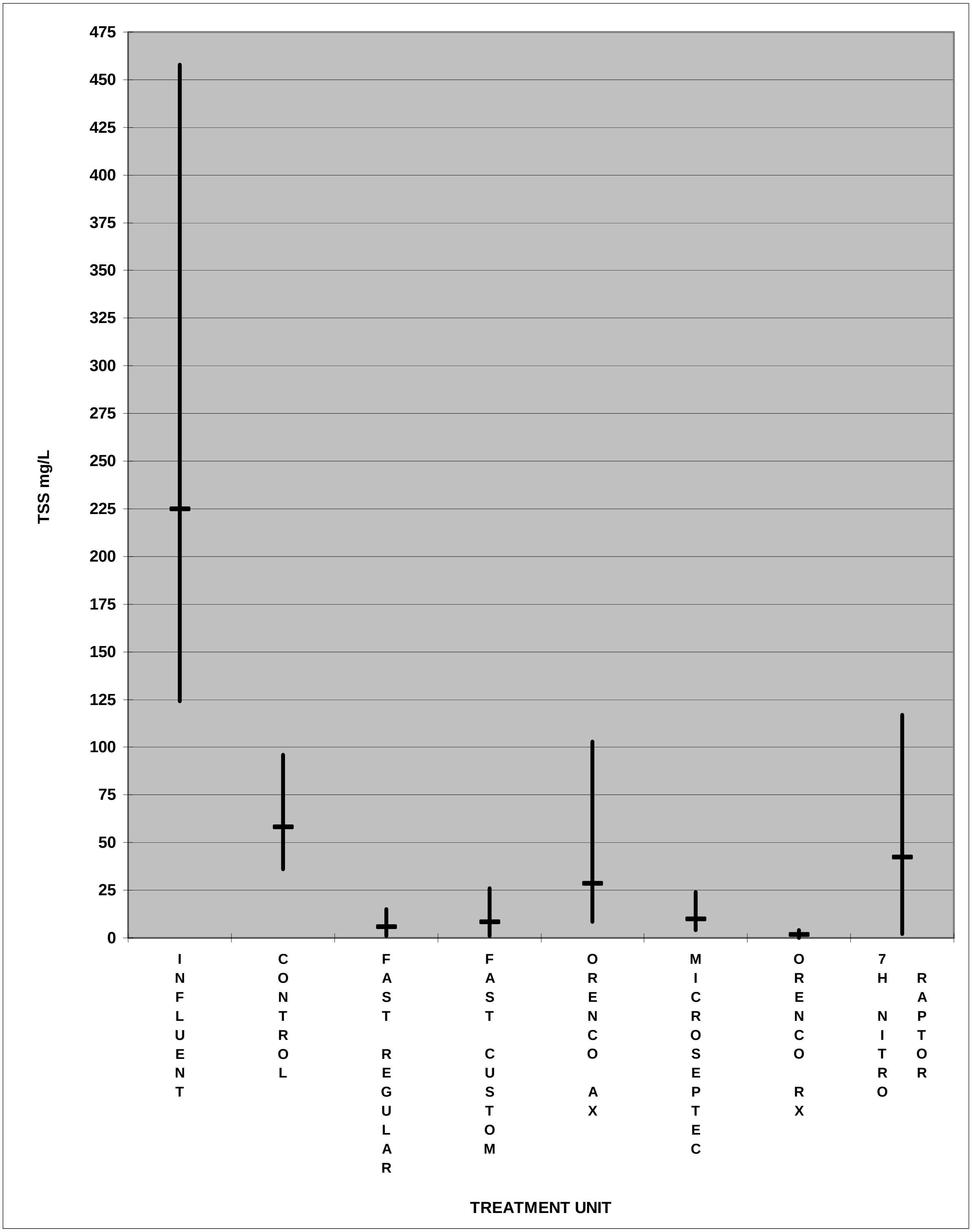

Figure 2. Total Suspended Solids Concentrations; Mean and Range.

Table 3. Percent reduction of effluent BOD_5 and TSS concentration from the influent.

