Treatment of Septic Tank Effluent: Comparison of Enviro-Septic® and Conventional Pipe and Stone Leaching Systems

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Summary

Many new technical devices have been devised to improve the function of standard septic systems. The Enviro-Septic® leaching system, manufactured by Presby Environmental, Inc., is purported to surpass conventional leaching systems for wastewater treatment. The purpose of the research projects described herein was to compare the performance of Enviro-Septic® systems to that of conventional pipe and stone leaching systems. Some of the research was carried out in collaboration with the Virology and Waterborne Disease Laboratory, Department of Microbiology, at the University of New Hampshire (UNH), Durham, NH, and with DBO Expert Inc., Magog, Quebec, Canada. The UNH project involved miniature model systems housed inside a laboratory on campus, whereas DBO Expert Inc., utilized larger underground model systems. Analyses of wastewater components, including ammonia, biochemical oxygen demand (BOD), chemical oxygen demand (COD), fecal coliforms (e.g. *E. coli*), nitrate, phosphorus, total Kjeldahl nitrogen (TKN), total suspended solids (TSS), and viral particles were conducted on the septic tank effluent (entering) and the leachate (exiting) of the model systems. The large-scale Enviro-Septic® model system set up by DBO Expert Inc., demonstrated percent removal values for TSS and fecal coliforms that were significantly greater ($P < 0.001$) than those of the conventional pipe and stone model system, suggesting that Enviro-Septic® performs better than conventional systems at filtering out these septic components. Furthermore, Enviro-Septic® in the large-scale models displayed significantly greater percent removal values of COD, BOD, TKN, phosphorus and ammonia ($P < 0.001$) and significantly greater production levels of nitrate ($P < 0.001$), suggesting that it treats wastewater better by promoting a more substantial aerobic microbial ecosystem than conventional systems. These results were consistent with findings from the small-scale systems in the UNH project, where the Enviro-Septic® models displayed significantly greater percent removal values of COD and ammonia ($P < 0.05$) than the pipe and stone models. In a study of wastewater flow through the DBO Expert Inc., model systems, it took approximately six months for septic tank effluent to flow through 60' of Enviro-Septic® pipe, whereas it took more than a year for effluent to flow through 40' of conventional perforated leaching pipe. These results suggested that more of the Enviro-Septic® pipe functions at treating wastewater over time, and that it distributes a more dilute leachate to a greater area of underlying soils than conventional systems.

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Introduction

Background Information

Residential septic systems are the largest source (by volume) of wastewater disposed to the land (Linsley *et al.*, 1992). Nearly 40% of new homes in the United States use them (Hallahan, 2002). Much attention has been focused on improving the performance of standard systems as their impact on the environment has been addressed. In fact, the U.S. Environmental Protection Agency, National Water Quality Inventory: 1996 Report to Congress (U.S. Environmental Protection Agency, 1998) states, "Improperly constructed and poorly maintained septic systems are believed to cause substantial and widespread nutrient and microbial contamination to ground water."

A standard septic system is defined here as the combination of a septic tank and leach field. The septic tank serves as a temporary holding tank for raw wastewater. It traps much of the solid waste by allowing it to settle. The solid waste must be emptied from the tank periodically as part of routine maintenance of the system. Little dissolved oxygen is available inside the septic tank; its environment is anoxic (anaerobic). Partial decomposition of waste within the tank is accomplished by anaerobic bacteria (bacteria that can tolerate or require the absence of oxygen). This partially treated wastewater then passes out to the leach field and is referred to as septic tank effluent (STE) (Winneberger, 1984).

A leach field typically consists of a series of subsurface perforated pipes arranged horizontally within a rocky or sandy medium. It functions to treat STE and distribute it under the surface to the underlying soils. The pipes and soils act as filters of wastes and allow further chemical breakdown and biodegradation of the STE before it is discharged to the environment. A conventional leach field is defined here as a pipe and stone system constructed of perforated PVC pipe (4" diameter) laid within a bed of crushed stone.

It is a priority of the U.S. Environmental Protection Agency and other environmentalists to improve the performance of standard septic systems and prevent groundwater contamination (U.S. Environmental Protection Agency, 2003). Therefore, many new septic system technologies have been introduced. Most of these innovations operate either inside the septic tank or between the tank and the leach field (Heufelder and Rask, 2001). Enviro-Septic® Leaching Systems by Presby Environmental, Inc., however, take a different approach to improving septic system function.

The unique design of Enviro-Septic® components is purported to enhance the efficiency of wastewater treatment within the leach field (Figure 1). Enviro-Septic® systems consist of corrugated, high-density plastic pipe with a 9.5" interior diameter. Exterior ridges on the peak of each corrugation are thought by Presby Environmental, Inc., to facilitate the flow of effluent around the circumference of the pipe. This, in addition to the large inner surface area and the relative thinness of the plastic, allow effluent to cool quickly within the pipe. Upon cooling, STE separates into its components: scum floats to the top and sludge sinks to the bottom. The liquid component of the STE flows through the pipe perforations, while the scum and sludge are retained within the pipes. Furthermore, plastic "skimmers" extend inwards from each hole. The skimmers are thought by Presby Environmental, Inc., to help capture grease and suspended solids, preventing them from escaping through the perforations. A thick layer of coarse, randomly-oriented plastic fibers surrounds the pipe. This layer serves as an attached culture system providing an extensive surface area on which microbial biofilms can grow. Moreover, a geo-textile fabric surrounds the plastic fiber layer, further supporting the growth of microbial biofilms. Finally, Enviro-Septic® systems are installed in clean medium-coarse sand (washed concrete sand).

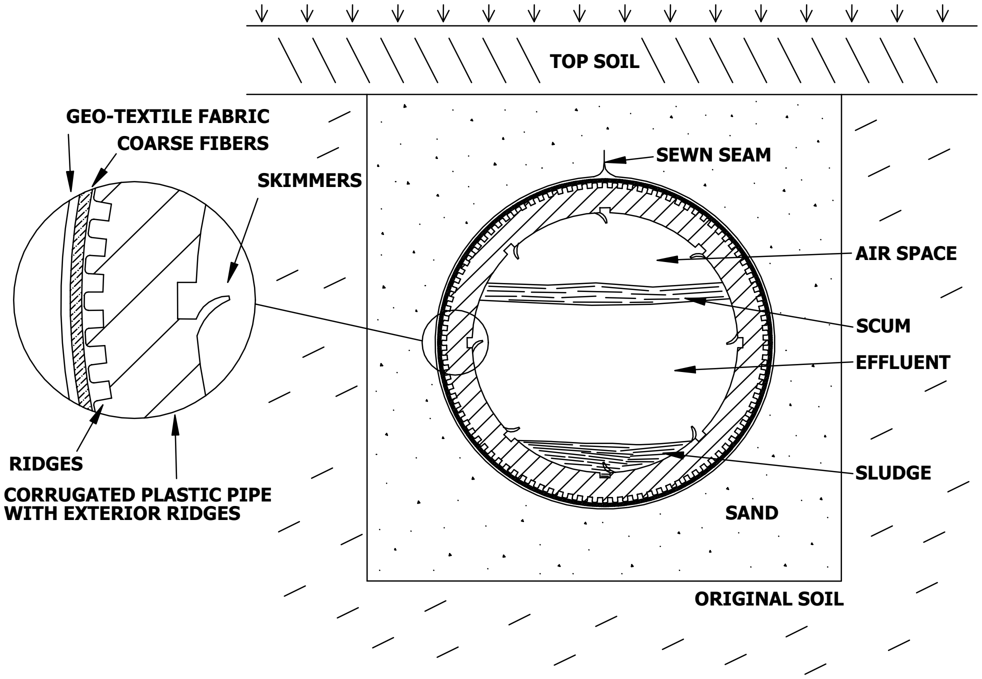

Figure 1. Components of the Enviro-Septic® pipe (from the Enviro-Septic® & Simple-Septic® Leaching Systems Design and Installation Manual, 2003).

Research Projects: Experimental Design

Two individual research projects were designed to compare the performance of Enviro-Septic® leaching systems to conventional pipe and stone leaching systems. Several hypotheses were tested.

- Hypothesis 1: The unique design of Enviro-Septic® pipe and the surrounding sand enable the system to filter total suspended solids, bacteria, and viruses better than conventional systems.

It is desirable to prevent bacteria, viruses, and other components of wastewater from escaping the leach field and contaminating the underlying groundwater. Filtering action can be measured by comparing the amount of these components in the STE to the amount in the leachate (wastewater leaving the leach field) and estimating the percent removal.

- Hypothesis 2: Enviro-Septic® systems accomplish decomposition of wastewater faster and more efficiently than conventional systems by promoting and maintaining a more substantial aerobic microbial ecosystem (microorganisms that require oxygen to live).

Aerobic decomposition works faster and more efficiently to break down natural and synthetic organic substances than anaerobic decomposition (Heufelder and Rask, 2001) (Grady *et al.*, 1999).

- Hypothesis 3: Enviro-Septic® systems distribute wastewater over a larger surface area than conventional systems because more of the system functions at any given time.

It has been observed that in a serially distributed conventional leaching system, only the first line or lines of pipe (and their underlying soils) take most of the burden of wastewater treatment most of the time (Winneberger, 1984). If leachate were to be distributed across a larger surface area, then it would be discharged to the environment in a more dilute form. This would allow the underlying soils to better filter and treat the wastewater before it enters the water table.

Presby Environmental, Inc., has participated in two individual research projects. The purposes of these were to test the above hypotheses by comparing the performance of Enviro-Septic® to conventional pipe and stone systems under controlled conditions. The first research project was carried out in collaboration with Aaron Margolin, Ph.D., Helene Balkin, and Robert Mooney at the Virology and Waterborne Disease Laboratory, Department of Microbiology, University of New Hampshire (UNH), Durham, NH. It involved small-scale model Enviro-Septic® and pipe and stone systems that were maintained in a UNH laboratory. The experiments of the UNH project were designed to test Hypotheses 1 and 2; they were conducted and completed in 2002.

A second research project is being carried out in collaboration with Denis Boucher, Benoit Boucher, and François R. Côté of DBO Expert Inc., Magog, Quebec, Canada. It involves larger, in-ground models that are more representative of real life systems. These systems were set up in Stoke, Quebec. The experiments were designed to test Hypotheses 1, 2 and 3; they were begun in 2002 and are ongoing.

<u>Testing Hypothesis 1</u>: Hypothesis 1 was tested by comparing the amount of total suspended solids, number of coliform organisms, and number of viral particles detected in the STE and leachate of the model systems. The amount of total suspended solids (TSS) is a direct measure (in mg/L) of solid septic components (dissolved and undissolved).

There are approximately 100 billion microorganisms present in every gram of human feces (Cano and Colomé, 1988). Among the natural flora that inhabit the intestine are the coliform bacteria including *Escherichia* such as *E. coli*. An aerobic leach field supports a wide variety of organisms including aerobic bacteria, rotifers, protozoans, and fungi (Heufelder and Rask, 2001). Bacteria are the smallest of these septic system-dwelling microbes (Fenchel *et al.*, 1998) and are, therefore, the most likely to escape filtration. The amount of bacteria in wastewater is measured by the most probable number of coliform organisms (MPN; presented as number per 100 mL). Some pathogenic (disease-causing) bacteria enter septic systems from residences, and it is especially desirable to prevent these types of bacteria from reaching the water table. There are so many different species of pathogenic bacteria, however, it is not feasible to test for each one individually. Therefore, MPN is often used in wastewater testing as a guideline to indicate the *possible* presence of pathogenic bacteria.

Viruses, some pathogenic, are also present in wastewater. The capacity of a leach field to filter out viruses can be determined by "spiking" a known quantity of viral particles (measured in plaque forming units; PFU) into the STE at a single point in time. The number of PFU in the leachate is then measured for a period of time following the initial spiking. Theoretically, the better the filtering action of the leaching system, the lower the amount of suspended solids, bacteria, and viruses there will be leaving the system.

<u>Testing Hypothesis 2</u>: Hypothesis 2 was tested by comparing levels of TSS, carbon-, nitrogen-, and phosphorous-containing compounds in STE to the levels in leachate. The increase of some and decrease of other particular substances in a septic system would be indicative of aerobic decomposition.

TSS – Total suspended solids were tested because the biodegradation of TSS is carried out, in part, by aerobic microorganisms. A reduction of TSS in the leachate compared with the STE would be consistent with the presence of an aerobic microbial ecosystem in the leaching system.

COD – Chemical oxygen demand is a measure of the amount of oxygen required to stabilize the waste in a sample of wastewater completely. Carbon-containing organic compounds can be chemically oxidized (broken down) to yield carbon dioxide. This is what is meant by “stabilize.” The amount of oxygen required for stabilization is proportional to the amount of carbonaceous compounds in the sample. COD is therefore an indirect measure of the amount of carbon-containing compounds in a sample. One would expect the COD of the leachate to be less than the COD of the STE if carbon-containing compounds are chemically broken down in the leaching system.

BOD – Biochemical oxygen demand is a measure of the amount of oxygen required to stabilize carbonaceous waste biologically (through the metabolic action of aerobic microorganisms). The BOD is therefore another indirect measure of the amount of carbon-containing compounds in a sample. The BOD_5 refers to the amount of oxygen utilized by a sample over a five-day period. Carbonaceous compounds are oxidized to carbon dioxide during aerobic microbial metabolism; therefore a reduction in COD and BOD would be consistent with the presence of an aerobic microbial ecosystem in a leaching system.

TKN and ammonia – Total Kjeldahl nitrogen is the amount of nitrogen contained within organic compounds (such as nucleic acids, amino acids, and urea) and in ammonia (NH_3). Ammonia is a natural bi-product of the breakdown of nitrogen-containing organic compounds during aerobic metabolism.

Nitrate and nitrite – Nitrate (HNO_3) and nitrite (HNO_2) are products of the process of nitrification, which involves the oxidation of ammonia by the following (unbalanced) chemical reactions:

$NH_3 + O_2 \rightarrow HNO_2 + H_2O$ (O_2 is oxygen; H_2O is water)

$HNO_2 + O_2 \rightarrow HNO_3 + H_2O$

The reactions of nitrification are carried out by aerobic bacterial species of *Nitrosomonas* and *Nitrobacter*, natural occupants of septic systems. Theoretically, as aerobic microbial metabolism proceeds, amounts of ammonia and TKN decrease, while levels of nitrate increase.

Phosphorus – Phosphorus is a constituent of wastewater that is contained in organic compounds such as sugar phosphates, phospholipids and nucleotides, and in inorganic compounds such as polyphosphates (used in synthetic detergents) and orthophosphates. Phosphorus and nitrogen are the nutrients responsible for eutrophication (massive growth of algae in lakes). Therefore it is desirable to prevent their release into the environment.

Testing Hypothesis 3: Hypothesis 3 was tested by the DBO Expert Inc., research project. The model leaching systems were set up in Stoke, Quebec, such that leachate was collected from separate sections of each system. This enabled researchers to monitor when wastewater reached various sections of the systems, and hence when sections of each system were operational.

Materials and Methods

Research Project 1: UNH

Two model Enviro-Septic® systems (deemed ES 1 and ES 2) and two model conventional pipe and stone leaching systems (deemed P&S 3 and P&S 4) were assembled (Figure 2). Each model was housed in a square 18” × 18” × 18” polypropylene container fitted with PVC pipe (1” diameter) and an injection port in the center of one side. Each container contained 3” of washed concrete sand at the bottom.

For the P&S systems, an 8” length of Standard Pipe Schedule 20 (4” diameter) distribution line was positioned horizontally in the center of the square container, attached to the 1” PVC pipe at one end, and capped at the other end. Clean washed 1-1.5” crushed stone was distributed around the distribution line as follows: 6” underneath, 4” on either side along its length, 2” on each capped end and 2” on top. This distribution line/stone unit occupied a total of one cubic foot in the center of the square container. A black polypropylene fabric was placed over the distribution line/stone unit (to prevent sand from falling into the void spaces of the stone), and the remainder of the square container was filled with washed concrete sand.

For the ES systems, a 12” length of Enviro-Septic® pipe, capped at one end, was positioned horizontally in the center of the square container and attached to the 1” PVC pipe. The pipe was then surrounded by washed concrete sand.

Assembling the pipe and stone model system

Assembling the Enviro-Septic® model system

Figure 2. Assembly of the model leaching systems used in the UNH research project. A) An 8” length of distribution line is surrounded by a cubic foot of washed stone atop 3” of washed concrete sand in a square container. B) The stone is surrounded by sand. C) A piece of fabric prevented sand from falling into the spaces between the stones. D) The components of the 12” length of Enviro-Septic® pipe and how they were assembled. The clear tubes were put in place to enable viewing the inside of the system. E) The Enviro-Septic® pipe was placed atop 3” of washed concrete sand in a square container and F) surrounded by sand.

A 1.5 quart chamber was mounted above each model unit and attached to the 1" PVC pipe. A timer-controlled diaphragm pump delivered STE to each of the chambers from a common holding tank. The bottom of each model system was equipped with a plastic screen and grid to enable the systems to drain. Drains were emptied into four individual recovery tanks via silicon tubing. The systems were housed in a temperature-controlled room in Rudman Hall on the campus of UNH and maintained at 18°C (Figure 3).

A pump filled four chambers (1.5 quart) with STE. These subsequently fed each system four times daily.

P&S 4
ES 1

ES 2
P&S 3

Temperature controls. The model systems were maintained at 18°C.

Leachate from each system drained into individual recovery tanks, which were emptied periodically.

Holding tank from which STE was pumped to each system. The contents of the holding tank were replaced weekly with fresh STE.

Figure 3. Model leaching systems were housed in a temperature-controlled room in Rudman Hall on the campus of UNH.

Septic tank effluent was supplied on a weekly basis from a residence in Sugar Hill, NH. Upon every new STE delivery, the old STE remaining in the holding tank was discarded and replaced with fresh STE. One and a half quarts of STE were pumped to each model system from the holding tank four times a day: 7:00 am, 8:00 am, 4:00 pm and 5:00 pm. The systems were fed for a period of at least two months before sample testing was begun. Samples of STE and leachate were collected weekly at the time of STE delivery. Once the STE in the holding tank was replaced with fresh STE, an additional pumping cycle was carried out. The STE sample was taken directly from the pump, and the leachate samples were taken directly from the model system drains immediately following this pump cycle.

Samples were transported on ice to Eastern Analytical, Inc., Concord, NH, where they were analyzed for ammonia, BOD, COD, nitrate, nitrite, TKN, and TSS. Tests for ammonia, BOD, COD, and TKN were begun after nine weeks of STE feeding and carried out for 22 weeks. Tests for TSS were begun after 14 weeks of STE feeding and carried out for 18 weeks. Tests for nitrate and nitrite were begun after 19 weeks of STE feeding and carried out for 12 weeks. Samples were also analyzed for fecal coliforms following ten weeks of STE feeding, for a total of 21 weeks. For the first 14 weeks of bacterial testing, MPN of fecal coliforms was determined by the Virology and Waterborne Disease Laboratory, UNH. For the final seven weeks, testing for *E. coli* was performed by Eastern Analytical, Inc. A Student's *t* test (NIST/SEMATECH e-Handbook of Statistical Methods, 2004) was done to assess statistical significance of the results.

After 28 weeks of feeding STE into the systems, known quantities of MS-2 virus (a bacteriophage or virus whose host is a bacterium) and poliovirus were "spiked" into the systems via their injection ports. The amounts of these viruses in the leachate were analyzed for 14 days following the initial spike. Virus spiking and enumeration were conducted by the Virology and Waterborne Disease Laboratory, UNH.

Research Project 2: DBO Expert Inc.

Installation of the Model Leaching Systems: A model Enviro-Septic® system and a model conventional pipe and stone leaching system were installed underground in Stoke, Quebec, Canada (Figures 4 and 5). Two trenches, 60' long by 3.5' wide, were dug side by side and encased in plywood. One trench would house the Enviro-Septic® system, while the other would house the conventional system. The bottom of each trench was divided lengthwise into three 20'sections. The first and second sections were 4.5' deep, while the third section was 5' deep (Figure 4A). The plywood trenches were made water-tight with an impermeable membrane liner (Soprema Inc., Wadsworth, OH; Figure 4B). An additional plastic canvas (yellow) was placed at the bottom of each trench in order to protect the membrane liner (Figure 4B). