VIRGINIA ADVANTEX® TESTING PROGRAM

Final Report

PREPARED FOR
Orenco Systems®, Inc.

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Executive Summary

In the state of Virginia, all individual home advanced wastewater treatment devices used in conjunction with reduced dispersal areas are required to undergo an extensive field performance and evaluation program. Virginia's testing program protocol requires six test sites in each of four soil types: Groups I, II, III, and IV. This study began testing Orenco Systems®, Inc.'s AdvanTex® textile filter system using Virginia's testing program in 2002. Each system was required to undergo a series of tests over a period of 18 months from the date of system startup. At the completion of this study, 18 systems were in place and had been tested in the three major soil types (Groups II, III, and IV). No test sites had been identified in soil Group I, so no "reduced footprint" AdvanTex systems had been installed in that soil type. Certified AdvanTex maintenance providers serviced all of the treatment systems under standard maintenance contracts. Only routine service was performed on these systems. No special adjustments or special maintenance was provided as part of this testing program. The AdvanTex test protocol is delineated under Virginia Department of Health (VDH) Guidance Memorandum Policy (GMP) #114.

This report is a summary of the results of the Virginia testing program, which was completed in August 2006.

The testing program and the associated report represent the results and synthesis of over 5,000 chemical and biological analyses performed or calculated (in the case of some of the nitrogen species) over the course of a 4-year period. The following outlines the program protocol:

1. AdvanTex systems were installed at residences in the state of Virginia. The residences were selected based upon:
   - the soil type (Groups I, II, III, and IV)
   - the fact that the dispersal system would have a reduced footprint under the Virginia Department of Health regulations (% reduction allowed)
   - the homeowner's agreement to allow sampling and analyzing of the system

   The residences were not selected for any special characteristics that might cause the influent wastewater to have other than typical residential strength and flow characteristics (15 sites were new construction, 3 sites were repair situations).

2. Soil types in Virginia are grouped by texture, and there are four texture groups. Group I soils are sandy, and Group IV soils are clayey. Groups II and III range from sandy loam to clay loam.

3. All homes were under standard service contracts, and no special service or maintenance was performed other than the standard operation and maintenance performed under all service contracts. That service included cleaning the effluent screen every 12 months, checking the pumps, checking the pressure, and reading and recording the pump counter and run time display information.

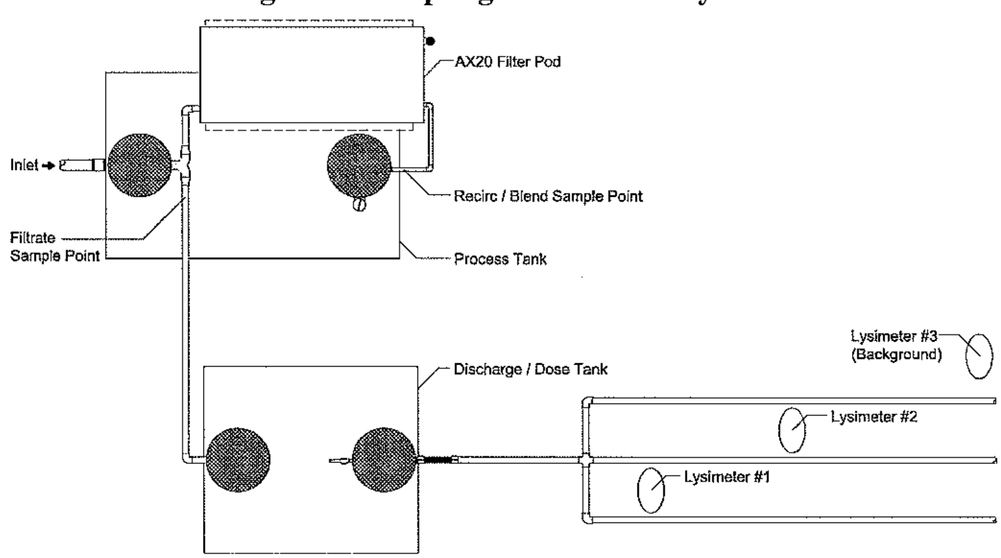
4. The purpose of the testing program is to determine if the Fecal Coliform or E. coli concentration at 12 inches below the application depth of AdvanTex effluent is less than or equal to 10 CFU/100 mL without the use of chemical or ultraviolet (UV) disinfection. Thus, all disinfection or Coliform removal other than that occurring in the AdvanTex system occurs in the soil absorption system.

5. Monthly and quarterly sampling was performed on each system. The samples were collected and analyzed by an independent laboratory approved by the State of Virginia, following proper Quality Assurance/ Quality Control (QA/QC) procedures. A schedule of analyses is shown in the table below:

Table 1: Sampling and Testing Locations and Frequencies

Analyses	Sample Point	Frequency
$CBOD_5$, TSS, Turbidity, TKN, NH_3-N, NO_3-N, TN (calculated)	Influent to AdvanTex® Filter (Recirc/Blend Tank)	Quarterly
$CBOD_5$, TSS, Turbidity, TKN, NH_3-N, NO_3-N, TN (calculated)	Final Effluent from AdvanTex Filter	Quarterly
Cl^-, E. coli, Temperature, pH	Influent to AdvanTex Filter (Recirc/Blend Tank)	Monthly
Cl^-, E. coli, Temperature, pH	Final Effluent from AdvanTex Filter	Monthly
E. coli, Cl^-	2) Lysimeters in Drainfield	Monthly
E. coli, Cl^-	Background Lysimeter	Monthly

Figure 1: Sampling Points in the System



Throughout the testing program, the AdvanTex systems produced consistently high quality effluent. The AdvanTex average and median effluent concentrations are shown in the following tables. Table 2 indicates the average concentrations in samples taken from the effluent from the AdvanTex systems, and Table 3 indicates the effluent median concentrations. Median concentrations are shown since the median values are more descriptive when multiple sites are sampled with many data points. By calculating the median values, the effects of very large values and very small values are attenuated into a more representative mass value.

Table 2: AdvanTex® Average Effluent Concentrations (All Data)

$CBOD_5$ mg/L	TSS mg/L	Turbidity NTU	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TN mg/L	CL^- mg/L	Alk mg/L	E. coli MPN/100mL
7	9	2	7	4	11	18	337	168	785.41*

* *Geometric Mean*

Table 3: AdvanTex Median Effluent Concentrations (All Data)

$CBOD_5$ mg/L	TSS mg/L	Turbidity NTU	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TN mg/L	CL^- mg/L	Alk mg/L	E. coli MPN/100mL
3	5	1	4	1	7	13	62	160	1100

Table 4: Lysimeter Sample Results

Test Point	Cl^- mg/L	E. coli MPN/100 mL
Lysimeter 1	105	1.08
Lysimeter 2	226	1.08
Lysimeter 3 (Background)	56	1.23

The values above, in Tables 2 and 3, include all data analyses of all systems, including systems that received wastewater with water softener backwash brine. During the sampling program, examination of the water quality data revealed high chloride levels in some of the systems, indicating that they might be receiving brine from water softener backwash events. There is no state-imposed prohibition against draining the water softener backwash brine into the onsite wastewater system through the house plumbing; however, Orenco Systems, Inc. imposes a restriction on the backwash brine discharge from water softeners into its advanced treatment processes (as do many other manufacturers of secondary treatment devices). Some of the systems showed excessively high concentrations of chloride (over 10,000 mg/L) in the processing tank blend as well as high concentrations in the AdvanTex filter effluent. Although the water softener backwash brine was to have been plumbed elsewhere, discussions with VDH led to a decision to leave them connected to the system until after the text period and to proceed with the testing to evaluate the long-term effects.

Over time, the AdvanTex systems receiving water softener backwash brine produced lower quality effluent than those not receiving water softener backwash brine (the most significant effect being the inhibition of the nitrification process). Comparing the average and median information in Tables 5 and 6 illustrates this observation.

Table 5: AdvanTex Average Effluent Concentrations
Water Softener Effects

Water Softener	$CBOD_5$ mg/L	TSS mg/L	Turbidity NTU	TKN-N mg/L	NH_3-N mg/L	NO_3-N mg/L	TN mg/L	CL^- mg/L	Alk mg/L	E. coli MPN/100mL
Without	4.7	6.9	1.6	5	1.8	12	15.3	57.9	160	634.7*
With	7	10	2	9	6	8	20	1207	177	1569*
% Change with Water softener Brine	49%	45%	25%	80%	233%	50%	30%	1984%	11%	147%

* *Geometric Mean*

Table 6: AdvanTex Median Effluent Concentrations
Water Softener Effects

Water Softener	$CBOD_5$ mg/L	TSS mg/L	Turbidity NTU	TKN-N mg/L	NH_3-N mg/L	NO_3-N mg/L	TN mg/L	CL^- mg/L	Alk mg/L	E. coli MPN/100mL
Without	3	5	1	3	0.4	7	12	50	157	840
With	4	8	1	4	2	6	14	1000	180	1600
% Change with Water softener Brine	33%	60%	0%	33%	400%	17%	17%	1900%	15%	90%

Introduction

The AdvanTex textile filter system has been approved in Virginia for performance in individual home wastewater treatment system applications having a reduced footprint dispersal area. In order to obtain this approval, the testing program commenced in 2002, and continued until 18 months of analyses were collected on each of 18 individual home wastewater treatment systems. All of the treatment systems were under service contracts with certified AdvanTex maintenance providers, however no special adjustments or special maintenance was provided as part of the testing program. Only the routine maintenance for all AdvanTex systems under contract with the maintenance providers was conducted during the testing program.

AdvanTex textile filters are media filter treatment units that contain a unique manufactured synthetic media. The AdvanTex systems are configured as multiple pass systems capable of sustaining greater loading rates than single-pass systems because hydraulic, biological, and chemical surges are blended and diluted with a portion of the aerobically treated filtrate in the processing tank.

The AdvanTex treatment system includes a processing tank with a screened effluent pump vault, the AdvanTex textile filter, a recirculating splitter valve (RSV), and a final dosing tank and pump to dose the soil absorption system. The system is controlled by float switches in the processing tank and the dosing tank. The control panel includes a microprocessor that coordinates the timed dosing to deliver small, frequent doses to the filter, maintaining unsaturated, aerobic conditions for treatment. The process tank provides significant treatment by storing, separating and treating the gross solids and fats, oils, and grease. The continual recirculation and intermittent dosing to the media ensures a moist environment and stable diet for the biota. The critical factors in controlling the environment for the biota are the recirculation ratio and time-controlled dosing. In the control panel, pump dose counts and pump run times are recorded and logged for both the recirculation and final-dispersal dosing pump. Each AdvanTex treatment system is followed by a soil absorption system that is sized based upon the hydraulic loading rate appropriate for the particular soil and site conditions.

Some of the treatment systems operate by returning the recirculated effluent to the primary compartment of the processing tank (Mode 3 — primarily for additional nitrogen reduction) and some of the systems operate by returning the recirculated effluent to the second compartment of the processing tank (Mode 1). Four of these systems were Mode 1 and the other 14 were Mode 3. Figures 2 through 5 illustrate the Mode 1 and Mode 3 system arrangements.

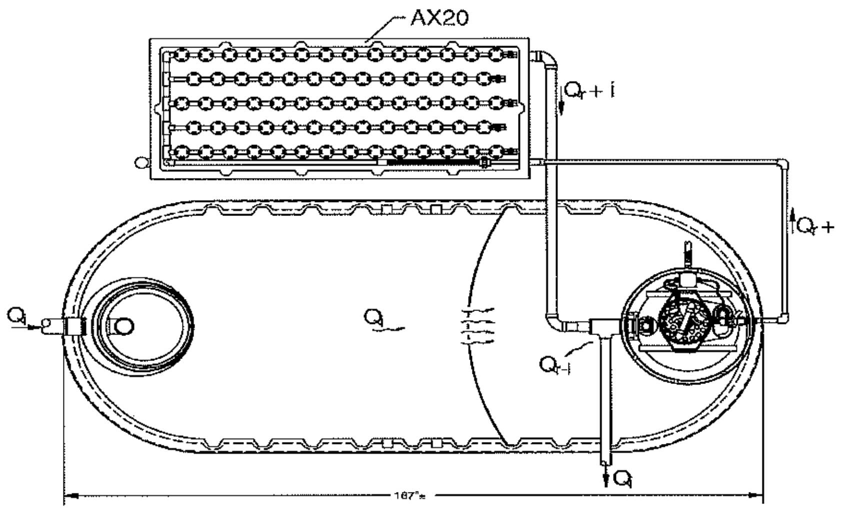


Figure 2: AdvanTex® Mode 1 – Plan View

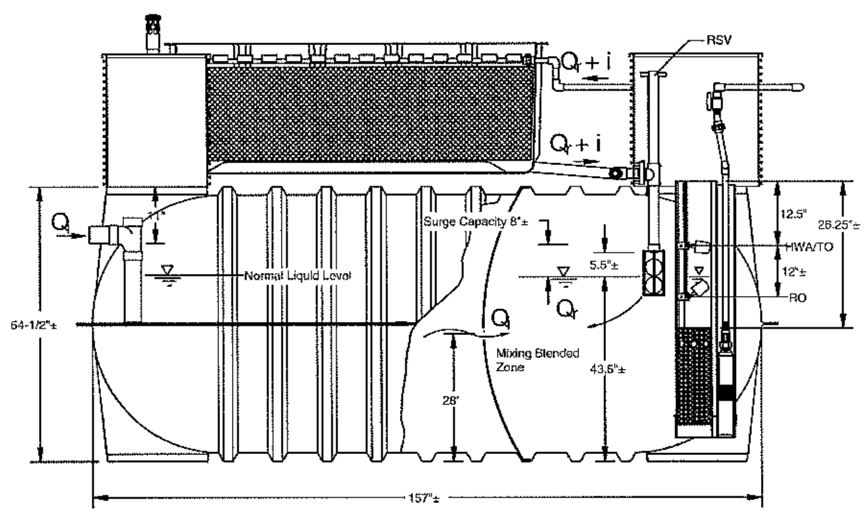


Figure 3: AdvanTex Mode 1 – Profile View

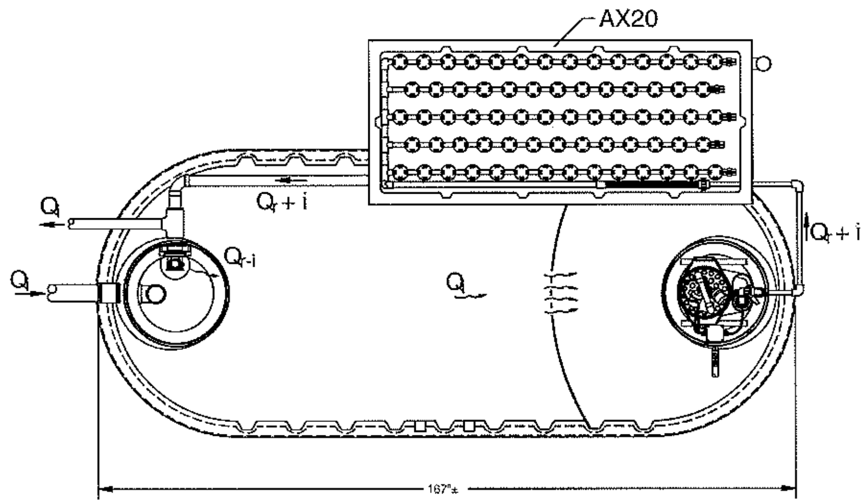


Figure 4: AdvanTex Mode 3 – Plan View

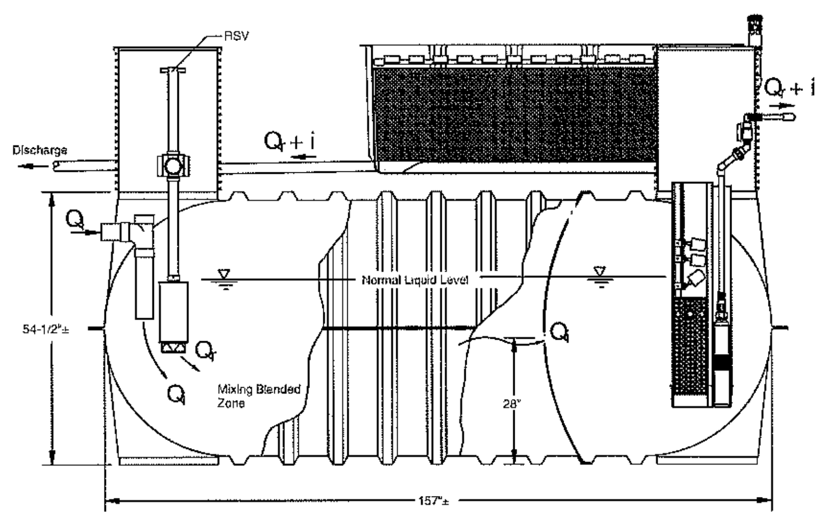


Figure 5: AdvanTex Mode 3 – Profile View

The soil absorption systems in this testing program were installed in Virginia Group II, Group III, and Group IV soils. No Group I soils have been identified. Because Group I soils are sandy and percolate quickly, it is unlikely that a reduced footprint dispersal area will be used with the AdvanTex system. Under the Virginia Guidance Memorandum Polices (GMP's) little benefit with respect to sizing the soil dispersal system is gained from using advanced secondary treatment and reduced footprint drainfields in Group I soils. To date, no AdvanTex treatment systems with reduced drainfields have been constructed in Virginia Group I soil.

This report is a summary of the results of the testing program as of its completion in August 2006.

Objectives

The primary objective of this testing program was to provide sufficient field performance information relative to Fecal Coliform removal — over an 18-month period — to the Virginia Department of Health (VDH), Division of Onsite Sewage and Water Services to give general approval of the AdvanTex wastewater treatment system for use in reduced footprint drainfield applications. Although the AdvanTex system has successfully completed NSF/ANSI Standard 40 testing and is an NSF certified advanced treatment system, the testing performed in this testing program was required by the VDH. The scope of this testing program however, is well beyond the minimum requirements set by VDH for the approval process. Orenco Systems, Inc. committed to collecting substantially more data than the minimum in order to present a more thorough and detailed picture of field performance capabilities of the AdvanTex system.

The VDH, under the provisional approval testing program, allowed installation of the AdvanTex treatment systems followed by soil absorptions systems having areas smaller than soil absorption systems that follow septic tanks with no advanced treatment. This approval was granted under the Guidance Memorandum and Policy (GMP) #114 "AdvanTex Treatment System Provisional Approval and Testing Protocol" of September 27, 2001. Under this GMP, two suction lysimeters were installed in the absorption area footprint 12 inches below the application depth of the treated wastewater, and one suction lysimeter was installed in a background location. Six systems in each of the soil groups were sampled for 18 months. The analyses required under the GMP are shown in Table 7.

Table 7: Original Analyses Required Under GMP #114

Analyses	Sample Point	Frequency
$CBOD_5$	Processing Tank, Filter Effluent	Monthly for the first year Quarterly for the following 6 months
Fecal Coliform (FC)	Processing Tank, Filter Effluent, Soil Absorption System Lysimeters, Background Lysimeter	Not Specified
Chloride	Soil Absorption System Lysimeters, Background Lysimeters	Not Specified

Virginia's standard GMP #114 protocol focuses primarily on the Fecal Coliform count in lysimeters located in the soil absorption areas. The GMP limits the geometric mean to less than 10 CFU/100 mL, with no single sample in excess of 200 CFU/100 mL. Following discussions with laboratories and with the VDH, the analytical requirements were adjusted slightly to include $CBOD_5$ and E. coli in lieu of BOD_5 and Fecal Coliform.

The $CBOD_5$ analysis was chosen because it gives a representation of the biochemical oxygen demand exerted by the carbon only, rather than the BOD_5 analysis which can include the nitrogenous biochemical oxygen demand as well as carbonaceous. As part of Orenco's commitment to the value of science and data, we requested additional analyses to include all of the nitrogen species; the $CBOD_5$ analysis combined with the nitrogen analyses better characterizes the wastewater. Turbidity was also included in the testing to back up and substantiate TSS and $CBOD_5$ results, and to establish a relative turbidity correlation for future field monitoring and troubleshooting. Alkalinity, nitrogen, and influent chlorides were also analyzed to further characterize the wastewater stream and to provide performance/troubleshooting support data.

The Fecal Coliform analysis includes mostly E. coli but could include other bacteria. Tests at the University of Arkansas and discussions with Professor Duane Wolf, a soil microbiologist, led us to conclude that the Fecal Coliform analysis and the E. coli analysis give the same results (MPN/100 mL) when septic tank effluent and soil solution is analyzed. The Fecal Coliform analysis is a complicated process of culturing plates of bacteria then fermenting and counting the test tubes (multiple tube fermentation) that produce gas, then using a look-up table to determine the most probable number (MPN) of Fecal Coliform. The E. coli analysis, using IDEXX, Inc. methods and materials, is now an EPA-approved method for analyzing using multiple-well polystyrene plates with overnight incubation. The method uses a staining technique that allows examination under ultraviolet light to determine the MPN/100 mL. Since the results are essentially the same and the price is approximately half that of the multiple tube fermentation method for Fecal Coliform, the E. coli analysis was chosen as the preferred analysis.

Along with these analyses, Orenco Systems, Inc. also included an increased sampling and analysis program that provides more information than the minimum requirements and additionally provides information to Orenco to evaluate the performance of the treatment systems.

Testing Program and Schedule

Site Selection

Sites were chosen based upon soil group and availability of installations. The VDH soil grouping structure is based solely upon textural classification. Soil structure, slope, redoximorphic features, or other characteristics do not enter into the group designation. Six AdvanTex systems have been installed in each of soil Groups II, III, and IV. The sites are located as far east as Gloucester Point, in Gloucester County to as far west as Greenville in Augusta County.

Table 8 lists the sites, locations, and the modes of operation.

Each homeowner was contacted and interviewed in person by Dr. Mark Gross and the Orenco Systems, Inc. Virginia AdvanTex dealer, Pete Kesecker of Commonwealth Onsite Solutions, to discuss the testing program. During site visits, contact was re-established with each available homeowner. Care was taken not to enter the property without making an effort to contact the homeowner.

Table 8: Sites Selected for AdvanTex® Testing

Site Address	Site #	Soil Group	County	Type of Soil Absorption System	AdvanTex Configuration
13 Palmer Street Greenville, VA	1	IV	Augusta	Infiltrator Trenches	Mode 3
46 Cedar Creek Lane Mount Sydney, VA	2	IV	Augusta	Infiltrator Trenches	Mode 3
707 Point Drive Bumpass, VA	3	IV	Louisa	Drip Irrigation	Mode 3
1822 Angus Road Gloucester Point, VA	4	II	Gloucester	Pads	Mode 1
2280 Genito W. Court Mosely, VA	5	II	Powhatan	Pads	Mode 3
2284 Genito W. Court Mosely, VA	6	II	Powhatan	Trenches	Mode 1
2675 Lam-Conley Lane Elkton, VA	7	IV	Rockingham	Drip Irrigation	Mode 3
3815 Summit Crossing Rd Fredericksburg, VA	8	IV	Spotsylvania	Trenches	Mode 3
4581 Waterside Drive Lanexa, VA	9	II	New Kent	Pads	Mode 3
5716 Buck Hunt Lane New Kent, VA	10	III	New Kent	Pads	Mode 3
5739 Buck Hunt Lane New Kent, VA	11	III	New Kent	Drip	Mode 3
5812 Buck Hunt Lane New Kent, VA	12	III	New Kent	Pads	Mode 3
5833 Buck Hunt Lane New Kent, VA	13	III	New Kent	Pads	Mode 3
6209 Lakeside Drive	14	II	New Kent	Pads	Mode 3
9008 Cuba Lane Gloucester Point, VA	15	II	Gloucester	Pads	Mode 1
9451 Deer Lake Drive Quinton, VA	16	III	New Kent	Drip Irrigation	Mode 3
9592 Big Buck Court New Kent, VA	17	III	New Kent	Pads	Mode 1
11515 McFaden Drive Spotsylvania, VA	18	IV	Spotsylvania	Drip Irrigation	Mode 3

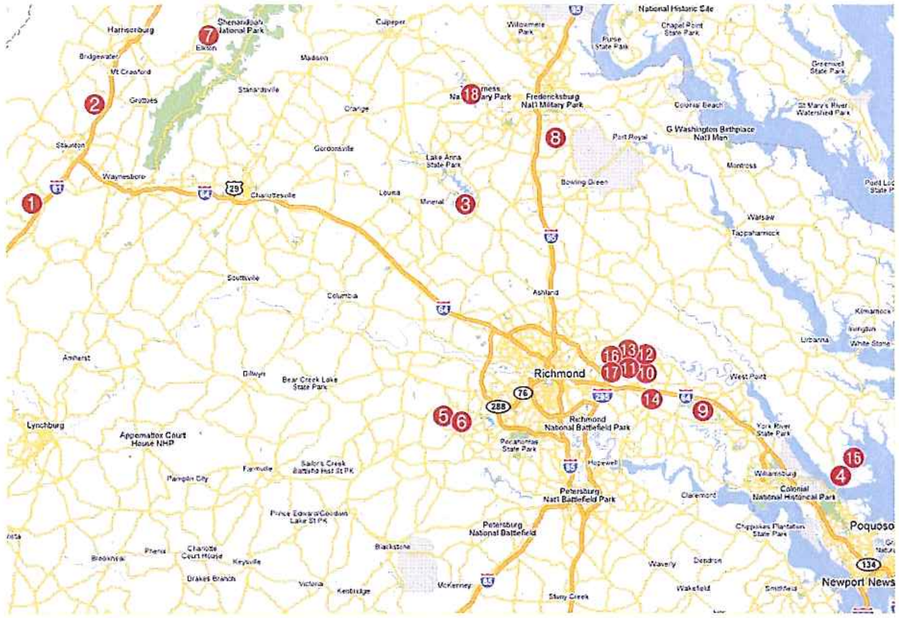


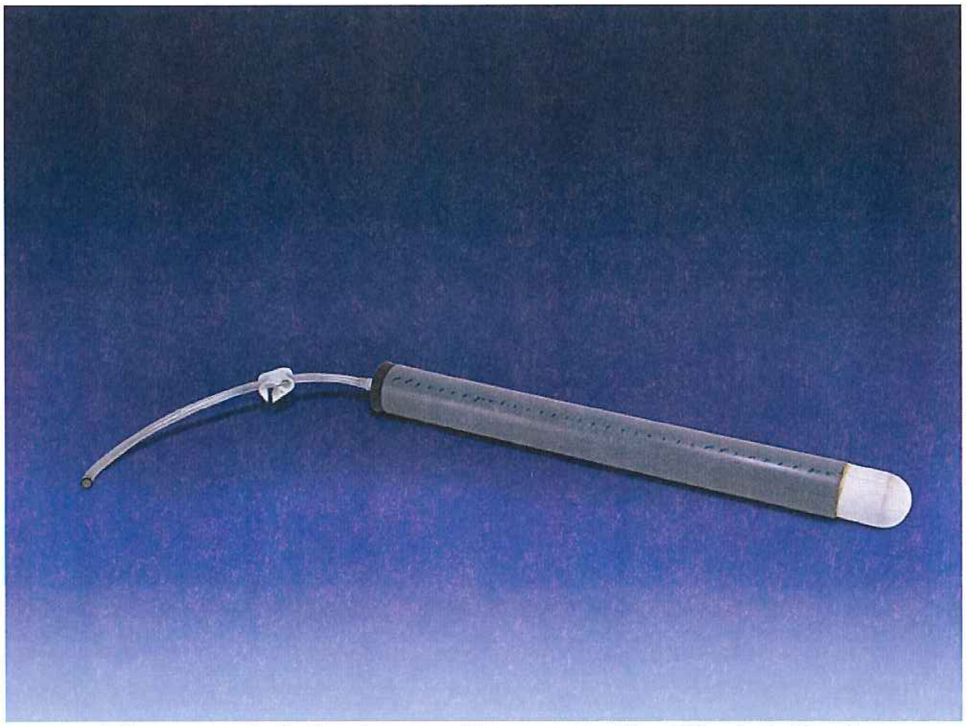
Figure 6: Virginia Map Showing Location of Sites

Photograph 1: Typical AdvanTex® Installation

Lysimeter Selection

Suction lysimeters have a reputation for being a poor method of sample collection for Fecal Coliform analysis in unsaturated soil water samples. Several lysimeter designs were investigated prior to installing any lysimeters for this testing program. Pan lysimeters, stainless steel screen tip lysimeters, and ceramic cup tip lysimeters were investigated through discussions with other researchers, regulators, and lysimeter manufacturers. Because most of the sampling, analysis, and research in the onsite wastewater system area in Virginia had been conducted by Dr. Ray Reneau and Dr. Charles Hagedorn and their team at Virginia Tech, they were contacted for advice for conducting this testing program and for lysimeter selection. Dr. Mark Gross traveled to Blacksburg to meet with Dr. Hagedorn and Mike Saluta, the field research technician who installed the lysimeters for Drs. Hagedorn and Reneau. Several times during the day, Dr. Hagedorn was asked about using lysimeters for Fecal Coliform sampling, and he confirmed that he has used them, and that he has compared lysimeter sample results to monitoring well results for Fecal Coliform analyses. His repeated confirmation was that the results are similar and that his team continues to use 1.0 bar suction lysimeters for Fecal Coliform sampling in Virginia. We were instructed in lysimeter installation procedures used by Virginia Tech researchers, so that all lysimeters were installed using Virginia's preferred methods, equipment, and materials.

The original lysimeters installed for this testing program were made by the Virginia Tech team, and consisted of vacuum pipe with the 1.0 bar Soilmoisture Equipment Company ceramic cup attached to the pipe with epoxy. The top of the pipe was closed with a rubber stopper with tubing penetrations. Some difficulty was experienced with this lysimeter construction due to unauthorized removal of the rubber stopper with subsequent contamination of the lysimeter tube with soil. When the first samples were collected, soil was found inside one of the lysimeter tubes, and the sample was considered invalid. All of the Virginia Tech lysimeters were removed from the testing program sites and replaced with factory-constructed and sealed lysimeters from Soilmoisture Equipment Company. All lysimeters in the testing program are now model 1920F1L24 B1.0 M2. This is a 24 –inch long sealed lysimeter with a 1.0 bar ceramic cup. Dr. Ray Reneau and Dr. Chuck Hagedorn use this same ceramic cup at Virginia Tech. The lysimeter body is sealed to prevent contamination, and the samples are collected using polyethylene tubes connected to the lysimeter by compression fittings. Photograph 2 shows the Virginia Tech lysimeter.


Photograph 2: Lysimeter Constructed by Virginia Tech

Lysimeter Installation
Two lysimeters were installed in the footprint area of each dispersal system. One lysimeter was installed in a background area of each site. The background area was typically chosen by finding a location outside of the lawn and upslope of the drainfield, if possible.

The lysimeters were installed using the following procedure:
1. Determine depth to the bottom of the soil absorption bed with a probing tool
2. Assemble the lysimeter tubing, connections, and tubing clamping rings
3. Auger a hole to 12" below the bottom of the infiltrative surface of the soil absorption bed using a 2 1/2 inch diameter auger
4. Prepare silica slurry using about 2 cups of silica flour. The slurry should be made sufficiently pourable so it flows easily into the auger hole
5. Pour the silica slurry into the bottom of the auger hole
6. Quickly set the lysimeter, pushing it into the silica slurry until it is completely embedded
7. Place some soil (about 2" or so) from the bottom of the auger hole onto the silica flour slurry (to keep the bentonite/sand mix from mixing with the silica slurry)
8. Fill the annular space with a bentonite/sand mixture
9. Dig around the top of the installation to make an excavation for the valve box
10. Place the valve box flush or nearly flush with the final grade, and finish grading to clean up around the valve box

11. Using a measuring tape, triangulate the valve boxes so that they may be located in the future in case landscaping or other activities cover them (typically, the measurements are taken from house corners or fence corners)
12. Record the address of the home, locations of the valve boxes, the depth of the installation, and the date of the installation
13. Photograph the site and the completed lysimeter installation

Photographs 3 and 4 show a completed lysimeter installation.

Photograph 3: Completed Lysimeter Installation with Sampling Tubes Exposed

Photograph 4: Completed Lysimeter Installation with Sampling Tubes Enclosed in Valve Box

Laboratory Selection

Because of the distance between the sampling sites, and the holding times required for E. coli analyses, two laboratories were chosen to perform the analyses. For all of the sites in the eastern part of the state, Universal Laboratories in Hampton, VA was chosen to collect and analyze the samples from those systems. For all of the sites in the western side of the state (the sites in the Shenandoah Valley), Inboden Environmental Laboratory in Mount Jackson, VA collected and analyzed samples until a new laboratory, Envirocompliance, was selected to perform the analyses.

Dr. Mark Gross and Pete Kesecker met with laboratory field personnel, and instructed them in sample collection techniques. Specifically, field personnel were shown how to collect samples from the lysimeters and where and how to collect samples from the filter effluent and from the processing tank. Particular attention was paid to preventing contamination of the sample containers when collecting lysimeter samples, and also preventing the inadvertent collection of solids or slime from sidewalls of pipes when collecting filter effluent samples and processing tank samples.

Sampling and Analysis Schedule

All samples were collected by the contract laboratory personnel, and were preserved according to EPA and Standard Methods protocol, and holding times were strictly observed. The samples were taken from the processing tank (recirculation tank), the AdvanTex filter effluent, and from each of the three lysimeters at each site. Table 9 shows the sample analyses, locations, and frequency for the testing program.

Table 9: Sampling Details

Analyses	Sample Point	Frequency
$CBOD_5$, TSS, Turbidity, TKN, NH_3-N, NO_3-N, TN	Influent to AdvanTex Filter (Recirc/Blend Tank)	Quarterly
$CBOD_5$, TSS, Turbidity, TKN, NH_3-N, NO_3-N, TN	Final Effluent from AdvanTex Filter	Quarterly
Cl^-, E. coli, Temperature, pH	Influent to AdvanTex Filter (Recirc/Blend Tank)	Monthly
Cl^-, E. coli, Temperature, pH	Final Effluent from AdvanTex Filter	Monthly
E. coli, Cl^-	(2) Lysimeters in Drainfield	Monthly
E. coli, Cl^-	Background Lysimeter	Monthly

Results

Performance Data

Typical screened septic tank effluent characteristics are shown in Table 10. Eighteen systems yielded samples with analytical results.

Table 10: Typical Screened Residential Septic Tank Wastewater Strengths*	Average	Weekly Peak	Rarely Exceed
BOD_5, mg/L	150	200	300
TSS, mg/L	40	60	150
TKN–n, mg/L	65	75	150
NH_3-N, mg/L	55	65	125
G&O, mg/L	20	25	25
Fecal Coliform, MPN/100 mL	10^6	10^7	10^8

**Based on 500 gpd flows*

Comparing these values to typical residential-strength wastewater as shown in Table 11 indicates that some treatment is expected in the septic tank.

Table 11: Typical Untreated Residential Wastewater Strengths*	Range	Typical
BOD_5, mg/L	110-400	210
TSS, mg/L	100-350	210
NH_3-N, mg/L	12-50	22
Grease and Oil, mg/L	50-150	90
Fecal Coliform, MPN/100 mL	10^3 - 10^7	10^4 - 10^5

From Crites and Tchobanolgous, *Small and Decentralized Wastewater Management Systems,* McGraw- Hill, 1998, based on 120 gpcd flow

Table 12 shows the averages of the sample results for all of the processing (recirculation) tanks and the AdvanTex filter system effluent samples. This data includes all analytical results from startup as well as results from several systems that had water softeners. In addition, there are data values included in this table that are obvious outliers. Table 13 provides the median values of the concentrations of the samples in the blend and in the filter effluent.

Table 12: Processing Tank Blend and Filter Effluent Water Quality – Averages
All Sample Analyses – Blend and Effluent

	$CBOD_5$ mg/L	TSS mg/L	Turbidity NTU	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TN mg/L	Temp °C	Cl^- mg/L	Alkalinity mg/L As $CaCO_3$	E. coli MPN/100 mL
Processing Tank	29	39	8	15	8	10	25	18	347	214	5758*
AdvanTex Filter Effluent	10	12	3	9	6	11	20	19	330	185	833*

** Geometric mean*

Table 13: Processing Tank Blend and Filter Effluent Water Quality – Medians
All Sample Analyses – Blend and Effluent

	$CBOD_5$ mg/L	TSS mg/L	Turbidity NTU	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TN mg/L	Temp °C	Cl^- mg/L	Alkalinity mg/L As $CaCO_3$	E. coli MPN/100 mL
Processing Tank	17	19	3	8	4	6	17	17	59	194	5900
AdvanTex Filter Effluent	4	6	1	4	1	7	14	17	60	162	1223

As noted in "Variability and Reliability of Test Center and Field Data: Definition of Proven Technology from a Regulatory Viewpoint," the median is a more descriptive statistic than the mean when data is taken from multiple sites over a long period of testing. For this reason, the median values are provided for all the data and for each analysis of each of the data subsets of this report. The mean values are also provided as a comparison to indicate the differences in describing the data.

The influent to the AdvanTex filter was taken from the processing tank. The liquid in the processing tank is a blend of the treated water recirculated from the filter and the raw sewage coming from the home. The effluent strength of the processing tank blend is lower than the strength of raw sewage because the raw sewage in the tank has been diluted by treated effluent from the AdvanTex filter. The dilution is a function of the recirculation ratio. Appendix B provides illustrations and equations for relating the recirculation ratio and the blend concentrations to the influent strength.

As shown in Table 13, the processing tanks showed median $CBOD_5$ effluent values of 17 mg/L. The median TSS concentration was 19 mg/L. Median Turbidity was 3 NTUs. Median Total Kjehldahl Nitrogen (TKN) was 8 mg/L. Median Ammonia as Nitrogen (NH_3-N) was 4 mg/L. Median Nitrate as Nitrogen (NO_3-N) was 6 mg/L and the median

Total Nitrogen (TN) was 17 mg/L. The median value of the chloride concentrations (CL^-) was 59 mg/L. Median alkalinity concentration in the processing tank blend was 194 mg/L as Calcium Carbonate ($CaCO_3$). The median value of the E. coli bacteria titer in the processing tanks was 5900 MPN/100 mL.

Even with the startup values and the results from systems with water softeners included, the median $CBOD_5$ in the AdvanTex effluent from all systems was 4 mg/L. The median TSS was 6 mg/L, and median turbidity was 1 NTU. The TKN concentration in the AdvanTex effluent had a median value of 4 mg/L. NH_3-N median concentration was 1 mg/L and the median TN was 14 mg/L. The median alkalinity was 162 mg/L as $CaCO_3$. The median Fecal Coliform concentration was 1223 MPN/100 mL.

Over 5,000 analyses were performed or calculated (in the case of some nitrogen species) in this field test.

The maximum $CBOD_5$ observed in the AdvanTex effluent was 79 mg/L and this was a startup concentration at one of the sites having water softener backwash brine discharging to the system. The minimum was less than 2 mg/L (below the detection limit). The maximum TSS observed in the AdvanTex effluent was 60 mg/L, and the minimum was less than 1 mg/L (below the detection limit). The maximum turbidity observed was 26.5 NTU and the minimum was 0.05 NTU. All of these values are summarized in Table 14. For the sake of comparison, Table 12 indicates the mean values for all of these parameters. The high TSS and $CBOD_5$ were observed in systems with water softener backwash brine discharging into the wastewater treatment system and one system also received wastewater resulting from baths using large quantities of bath oils. This particular system was investigated in detail and the water softener backwash brine was removed from the waste stream, and the homeowners were counseled regarding introducing bath oils into the system. Thereafter, the AdvanTex unit began to perform quite well, producing effluent quality consistent with the other systems being analyzed. However, because the water softener backwash brine was removed from the wastewater stream, and homeowner counseling regarding bath oils was provided simultaneously, no clear conclusion can be drawn to which factor might have contributed greatest to causing the degradation in performance. However, the fact that some actions were taken and the treatment system performance subsequently improved illustrates the importance of system observation and homeowner counseling in the long-term maintenance program of the AdvanTex system. Table 14 shows the values of the minimum, maximum, mean, and median values of the water quality parameters observed in the AdvanTex effluent using all systems including those with water softeners.

Table 14: Minimum, Maximum, Mean, and Median Values
AdvanTex Effluent – All Systems, All Data including Startup, Water Softeners, and Outliers

	Min	Max	Mean	Median	Standard Deviation (All Systems)	Standard Deviation (Excluding Systems with Water Softeners)
$CBOD_5$, mg/L	<2	90	10	4	16	5
TSS, mg/L	1	192	12	6	21	7
Turbidity, NTU	0.05	50	3	1	7	2
TKN, mg/L	0.1	105	9	4	15	5
NH_3-N, mg/L	0.1	64.9	6	1	11	3
NO_3-N, mg/L	0.2	69.9	11	7	12	11
TN, mg/L	0.2	116	20	14	19	11
Cl^-, mg/L	10	4400	330	60	692	31
Alkalinity, mg/L	11	2000	185	162	182	74
E. coli MPN/100 mL*	<1	160,000	833	1223	19064	12512

**Geometric mean*

Analysis of The Data and Removal of Outliers

In evaluating outliers, several factors were considered. The data set for each system was carefully examined and the analytical values were compared from date to date and from analyte to analyte. For example, at 2280 Genito West Court, on 10/2/03, the NH_3-N value is reported as 31.2 mg/L in the AdvanTex effluent. Also on 6/24/04, the NH_3-N concentration is reported as 26 mg/L. Comparing these values to the other values for ammonia nitrogen for the same system's quarterly sampling events shows that a value of 31.2 mg/L is an order of magnitude higher than the other quarterly sample concentrations, which range from 0.3 mg/L to 6.8 mg/L. In addition, when the value for ammonium-nitrogen for the October 2003 sample is compared to the turbidity (0.88 NTU) and to the $CBOD_5$ (less than 2 mg/L), it is inconsistent with those values. In addition, the ammonium-nitrogen in the blend to the AdvanTex unit is lower than the effluent from the filter. This is quite unlikely and using this approach, the NH_3-N value for the AdvanTex effluent sample for 2280 Genito West Court on 10/2/03 can be determined to be an outlier, and can be excluded from the data set. With this simple method of comparing the analytical values to the samples taken before and after, as well as comparing each analyte to the others for that particular sample, a common sense approach to determining outliers was developed. In addition to evaluating sample deviation from their mean values, the method of comparing the analytical values to the samples taken immediately before and after, as well as comparing each analyte to the others for that particular sample set, provides a strong common sense approach to identify outliers.

Using this method, the data set was carefully examined and outliers were extracted from the averages and subsequent analysis. Not only were high values removed, but inconsistently low values were also removed as outliers. The purpose of this procedure is to perform a data analysis that more nearly represents normal average performance levels occurring within the systems without the indiscriminate effects of unexplainable deviations from the norm. In many cases, bad data (high or low) is worse than no data at all. When performing statistical analyses on extremely large data sets, it may be possible to eliminate outliers using statistical analysis methods (such as interquartile statistics practices by NSF). With this data set, however, the analyses were quarterly analyses over an 18-month period for each system, and as discussed below, each system had its individual performance that was affected by factors other than sampling or laboratory analyses.

Water Softener Backwash Effects

As mentioned earlier, 18 AdvanTex treatment systems had been intensively sampled, analyzed, and investigated for a period of four years. Of these 18 systems, five systems have water softeners discharging into the wastewater system. In some cases, the analytical results have shown poorer quality effluent from treatment systems where the brine is backwashed into the processing tank. Figure 7 graphically illustrates $CBOD_5$ and TSS differences in the mean concentrations between the systems with water softeners backwash brine and the systems without.

The water softener backwash brine laden effluent is easily identified by high chloride concentrations – in one case, as high as 10,900 mg/L. Even in this case, the $CBOD_5$ concentration in the AdvanTex effluent ranged from below detection limits to 6 mg/L for nearly a year, after which the $CBOD_5$ in the effluent increased to as high as 60 mg/L. In some cases, the second year of treatment produced a poorer effluent quality than the first year in the systems having water softeners. Another noticeable effect of the water softener backwash brine can be seen in Table 14. The systems receiving water softener backwash brine have a higher standard deviation in the AdvanTex effluent – that is, reduced performance of the AdvanTex systems.

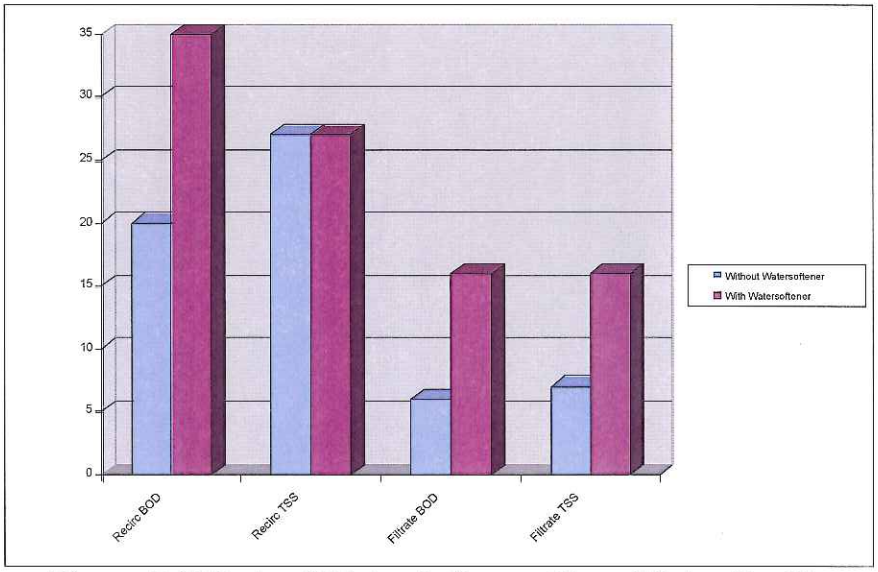


Figure 7: Effects of Water Softeners Upon Water Quality

Figure 8 illustrates the change (degradation) in the effluent $CBOD_5$ over time of a particular system that received water softener backwash brine. This particular system had a mean chloride concentration of 2,280 mg/L in the processing tank and a mean chloride concentration of 2,009 mg/L in the AdvanTex effluent. The chloride concentrations for this system are shown in Figure 9. The highest chloride concentration observed in this system was 10,900 mg/L in the AdvanTex effluent. The inference from this data is that the sample was most likely taken shortly after a backwash cycle from regenerating the water softener. As shown in Figure 8, the system performed reasonably well during the first year of operation, and then its performance began to deteriorate. During the first nine months of operation, the system produced $CBOD_5$ less than 5 mg/L, and then over the next nine months, the effluent quality worsened, with the last sample showing a $CBOD_5$ of 60 mg/L. This $CBOD_5$ concentration is quite uncharacteristic of the AdvanTex Treatment System. In addition, examination of the grab sample data shows that the chloride concentration in the process tank is generally (except for one sampling event) less than or equal to the chloride concentration in the AdvanTex effluent. This leads to suspicion that the salt from the briny backwash may be reconcentrating or recrystallizing on the media filter or biomass under aerobic conditions, and causing a deterioration of the treated effluent quality and a higher concentration in the media filter effluent than in the process tank (influent to the media filter). Reference to the EPA Public Owned Treatment Works identifies that chloride levels of 180 mg/L are toxic to nitrogenous microbes.

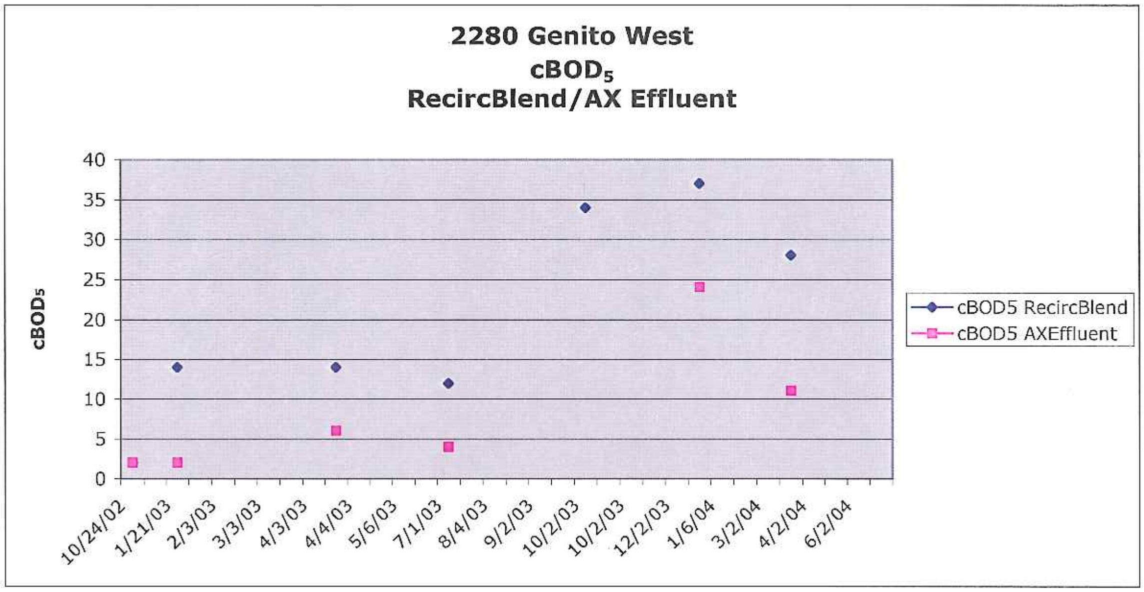


Figure 8: Degradation in Effluent $CBOD_5$ at 2280 Genito West

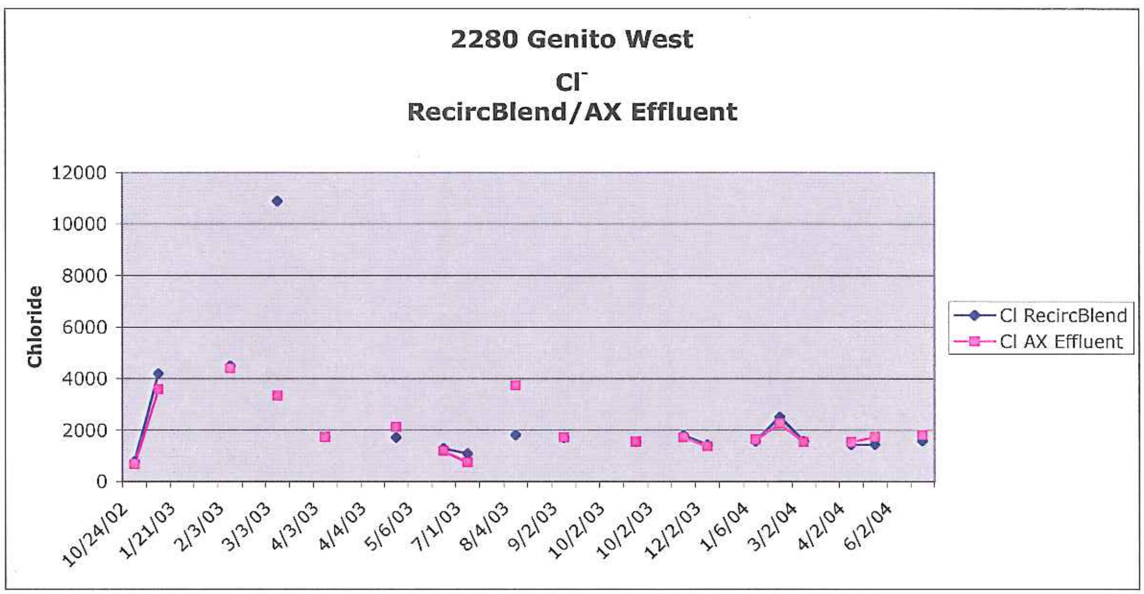


Figure 9: Chloride Concentrations at 2280 Genito West

Figure 10 also illustrates the deterioration of effluent quality over time for the AdvanTex system at 9008 Cuba Lane. Again the system produced an effluent $CBOD_5$ well below 5 mg/L for nearly 18 months, then the final analysis showed a $CBOD_5$ concentration of 50 mg/L – a value inconsistent with previous performance and inconsistent with all of the systems without water softener backwash as part of the waste stream. The chloride concentration in the process tank and the AdvanTex effluent was 774 mg/L and 837 mg/L, respectively. The maximum values were 2,650 mg/L in the process tank and 4,250 mg/L in the AdvanTex effluent, respectively. Again, this reinforces the inference that the water softener backwash affects the treatment process over time – possibly a year or more. The higher concentration in the AdvanTex effluent (higher than the process tank) supports the theory that the salt from the water softener regeneration accumulates on or in the treatment media over time.

Figure 11 shows the chloride concentrations over time for the 9008 Cuba Lane system.

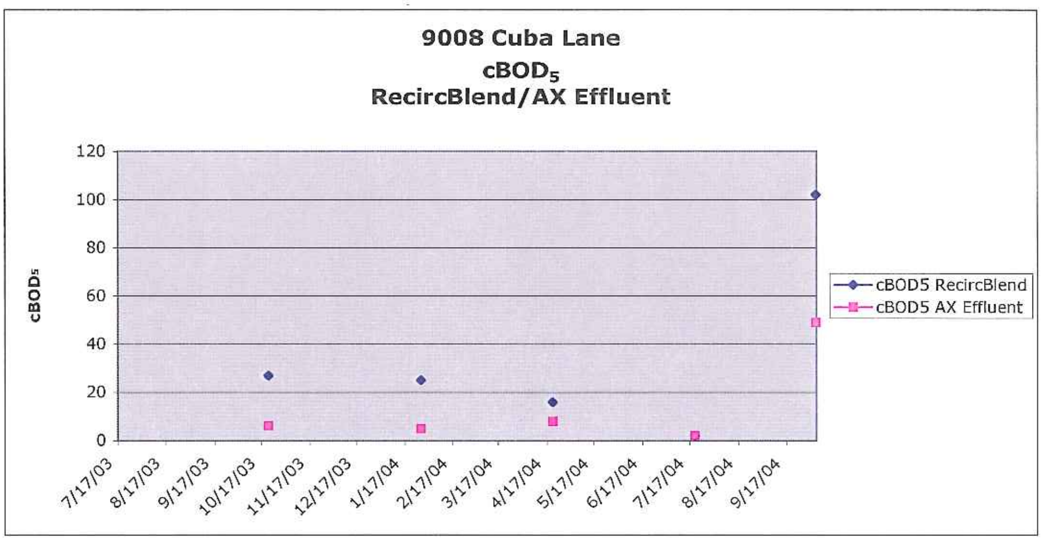


Figure 10: Degradation in Effluent $CBOD_5$ at 9008 Cuba Lane

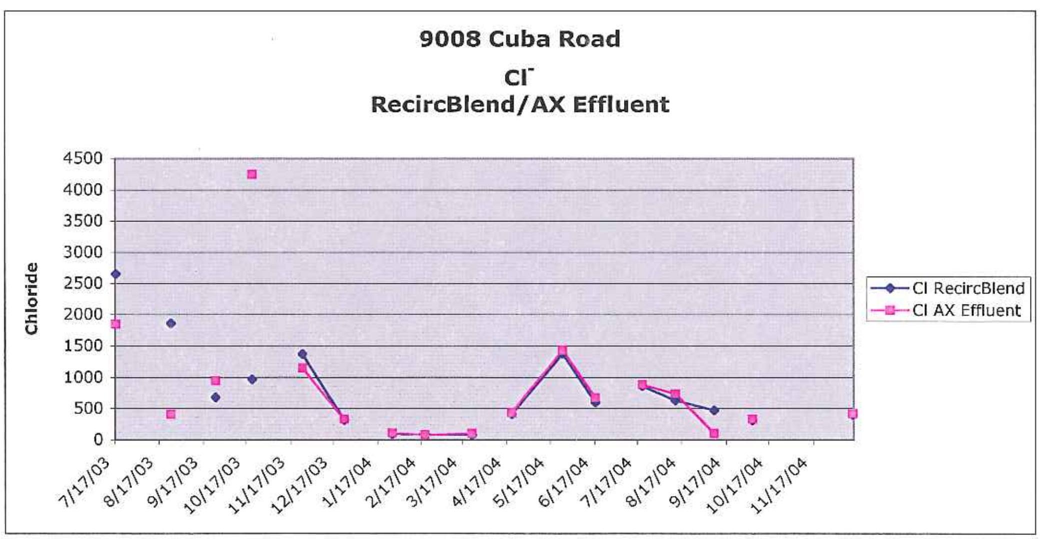


Figure 11: Chloride Concentrations at 9008 Cuba Lane

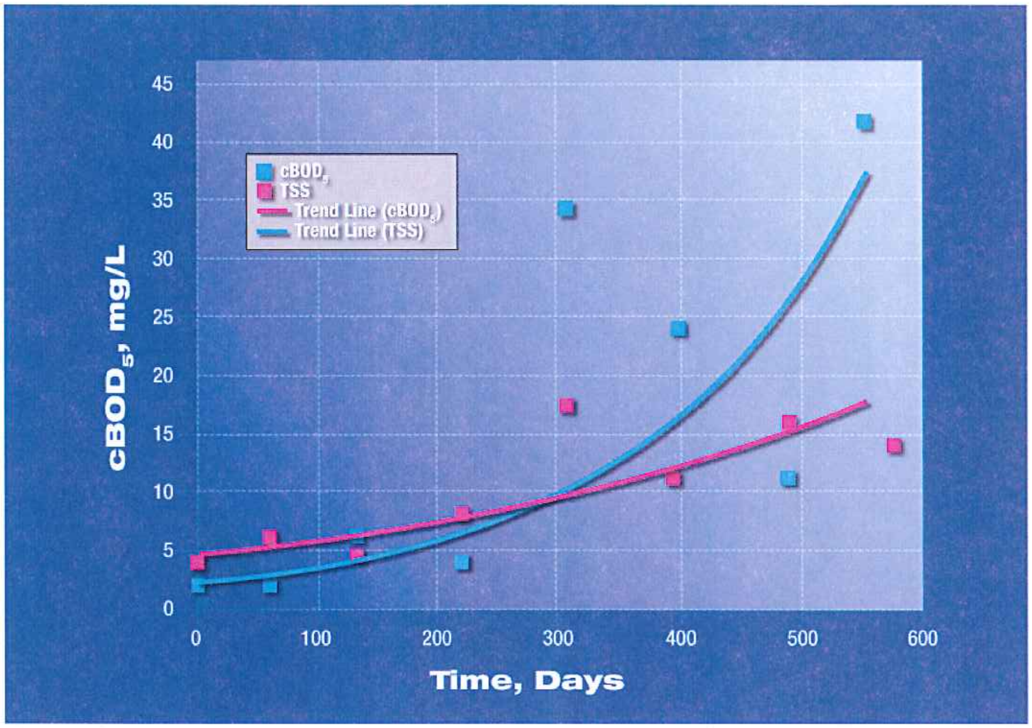


Figure 12: $CBOD_5$ Performance Trend with Water Softener Backwash Brine at 9008 Cuba Lane

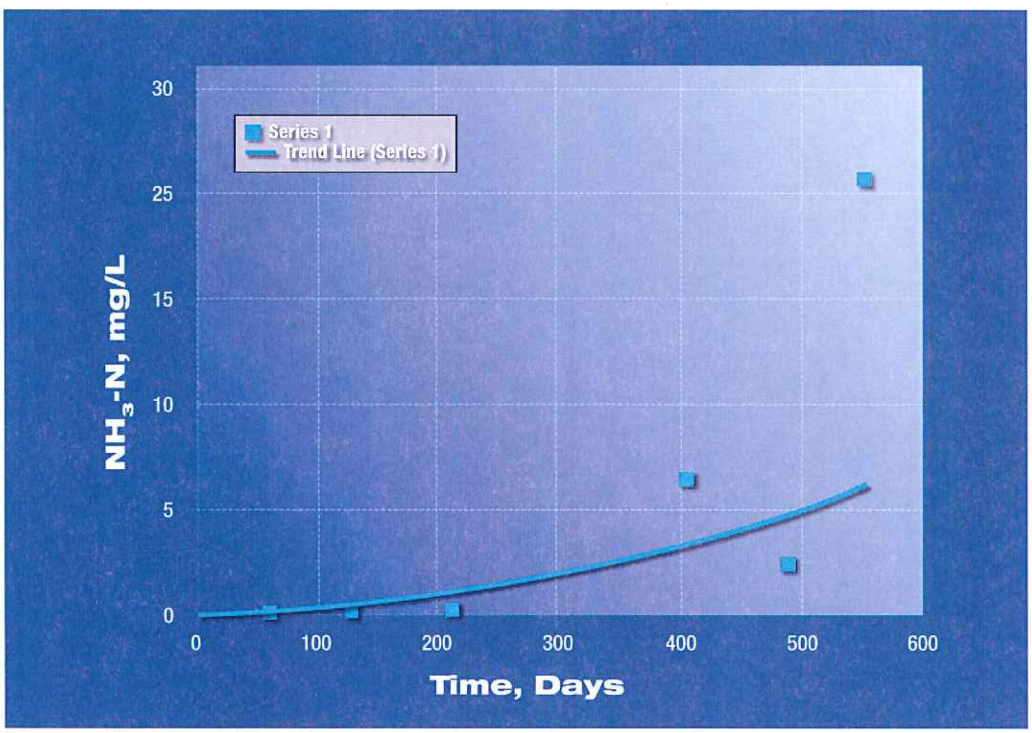


Figure 13: NH_3-N Performance Trend with Water Softener Backwash Brine at 9008 Cuba Lane

Figure 12 illustrates a trend line showing the effects of water softener backwash-brine over time. The $CBOD_5$ in the AdvanTex effluent increased steadily over time, and after over 500 days of operation, the $CBOD_5$ concentration was over 30 mg/L. This concentration is abnormally high for the AdvanTex effluent and indicates an improperly performing system.

Figure 13 is a trend line of the ammonia-nitrogen over time and it indicates that the nitrification deteriorated over time in a trend consistent with the $CBOD_5$ removal by the system.

These graphs indicate that wastewater treatment system performance, relative to the effects of water softener backwash brine, should be evaluated over a relatively long period of time – one to two years – rather than simply a six-month test period, if the evaluation is to be meaningful.

The phenomenon of treatment deterioration over time due to water softener backwash brine was not consistent in all cases, however. Two other systems, 2284 Genito West Court and 1822 Angus Drive also had water softener backwash brine discharging into the wastewater stream. In the case of 2284 Genito West Court, the average chloride concentration in the process tank was 367.8 mg/L and the average concentration in the AdvanTex effluent was 398.3 mg/L. These concentrations were much lower than those of the systems exhibiting deterioration of treatment over the testing period. The average chloride concentration in the process tank effluent at 1822 Angus Drive was 1,523 mg/L and in the AdvanTex effluent, it was 1,564 mg/L. These values were higher than the chloride concentrations in the tank at 9008 Cuba Lane, yet the AdvanTex Treatment System consistently produced an effluent $CBOD_5$ of less than 10 mg/L, with only one effluent value of 11 mg/L. These systems were only analyzed for 18 months in accordance with GMP #114.

Following the testing required by the VDH, the water softener backwash brine flows were rerouted away from the wastewater treatment system. It is unclear whether or not, over a longer period of time and accumulation, the treatment would have deteriorated had the softeners continued to discharge backwash brine into the wastewater and the analysis had been continued for a longer time. Another concern would be the combined effects of backwash brine with other abnormal characteristics such as bath oils, high grease and oil concentrations, pharmaceuticals, etc. Figures 14 through 17 graphically illustrate the $CBOD_5$ and chloride analyses over time for the systems located at 2284 Genito West Court and at 1822 Angus Lane.

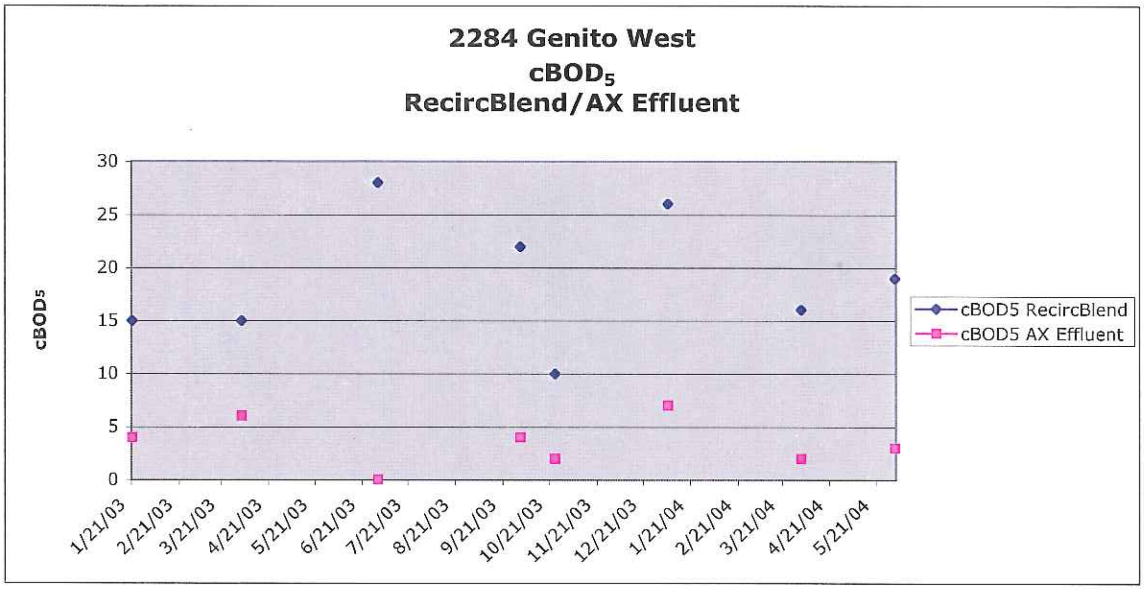


Figure 14: CBOD$_5$ Analysis at 2284 Genito West

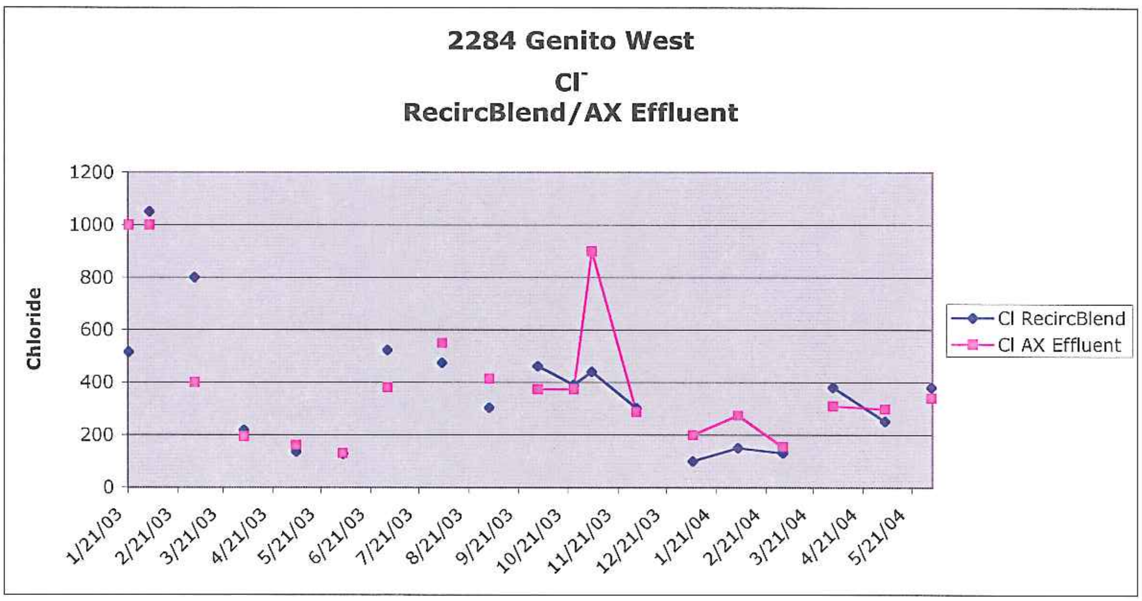


Figure 15: Chloride Analysis at 2284 Genito West

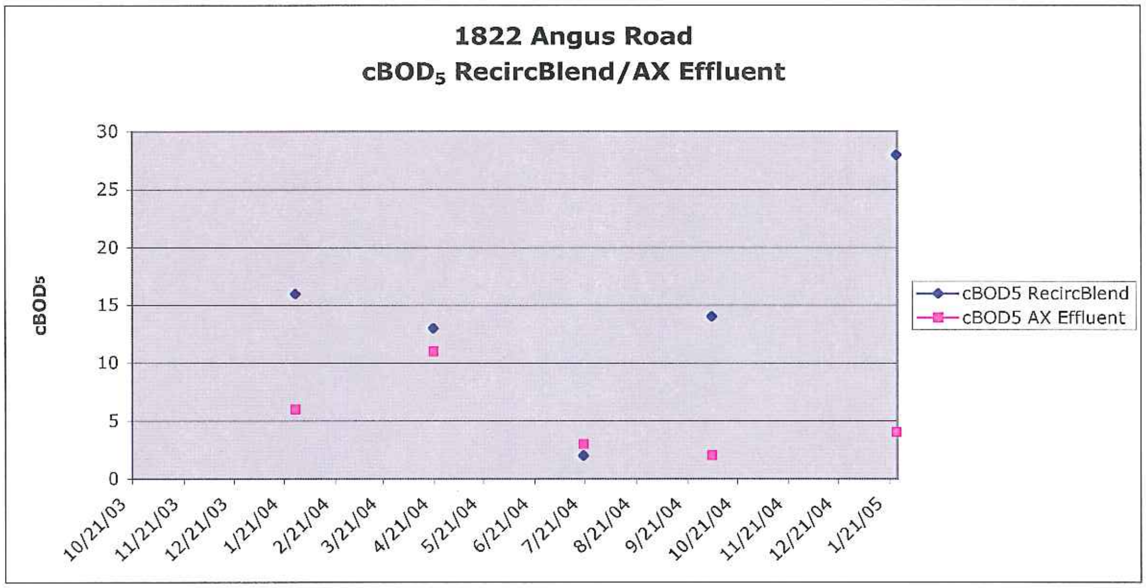


Figure 16: CBOD$_5$ Analysis at 1822 Angus Road

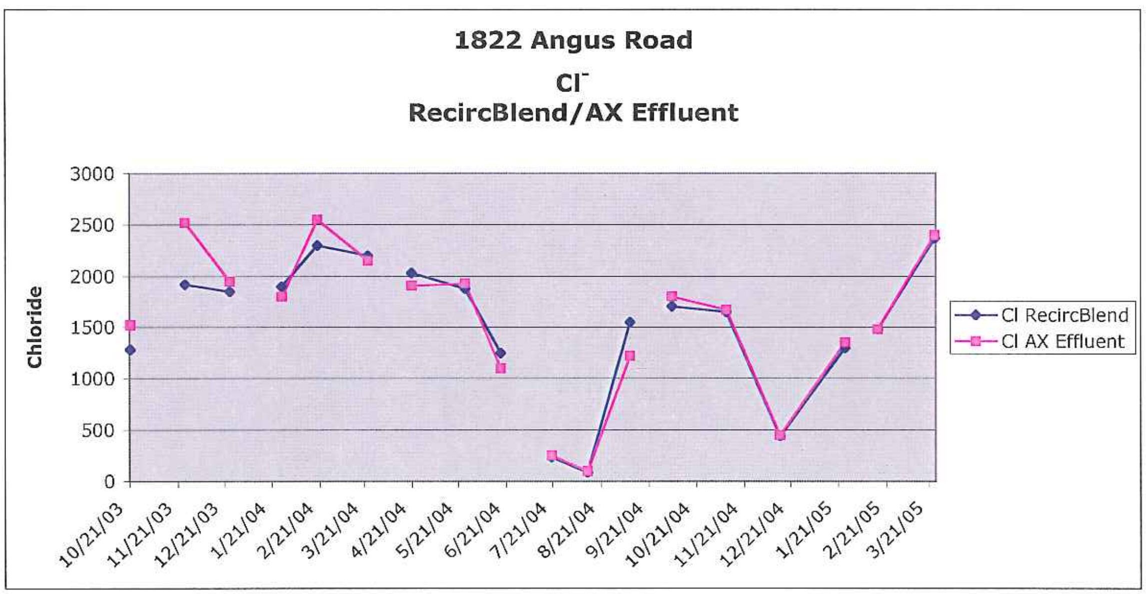


Figure 17: Chloride Analysis at 1822 Angus Road

The treatment system at 3815 Summit Crossing Road provides further insight into the effects of water softener backwash brine on the media filter. Upon startup, the treatment system had the backwash from water softener regeneration plumbed into drains that fed into the wastewater system. The treatment system immediately showed poor performance, and initially, this was attributed to startup conditions and acclimatizing microbial populations.

As the treatment system startup period passed – normally expected to be from one to three months for nitrifiers to colonize and begin nitrifying, depending upon temperatures – the system continued to perform poorly, producing $CBOD_5$ concentrations in the range of 30 to 60 mg/L. This is unusual for $CBOD_5$ reduction by an AdvanTex system. Generally, $CBOD_5$ would be treated to the 30 to 40 mg/L level within a day or two. The system was investigated and a thick coating was found over the surface of the textile sheets. The coating appeared to be rich in fats, oils, and grease (FOG); however, no FOG laboratory analysis was performed.

Although the chloride concentrations were only moderately high – ranging from 83 mg/L to 182 mg/L in the processing tank and from 81 mg/L to 443 mg/L in the AdvanTex effluent as shown in Figure 19 — the effluent quality from the AdvanTex filter was not consistent with results of other systems in the testing program.

An interview with the homeowner was conducted, revealing that a whirlpool bath was in use and the residents used relatively large quantities of bath oils on a regular basis in the whirlpool bath. The homeowners were advised against the use of the oils and large quantities of water (such as the whirlpool bath) on a regular basis, and the water softener backwash was removed from the discharge plumbing to the wastewater treatment system. In addition, the AdvanTex textile sheets were thoroughly cleaned and the tanks were pumped.

Following these measures, the next sampling period revealed an effluent $CBOD_5$ from the AdvanTex unit of 3 mg/L. This change is shown in the graphical representation of Figure 18. In addition, the Coliform bacteria concentration in the processing tank increased by an order of magnitude as shown in Figure 20 and the TKN in the AdvanTex effluent decreased by tenfold as shown in Figure 21. The total nitrogen in the AdvanTex effluent decreased by a factor of five – from 59 mg/L in the previous quarter's sample to 12 mg/L following removal of the water softener and counseling the homeowners. The total nitrogen concentration with time is shown in Figure 22.

Apparently, removing the water softener backwash and removal/reduction of bath oils from the wastewater stream had a significant effect upon the recovery of the AdvanTex treatment system and allowed it to produce the high-quality effluent consistent with the other treatment systems that were not influenced by water softener backwash.

This procedure and the associated analyses indicate that the brine from the water softener backwash cycles is detrimental to advanced secondary treatment processes. The softened water itself has no observed effect. Only the backwash brine causes the treatment to prematurely deteriorate.

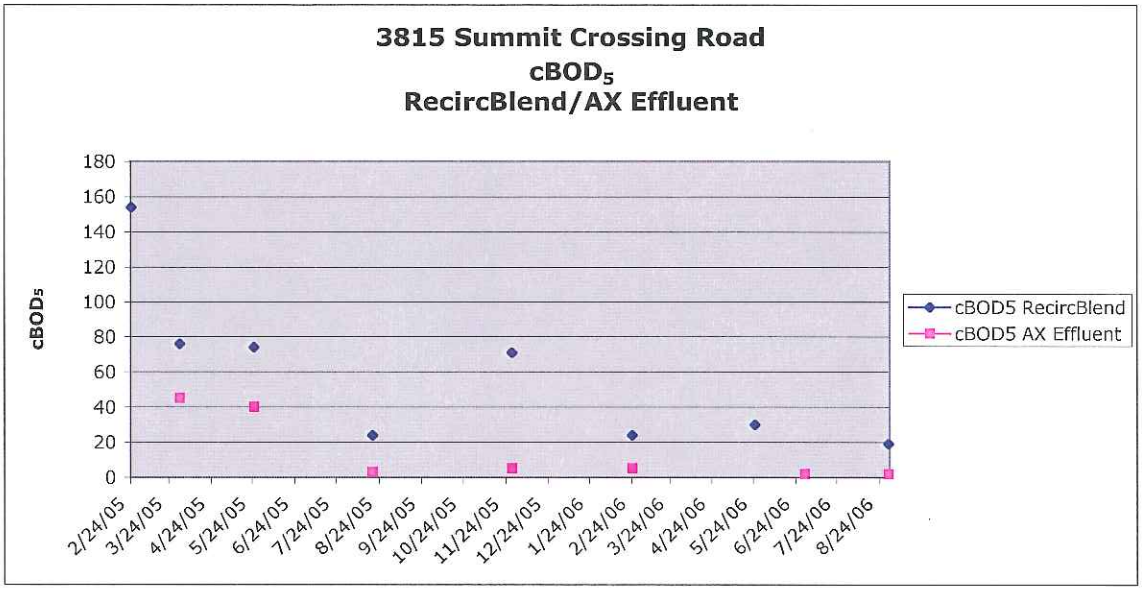


Figure 18: $CBOD_5$ Analysis at 3815 Summit Crossing Road

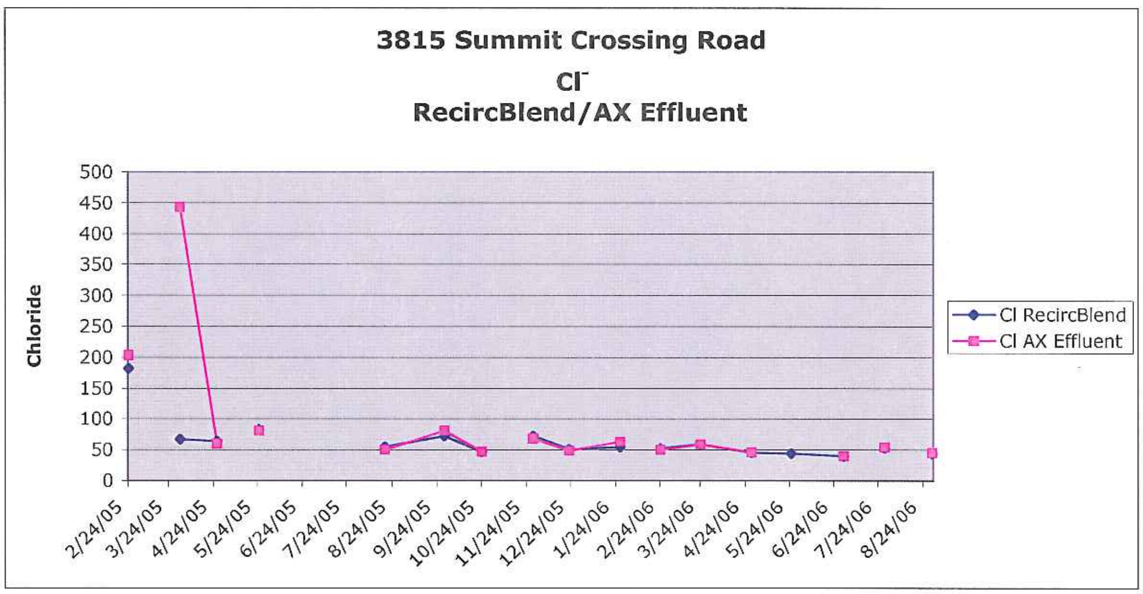


Figure 19: Chloride Analysis at 3815 Summit Crossing Road

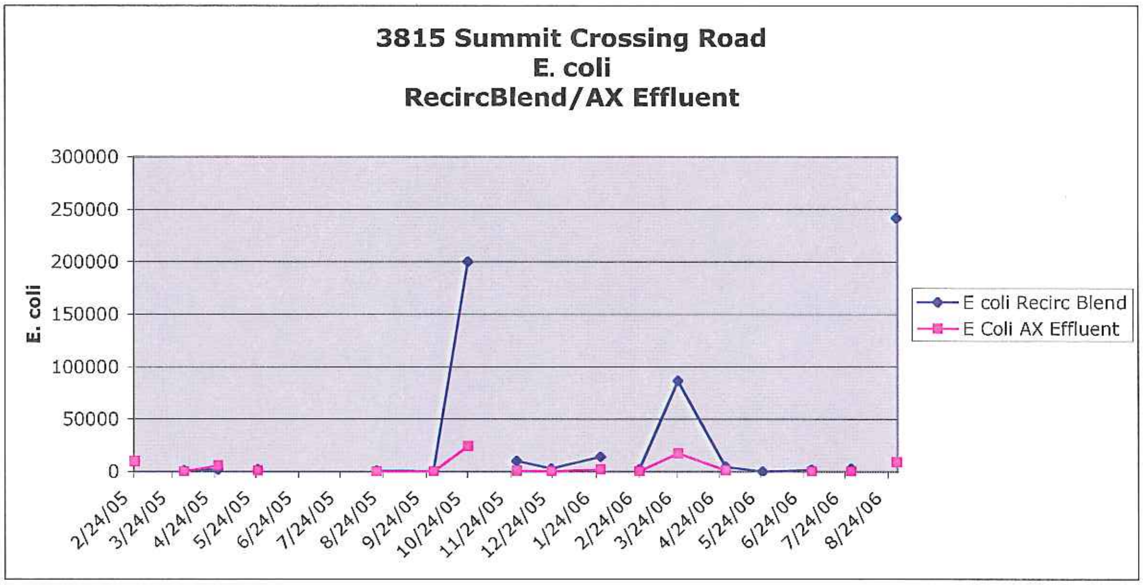


Figure 20: E. coli Analysis at 3815 Summit Crossing Road

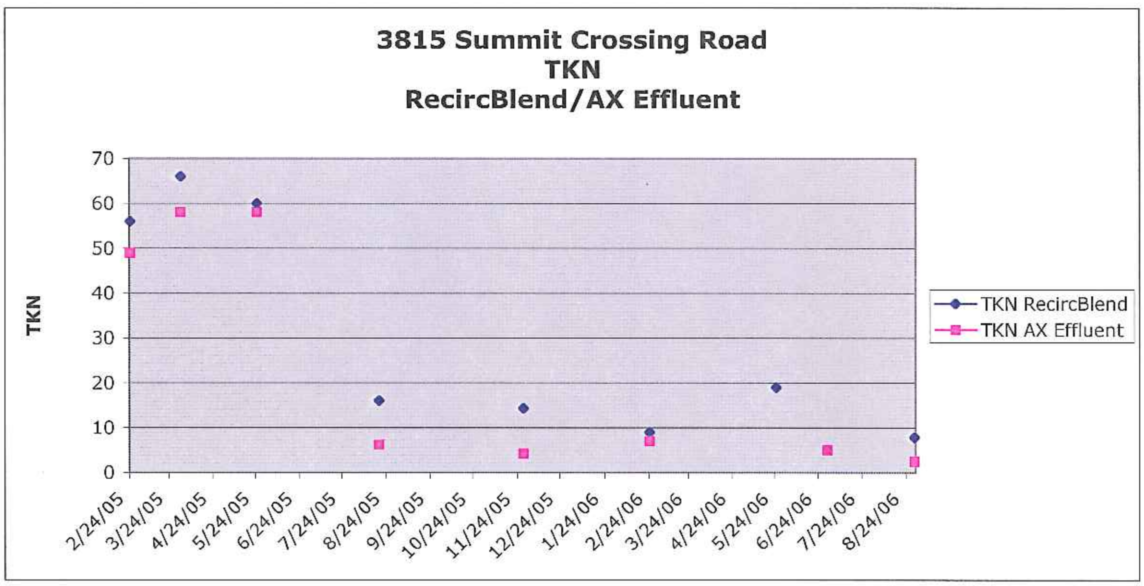


Figure 21: TKN Analysis at 3815 Summit Crossing Road

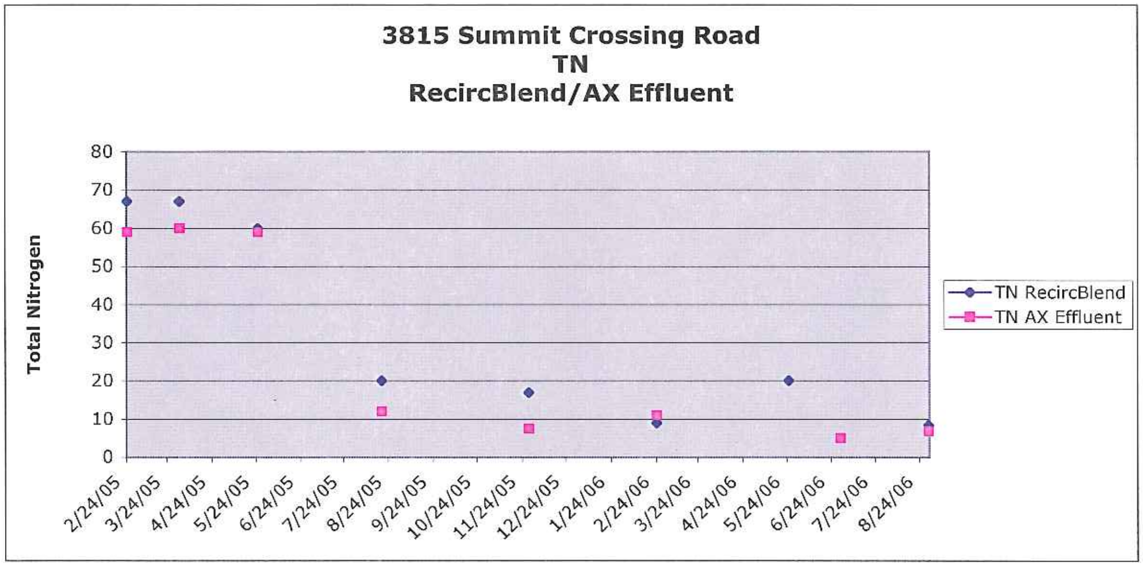


Figure 22: Total Nitrogen Analysis at 3815 Summit Crossing Road

Treatment Systems Receiving Typical Residential Wastewater 'Without' Water Softener Backwash Brine

Separating the data sets between systems receiving water softener backwash-brine and systems without the backwash brine into two categories illustrates a comparative picture of the performance trends of typical AdvanTex systems. Several observations may be made when viewing the data.

First, the standard deviations of nearly all of the analytes – with the exception of turbidity – are smaller, indicating more consistent treatment. For example, the standard deviation of the $CBOD_5$ for the systems that do not receive water softener brine shows 5.0 with a mean of 5 mg/L and a median of 3 mg/L. Those receiving the water softener backwash have a standard deviation of the $CBOD_5$ concentrations of 10 mg/L, a mean of 7.3 mg/L and a median of 4 mg/L. In comparison, this could be regarded as indicating that the systems without water softeners are twice as consistent in terms of producing a high-quality effluent.

In addition, the average effluent quality from those "normal" systems is slightly over 2 1/2 times better than those systems receiving water softener backwash brine. Although the systems with water softeners, on average, still produce effluent quality far better than is required to pass NSF Standard 40 criteria, the effluent is not nearly as consistent as those treatment units that do not receive the water softener backwash brine.

Table 15 is a compilation of the testing results for the systems that did not receive water softener backwash-brine.

Table 15: Minimum, Maximum, Mean, and Median Values AdvanTex Effluent — Systems Without Water Softener Backwash Brine						
	Min	Max	Mean	Median	Standard Deviation All Systems	Standard Deviation Excluding Systems with Water Softeners
$CBOD_5$, mg/L	2>	25	4.7	3	16	5
TSS, mg/L	1	46	6.9	5	21	7
Turbidity, NTU	.05	10.6	1.6	1	7	2
TKN, mg/L	0.1	39	5	3	15	5
NH_3-N, mg/L	0.1	14	1.8	0.4	11	3
NO_3-N, mg/L	.26	45.5	11.9	7	12	11
TN, mg/L	.2	52	15.3	12	19	11
Cl^-, mg/L	10	183	57.9	50	692	31
Alkalinity, mg/L	11	486	160	157	182	74
E. coli MPN/100 mL	1	160000	634.7*	840	19064	12512

** Geometric mean*

In terms of nutrients – which is a major concern in many parts of the United States – the systems receiving the backwash brine from the water softeners had a mean Total Nitrogen (TN) concentration of 19.9 mg/L; a median TN concentration of 14 and a standard deviation of 19 mg/L. The systems receiving no water softener backwash brine – that is the systems receiving typical domestic wastewater – produced an effluent with TN concentrations averaging 15.3 mg/L; a median concentration of 12 mg/L; and a standard deviation of 11 mg/L.

Interestingly, the systems receiving typical residential wastewater without the water softener brine also have a mean chloride concentration of 62.9 mg/L in the processing tank and a mean concentration of 57.9 mg/L in the AdvanTex effluent. The median values were 48 mg/L and 50 mg/L, respectively with standard deviations of 74 mg/L and 31 mg/L. This indicates that, under normal conditions, the chlorides will pass through the treatment unit creating little effect on the treatment process and will allow the treatment system to biodegrade the CBOD and transform the organic and ammonium nitrogen to nitrate and further denitrify.

Figures 23 through 26 graphically illustrate the data from the testing. These graphs show lower mean values of every constituent when no water softener backwash is discharged to the treatment system. In addition, the graphs show that the treatment system effluent concentrations were much more consistent when no water softener backwash was discharged to the system. As shown in Figure 26, the graph for TN, 77% of the samples were at or below the mean value when no water softener backwash was discharged to the wastewater treatment system. By contrast, 61% of the TN samples were at or below the mean value when the systems received water softener backwash.

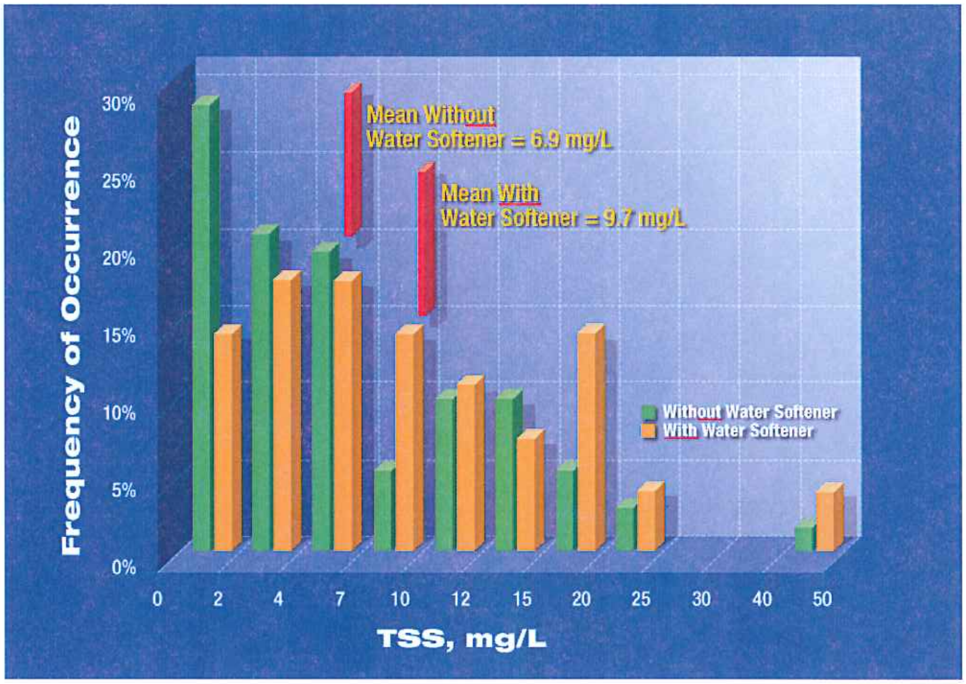


Figure 23: Water Softener Effects Upon TSS

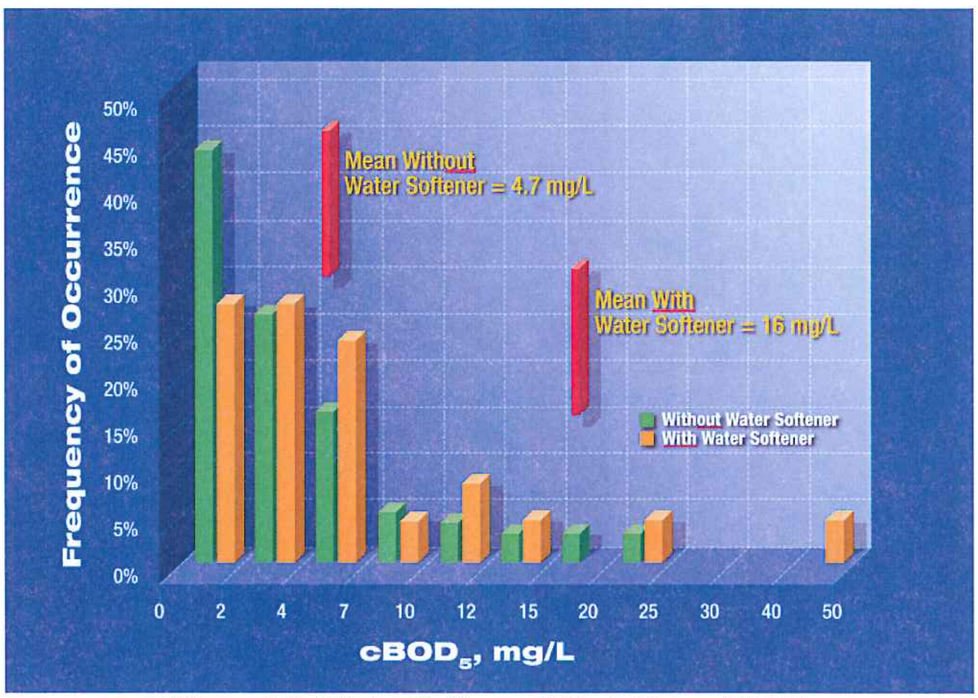


Figure 24: Water Softener Effects Upon CBOD

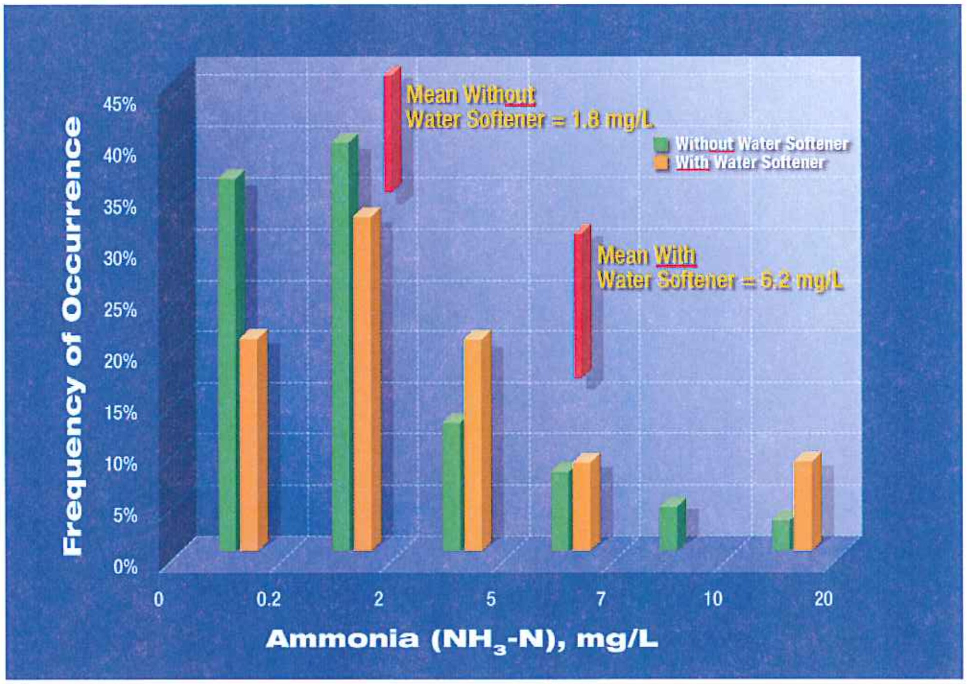


Figure 25: Water Softener Effects Upon NH_3-N

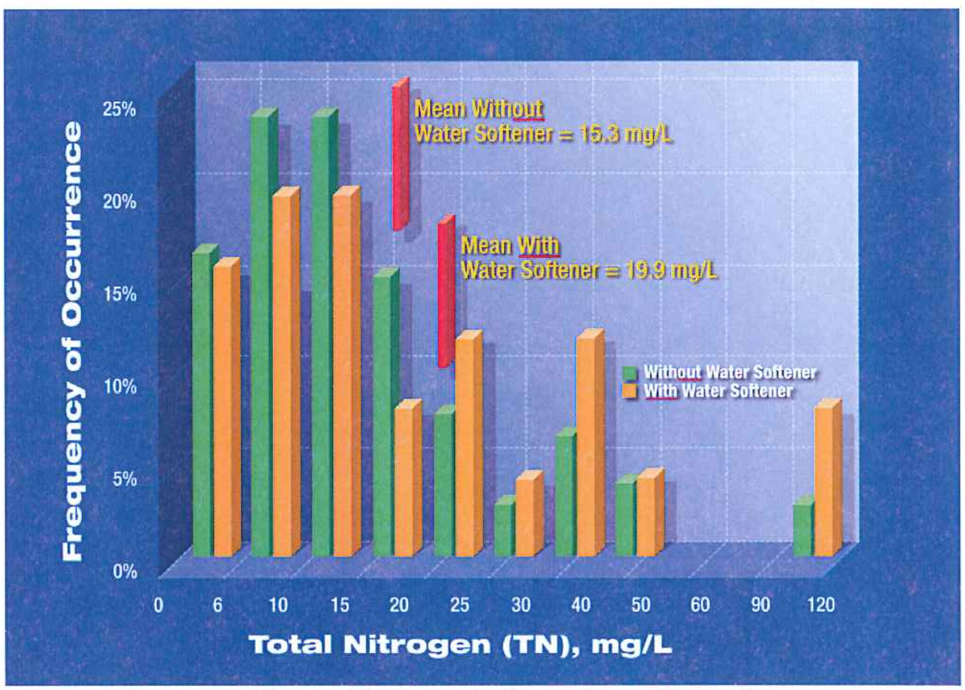


Figure 26: Water Softener Effects Upon Total Nitrogen

Photograph 5: AdvanTex® System Receiving Residential Effluent with Water Softener Backwash Brine

Photograph 6: AdvanTex® System Receiving Residential Effluent with No Water Softener Backwash

Startup Considerations

Three systems show the effect of startup upon nitrification. The system at 9451 Deer Lake Drive was first sampled on January 7, 2003 shortly after startup. The ammonium-nitrogen concentration in the first sample was approximately 31 mg/L. The next sample, taken 3 months later on April 7, 2003 showed an ammonium concentration of approximately 6 mg/L. The nitrate concentrations showed the similar (but reversed) trend with no nitrate in the first sample and approximately 14.5 mg/L in the second sample.

The system at 1822 Angus Road had an effluent ammonium concentration of approximately 42 mg/L upon startup with a concentration of approximately 2 mg/L after 3 months, with the remainder of the sampling events showing ammonium-nitrogen concentrations less than 5 mg/L for the duration of the testing program.

The system at 5716 Buckhunt Lane was first sampled on January 8, 2003, immediately after startup. The ammonium-nitrogen concentration in the first sample was approximately 65 mg/L and the nitrate as nitrogen concentration was below detection limits. The next sample, taken 3 months later showed ammonium and nitrate as nitrogen concentrations of 5 mg/L and 5 mg/L, respectively.

In all cases, that showed startup effects upon the nitrification, the systems performed consistently with other media filter systems, building a population of nitrifiers within a short period, and producing a highly nitrified effluent within three months of startup, even in winter conditions. This performance is consistent with laboratory studies showing an adequate nitrifier population within 2 to 3 weeks at room temperature while operating media filters.

Lysimeter Samples

Of the samples taken from the lysimeters, the only lysimeters showing any E. coli in the lysimeter samples had positive results in the background lysimeters as well as the lysimeters in the footprint area of the soil absorption system. The highest concentration of E. coli in any of the lysimeters placed in the footprint area was 36 MPN/100 mL. The background lysimeter contained 130 MPN/100 mL during the same sampling event. All lysimeters in the soil absorption area footprint showed a higher chloride concentration than the background lysimeters. This analytical result was interpreted to indicate that the soil absorption lysimeters were indeed intercepting the AdvanTex effluent being introduced into the soil absorption system.

In one case, following Hurricane Isabel, a tree was uprooted near the soil absorption system at one of the sites. Gravel in the soil absorption system was exposed, and the water in the gravel was sampled. At the same time, a pool of water in the lawn upslope and out of the influence of the soil absorption system was sampled as well as the effluent from a subsurface drain for the front lawn, an up gradient and approximately 100 feet from the soil absorption system. The results for E. coli sampling follow:

- Water in soil absorption area: 28 MPN/100 mL
- Pool in lawn: 1600 MPN/100 mL
- Drain in front lawn: 110 MPN/100 mL

Conclusions

1. The AdvanTex systems installed in Virginia and monitored for the past three and a half years have produced a high quality effluent in terms of $CBOD_5$, TSS, turbidity, nitrogen species, and E. coli.
2. The effluent quality has been consistent from the AdvanTex systems.
3. Some of the wastewater systems receiving water softener backwash brine have produced a poorer quality and less consistent effluent after approximately a year of operation.
4. The AdvanTex systems do not have a negative impact with respect to E. coli upon the shallow groundwater at a depth of 12 inches below the infiltrative surface where the treated effluent is introduced. The lysimeter sampling yielded E. coli less than 1 MPN/100 mL.

Table 16: Comparative Means and Medians AdvanTex Effluent

	Mean All Data Point	Mean without WS-Brine	Mean with WS-Brine	Median All Data Points	Median without WS-Brine H/L Outliers	Median with WS-Brine
$CBOD_5$, mg/L	7	4.68	7.34	3	3	4
TSS, mg/L	9	6.87	9.76	5	5	8
Turbidity, NTU	2	1.6	2.12	1	1	1
TKN, mg/L	7	4.96	9.06	4	3	4
NH_3-N, mg/L	4	1.78	6.25	1	0.4	2
NO_3-N, mg/L	11	11.9	8.35	7	7	6
TN, mg/L	18	15.3	19.9	13	12	14
Cl^-, mg/L	337	57.9	1207.1	62	50	1000
Alkalinity, mg/L	168	160	177	160	157	180
E. coli MPN/100 mL*	785.4	634.7	1568.5			

** Geometric mean*

Table 17: Performance Relative to Typical Septic Tank Average Strengths

	Mean ST Effluent	Mean AX Effluent	Reduction
BOD_5, mg/L	150	4.7	97%
TSS, mg/L	40	6.8	83%
TKN–n, mg/L	65	4.6	93%
NH_3-N, mg/L	55	1.78	97%
E. coli MPN/100 mL	10^6	634	5 log

Appendix A:
Recirculating Filter Schematic and Equations

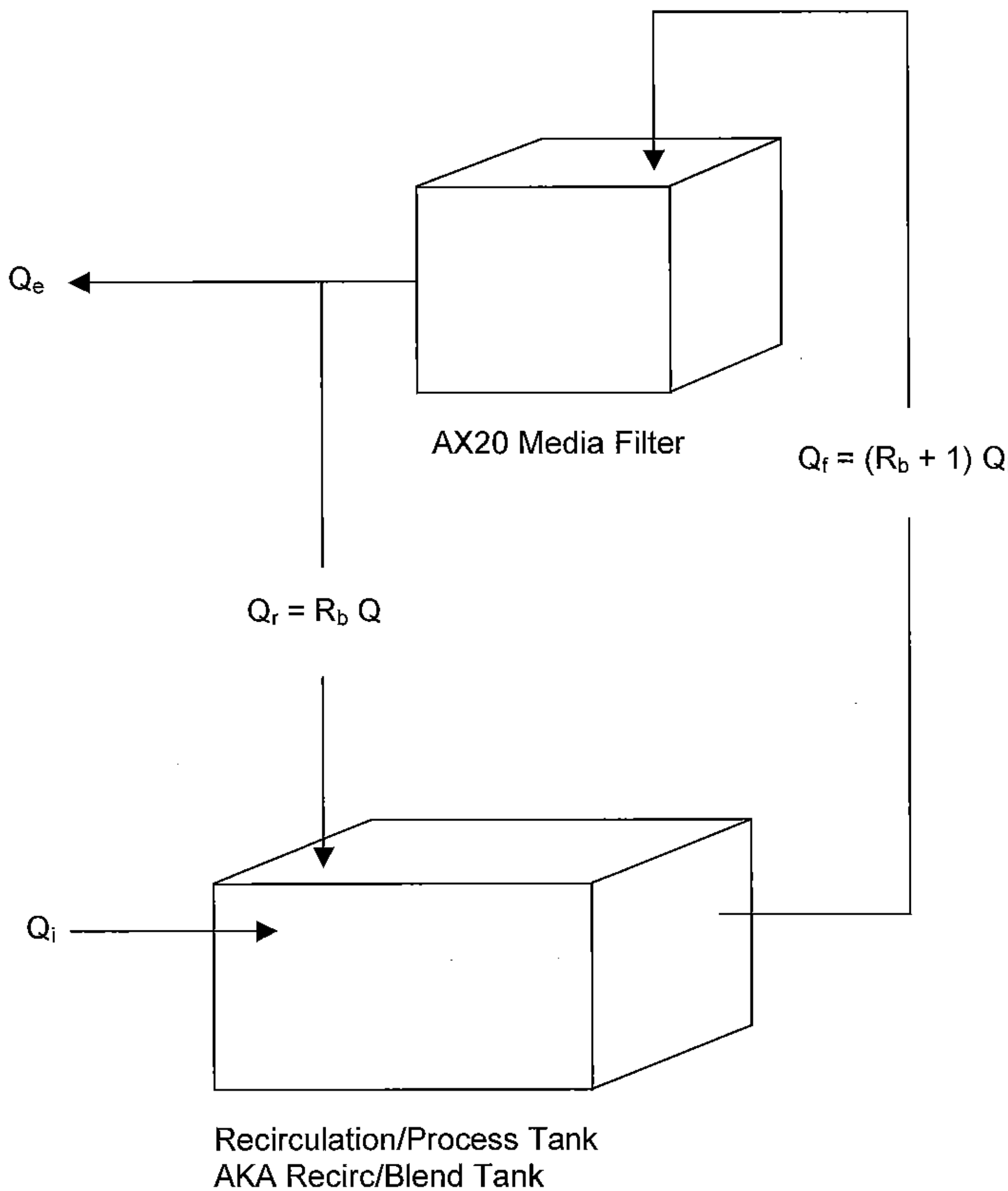


Figure A-1: Recirculating Filter Schematic

Recirculation (recirc-blend) Ratio (R_b)

The Recirculation Ratio (R_b) is defined as the ratio of the daily flow returned (Q_r) to the recirc-tank to blend with the daily inflow (*influent or forward*) wastewater flow (Q_i) as shown in the following expression:

$$R_b = Q_r/Q_i$$

$$Q_r = R_b Q_i$$

where:
R_b is the recirculation (recirc-blend) ratio
Q_r is the daily flow returned to the recirc-tank, gpd
Q_i is the daily inflow (or forward flow), gpd

Q_e is the effluent flow, which is equal to Q_i, gpd, and Q_f is the daily flow to the filter unit,, which is equal to $Q_r + Q_i$.

$$Q_f = Q_r + Q_i = Q_{r+i}$$

By adjusting the R_b, the dilution and blend concentrations within the recirc-chamber can be balanced, as shown by the following expression.

$$Q_i S_i + Q_r S_e = Q_{r+i} S_b$$

$$Q_i S_i + Q_i R_b S_e = (R_b+1) Q_i S_b$$

or

$$S_i + R_b S_e = (R_b + 1) S_b$$

where:
Q_i is the daily inflow (or forward flow), gpd
Q_{r+i} is the daily filter hydraulic load, gpd
or $Q_{r+i} = Q_f = (R_b + 1) Q_i$
Q_r is the daily flow returned to the recirc-tank, gpd
S_i is the inflow substrate concentration, mg/L
S_e is the filtrate substrate concentration, mg/L
S_b is the blended substrate concentration, mg/L

Therefore, the recirculation tank blended substrate concentration may be determined directly by the following expression:

$$S_b = (S_i + R_b S_e)/(R_b+1)$$

As shown by the equation above, the dilution and blend concentrations in the recirculation chamber can be controlled or balanced by adjusting the recirculation ratio, R_b.