System	% reduction from influent BOD_5	% reduction from influent TSS
Standard septic	11	74
Fast Regular	93	97
Fast Custom	91	96
Orenco AX	68	87
MicroSepTec	97	96
Orenco RX	94	99
7H	85	81

Percent reductions of effluent BOD_5 and TSS concentration from the control are provided in Table 4. All the systems reduced BOD_5 and TSS concentrations from the control effluent by greater than 83 %, except for Orenco AX and 7H. MicroSepTec was the most effective at removing BOD_5 below a standard septic system at 97 % reduction. Orenco RX was the most effective at removing TSS below a standard septic system at 97 %. Overall, the system that reduced the most combined BOD_5 and TSS was the Orenco RX.

Table 4. Percent reduction of effluent BOD_5 and TSS concentration from the control.

System	% reduction from control BOD_5	% reduction from control TSS
Fast Regular	92	90
Fast Custom	90	85
Orenco AX	63	51
MicroSepTec	97	83
Orenco RX	93	97
7H	83	27

Nitrogen Reductions

Nitrogen is a difficult nutrient to remove. Biological nitrogen removal requires moving the wastewater through alternating zones of aeration and anoxic environments. Nitrogen removal includes two steps of nitrification and denitrification. Nitrification converts ammonia-nitrogen to nitrate-nitrogen and denitrification converts nitrate-nitrogen into nitrogen gas, which is released to the atmosphere (7). Under aerobic conditions and long residence times, nitrifying microorganisms convert much of the organic and ammonia nitrogen in wastewater to nitrate nitrogen. If nitrified effluent is then placed under anoxic conditions, denitrifying microorganisms utilize nitrate as an energy source and convert the nitrate to gaseous forms of nitrogen, which are discharged to the air. This reaction requires a bio-available source of carbon for denitrifying organism synthesis and a lack of free oxygen in the system. Also, denitrification requires temperatures above 5^oC and the reaction rate increases with increasing temperatures. (1)

The mean influent NH_3-N concentration was 18.6 mg/L (Table 2). Figure 3 shows a significant reduction in NH_3-N concentrations by the following systems, Fast Regular, MicroSepTec, Orenco RX, and 7H. The mean concentrations were 1.2 mg/L, 1.0 mg/L, 1/0 mg/L, and 1.3 mg/L, respectively. The mean effluent NH_3-N concentration ranged from 13.9 mg/L for the Fast Custom to 1.0 mg/L for the MicroSepTec and the Orenco RX. The concentration of NH_3-N in the control effluent actually increased over the influent to 27.7 mg/L.

The mean influent concentration of NO_3-N was 7.2 mg/L in Figure 4. Nitrate-N concentration decreased to 0.2 mg/L in the control effluent. The mean effluent concentrations of NO_3-N ranged from 1.1 mg/L for Fast Custom to 14.9 mg/L for Fast Regular. The following four systems increased in NO_3-N concentration, Fast Custom, MicroSeptec, Orenco RX, and 7H. There concentrations were 14.9mg/L, 10.3 mg/L, 9.1 mg/L, and 10.4 mg/L. The increase in nitrate-N in these four systems correlated with their subsequent decrease in ammonia-N (Figure 3). This resulted from the ammonia-N being converted into nitrate-N, indicating nitrification. The following two systems decreased in nitrate-N, Fast Custom and Orenco AX. Their concentrations were 1.1 mg/L and 3.0, respectively. The decrease in nitrate-N concentrations in these two systems correlated with higher concentrations of ammonia-N (Figure 3). Fast Custom and Orenco AX treatment indicated less nitrification.

The STNR effluent performance standard for Total nitrogen is 10.0 mg/L. Total nitrogen is defined as the sum of the organic and the inorganic nitrogen. This includes ammonia-N, nitrate-N, nitrite-N, and organic N. None of the systems were able to produce an average total N below 10 mg/L, as required by the STNR effluent standards. The system that came the closest was Orenco RX. The total N influent concentration of 38.6 mg/L decreased to 11.4 mg/L for the Orenco RX. The mean effluent Total N concentrations ranged from 11.4 mg/L for Orenco RX to 19.5 mg/L for Fast Regular and Orenco AX. Overall, the system that most effectively reduced total N was Orenco RX.

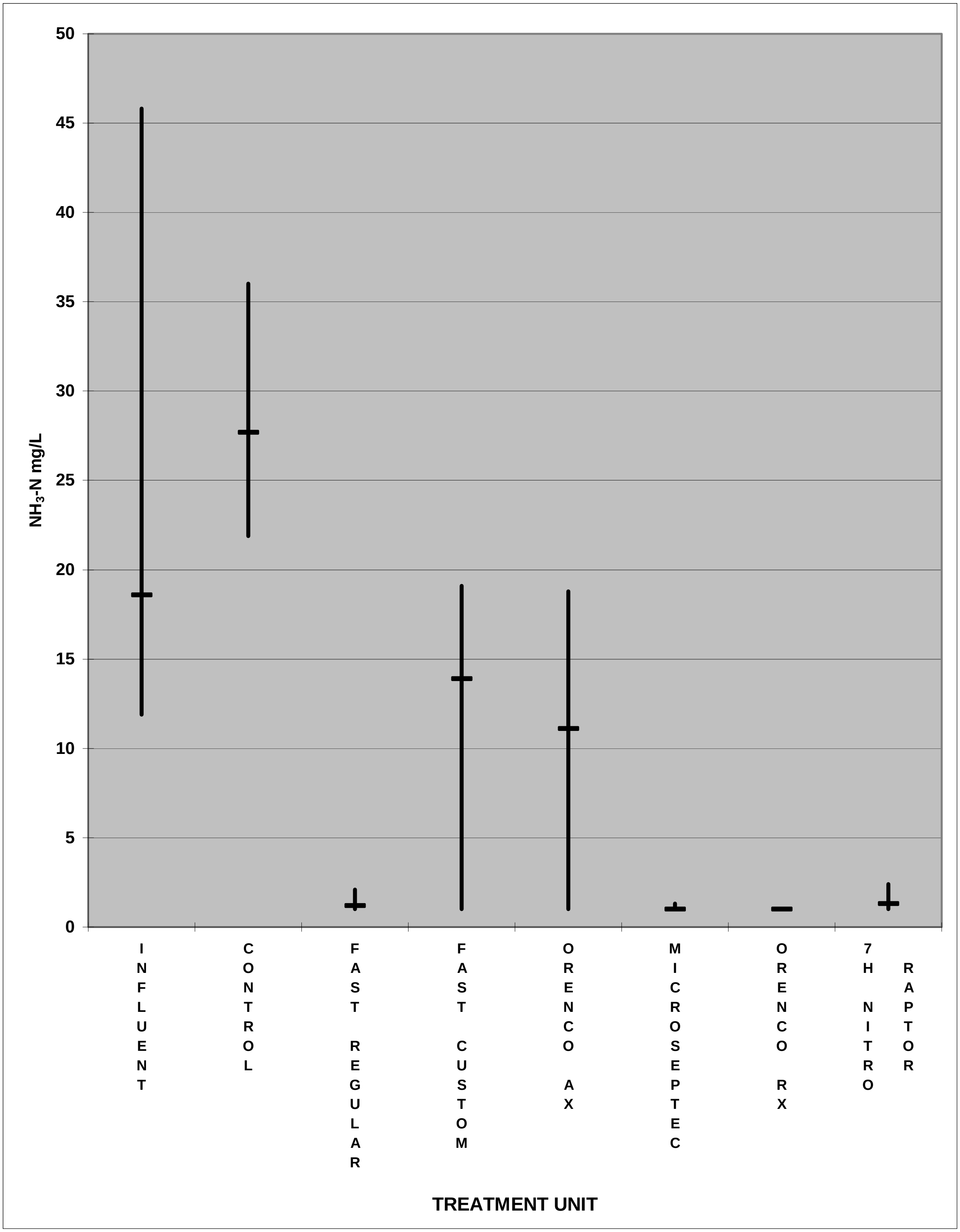

Figure 3. Ammonia-nitrogen Concentrations; Mean and Range.

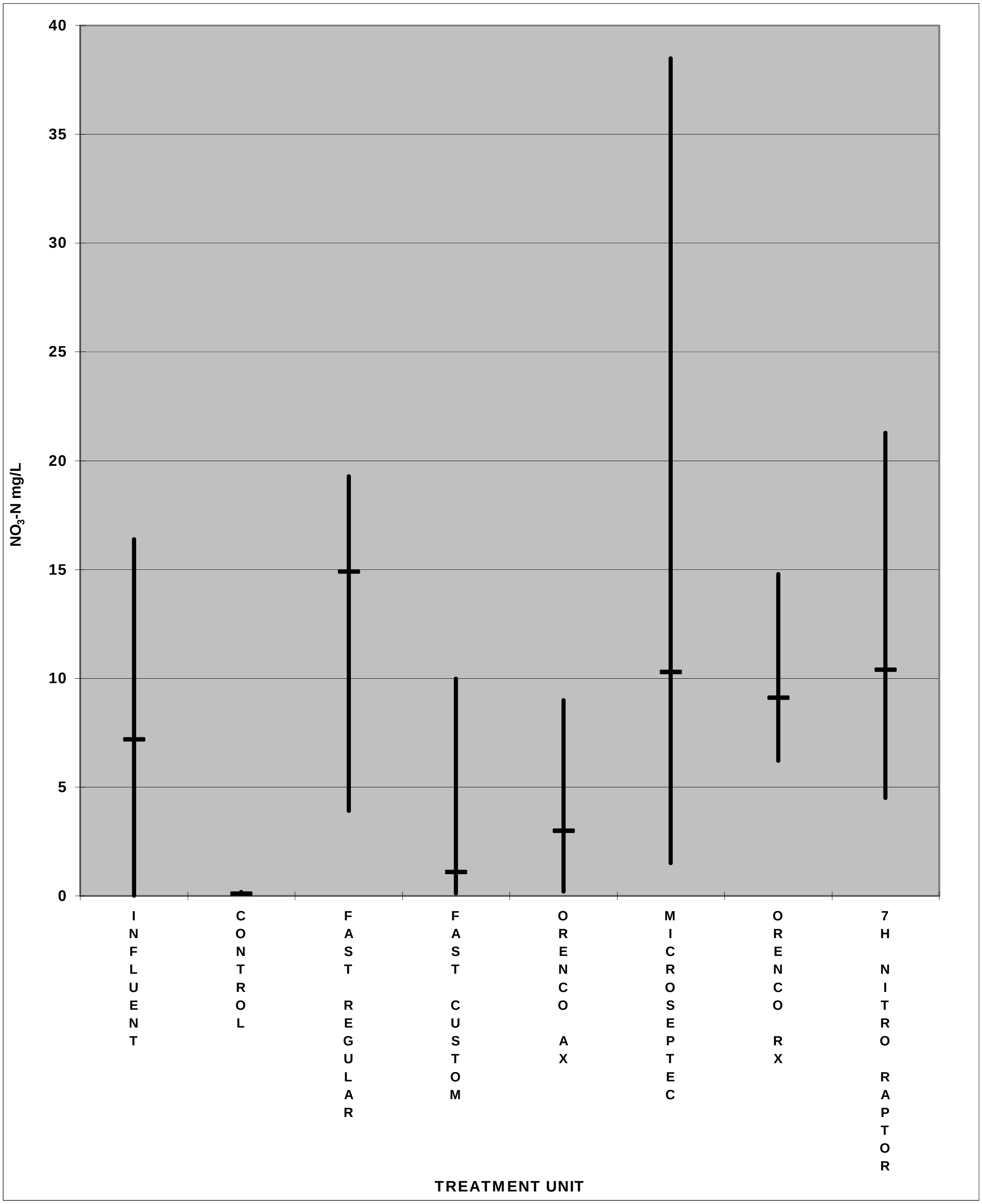

Figure 4. Nitrate-nitrogen Concentrations; Mean and Range.

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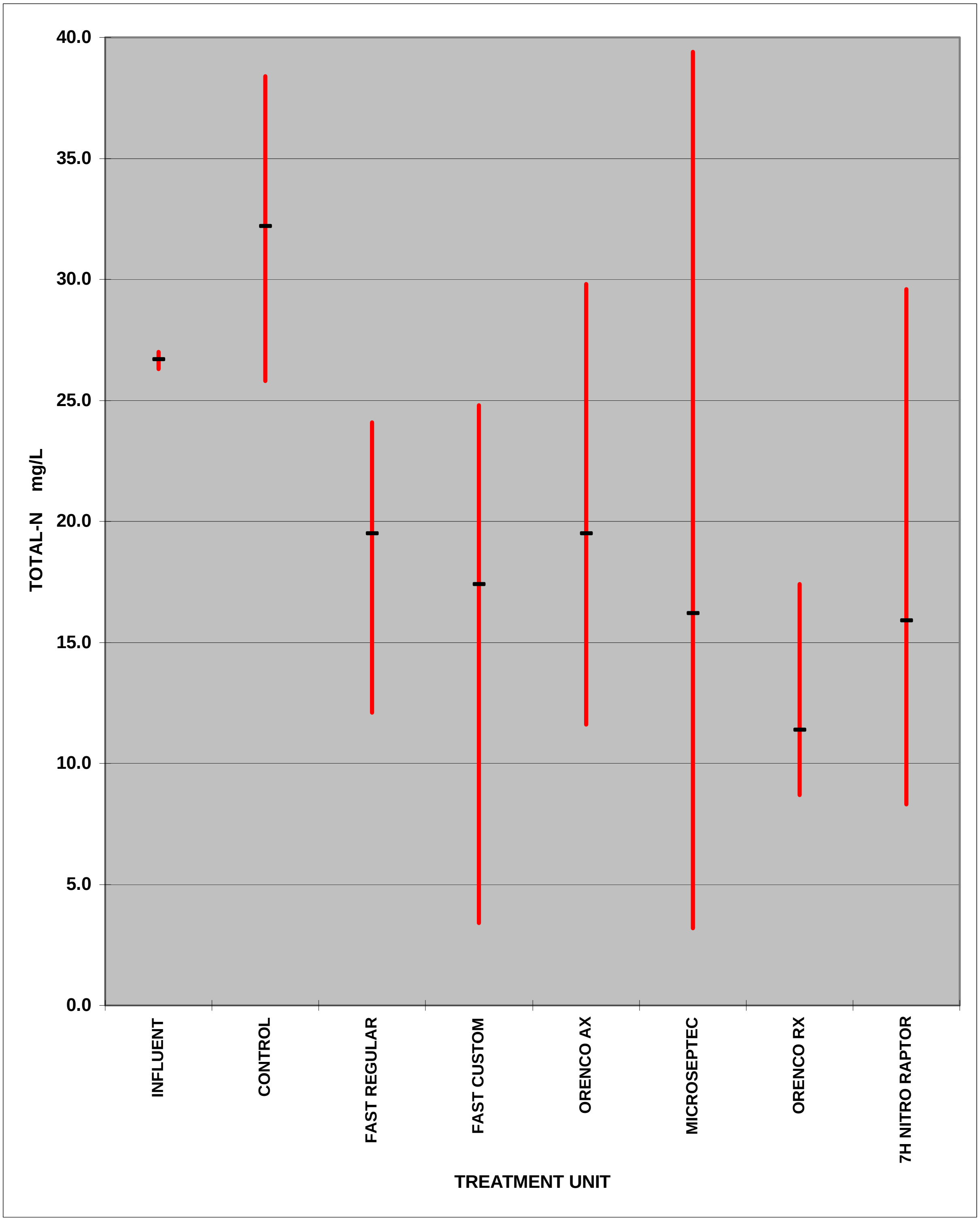

Figure 5. Total Nitrogen Concentrations; Mean and Range.

Tables 4 shows the percent change in all the tested forms of effluent nitrogen concentrations from the original influent concentration. All the systems produced a reduction in total organic and inorganic N, including the control effluent.

Table 4. Percent change in effluent nitrogen concentrations from the influent.

Units **System**	% NH_4-N	% NO_2-N	% NO_3-N	% TKN	% Total inorganic N	%Total organic + inorganic N
Standard septic	+49	-87	-97	+5.7	+2.6	-17
Fast Regular	-93	-56	+107	-87	-39	-50
Fast Custom	-25	-87	-88	-46	-44	-55
Orenco AX	-40	-75	-58	-46	-47	-50
MicroSepTec	-95	-87	+43	-82	-59	-59
Orenco RX	-95	-87	+26	-93	-62	-70
7H	-93	-31	+44	-85	-53	-58

(+) Sign indicates a percent increase in concentration
(-) Sign indicates a percent decrease in concentration

Table 5 shows the percent change in the tested forms of effluent nitrogen concentrations from the controlled standard septic system and the fold increase for nitrate-N. Due to the lack of aeration treatment in the standard septic system there is a marked increase across the board for nitrate-N in all treatment systems. This is due to the tanks receiving aeration treatment, which enhanced nitrification. Nitrite-N concentrations are typically low; therefore percent increases are more pronounced. This does not indicate high levels of nitrite-N. All systems reduced total organic and inorganic N by 38.9 % or more.

Table 5 shows the percent change in the tested forms of effluent nitrogen concentrations from the controlled standard septic system and the fold increase for nitrate-N. Due to the lack of aeration treatment in the standard septic system there is a marked increase across the board for nitrate-N in all treatment systems. This is due to the tanks receiving aeration treatment, which enhanced nitrification. Nitrite-N concentrations are typically low; therefore percent increases are more pronounced. This does not indicate high levels of nitrite-N. All systems reduced total organic and inorganic N by 38.9 % or more.

Table 5. Percent change in effluent nitrogen concentrations and fold increase for nitrate-N from the control.

Units **System**	% NH_4-N	% NO_2-N	Fold increase NO_3-N	% TKN	% Total inorganic N	% Total organic + inorganic N
Fast Regular	-96	+250	+75	-88	-40	-39
Fast Custom	-60	0.0	+5.5	-49	-46	-46
Orenco AX	-60	+100	+15	-49	-48	-39
MicroSepTec	-96	0.0	+51	-83	-60	-50
Orenco RX	-96	0.0	+45	-93	-63	-64
7H	-95	+450	+52	-86	-54	-50

(+) Sign indicates a percent increase in concentration
(-) Sign indicates a percent decrease in concentration

Multi-log Pathogen Reductions and Chlorine Residual for MicroSepTec

Another STNR effluent performance indicator was multi-log pathogen reduction. During the three-month testing period all systems were analyzed for total coliform and fecal coliform (mpn/100mL). The total and fecal coliform for the influent and the control effluent tested consistently as >1600 mpn/100mL (Table 2). Throughout the STNR comparison study, all the systems tested consistently as >1600 mpn/100mL, except for MicroSepTec. The mean concentration of MicroSepTec for fecal coliform was 219.5 mpn/100mL and for total coliform the mean concentration was 357.1 mpn/100mL. The reason MicroSepTec was able to reduce coliform counts while the other system were not able to was because MicroSepTec included chlorinating treatment, which served to eliminate a significant number of the coliforms. According to the data, there was a period between 12/27/00 to 1/23/01 where the total coliforms ranged from 80 to >1600 mpn/100mL for the MicroSepTec. Not surprisingly, during this time, the chlorine residual was at its lowest concentration for MicroSepTec, ranging from 0.1 to 2.0 mg/L. In order for the concentration of the total coliforms to decrease to <2 mpn/100 ml, the residual chlorine seemed to require a concentration of 6 mg/L or greater. The residual Chlorine concentrations for the MicroSepTec ranged from 0.1 to 45.0 mg/L.

Total Phosphorus Reductions (TP)

Total Phosphorus was not part of the STNR effluent performance standards. However, TP is an important nutrient to measure because of its contamination in the ground water that subsequently cause eutrophication in bodies of water. The mean influent TP was 3.2 mg/L. The control decreased to 2.9 mg/L. The mean effluent TP concentrations ranged from 2.5 mg/L for Orenco AX to 3.1 mg/L for MicroSepTec. All the systems reduced the TP below the influent concentration. MicroSepTec is the only system that increased in concentration above the standard septic tank control unit. MicroSepTec mean TP concentration was 3.1 mg/L. Overall, Orenco AX reduced TP concentrations the most. However, the range between systems was only 0.6 mg/L TP, therefore comparison between units is not very significant.

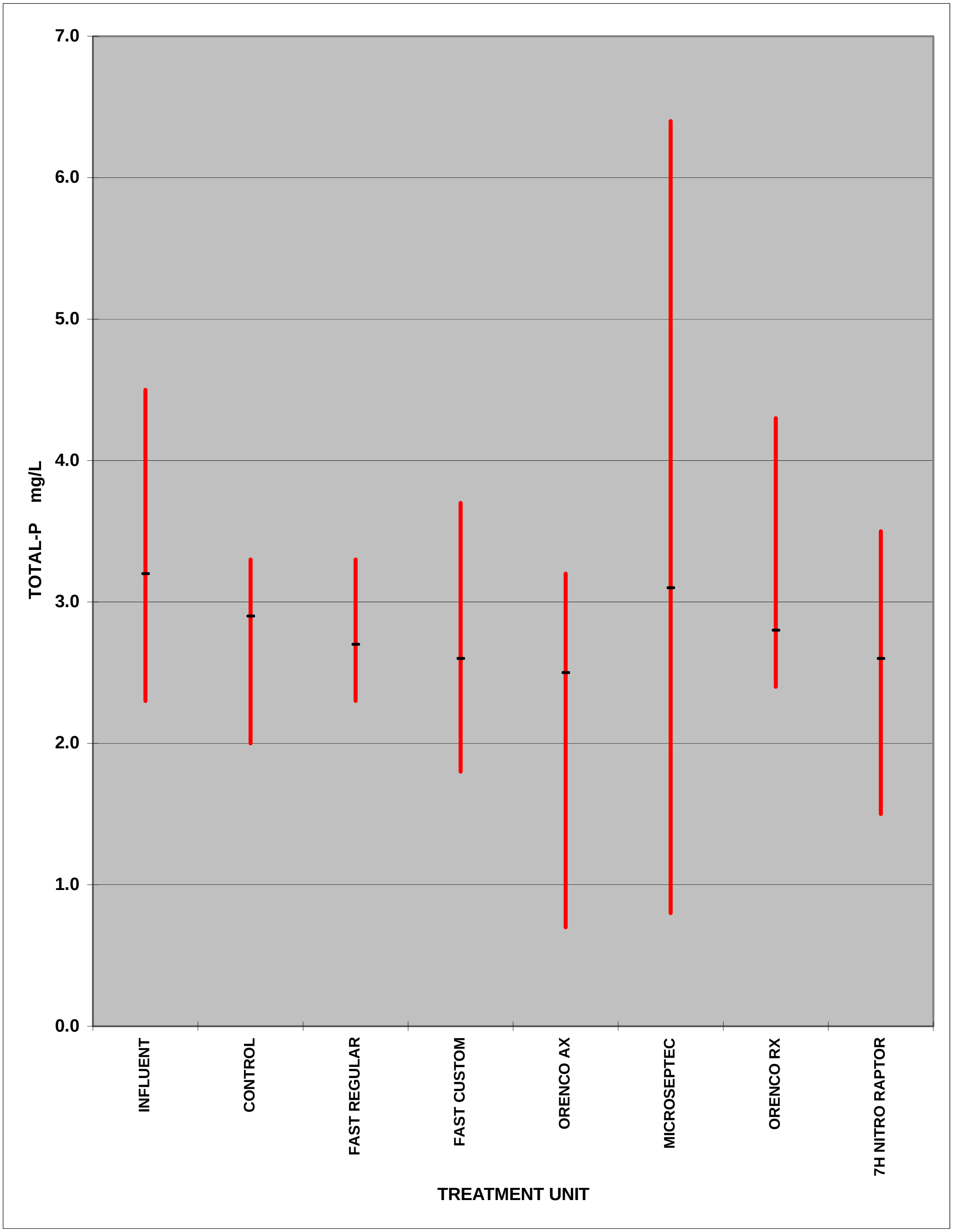

Figure 5. Total Phosphate-phosphorus Concentrations; Mean and Range.

5.0 CONCLUSION AND RECOMMENDATIONS

Summary of Treatment Performances

The STNR project evaluated six advanced onsite sanitary systems for potential improvement over conventional septic wastewater treatment. The systems were officially operated and evaluated for 85 days receiving hydraulic loading rates comparable to average household water use. During the period of operation, laboratory analysis led to the following conclusions:

1) All systems provided improved treatment beyond that of a standard septic system;

2) All systems removed >67 % BOD_5 and >81 % TSS from the untreated influent wastewater;

3) STNR effluent treatment to less than 30 mg/L biological oxygen demand (BOD_5) and 30 mg/L total suspended solids (TSS) were met by the calculated mean values for the following systems: Fast Regular, Fast Custom, MicroSepTec, and Orenco RX;

4) STNR effluent treatment to less than 30 mg/L BOD_5 and 30 mg/L TSS were met consistently by MicroSepTec and Orenco RX;

5) Mean total nitrogen (TN) reductions of >50 % from the untreated influent waste water are achievable by all systems;

6) The most effective TN reducing unit was Orenco RX, with a mean effluent TN concentration of 11.4 mg/L and no sample concentrations higher than 17.4 mg/L;

7) MicroSepTec was the only system capable of multi-log pathogen reduction because of its chlorinating treatment, reducing influent wastewater from >1600 to a mean concentration of 219.5 mpn/100 ml;

8) All systems removed some total phosphorus (TP). Percent TP reductions were not very significant, ranging from 3 % (MicroSepTec) to 22 % (Orenco AX).

Recommendations Based on Treatment System Performance

The results of this study show moderate variation in the nutrient reduction between systems. Results indicated that some of the systems evaluated provided better wastewater treatment than the STNR performance standards for BOD_5 and TSS, but were not capable of meeting the STNR effluent performance standards for all parameters (30 mg/L BOD_5, 30 mg/L TSS, 10 mg/L TN, multi-log pathogen reductions). Therefore, recommendations are made for each unit based on the standards that they met for each parameter evaluated. The STNR effluent performance standards were adjusted to provide six different recommendation categories based on mean concentration values.

Significant variations about these mean values were measured over the various sampling events. This is typical of domestic wastewater from individual homes. Therefore, at any given sampling event the concentrations may be greater than these mean values.

A unit may be selected based on importance of an individual parameter performance. For instance, if total coliform were a concern for the treatment site, then MicroSepTec or an add-on chlorine tablet system would be strongly recommended. Or, if TN were a concern for the treatment site, then Orenco RX would be strongly recommended.

The six different systems are recommended based on the results from the STNR field study under the following adjusted performance standards:

1) A mean effluent water quality of <11 mg/L BOD_5, <2 mg/L TSS, <12 mg/L TN, >1600 mpn/100 ml total coliform.
   UNIT RECOMMENDED: Orenco RX

2) A mean effluent water quality of <5 mg/L BOD_5, <10 mg/L TSS, <16 mg/L TN, < 220 mpn/100 ml total coliform
   UNIT RECOMMENDED: Micro Septec or another unit with add-on disinfecting

3) A mean effluent water quality of <14 mg/L BOD_5, <6 mg/L TSS, <20 mg/L TN, >1600 mpn/100 ml total coliform.
   UNIT RECOMMENDED: Fast Regular or Orenco RX

4) A mean effluent water quality of <16 mg/L BOD_5, <9 mg/L TSS, <18 mg/L TN, > 1600 mpn/100 ml total coliform.
   UNIT RECOMMENDED: Fast Custom or Orenco RX

5) A mean effluent water quality of <28 mg/L BOD_5, <43 mg/L TSS, <17 mg/L TN, > 1600 mpn/100 ml total coliform.
   UNIT RECOMMENDED: 7H Nitro Raptor, MicroSepTec, or Orenco RX

6) A mean effluent water quality of <58 mg/L BOD_5, <29 mg/L TSS, <20 mg/ L TN, >1600 mpn/100 ml total coliform.
   UNIT RECOMMENDED: Any demonstrated unit.

The demonstration indicates Advanced Onsite sewage treatment systems provide tremendously improved wastewater treatment over standard septic systems. Advanced Onsite treatment should be included among the tools, which civilized people use to prevent pollution.

APPENDICIES

And

PHOTOGRAPHS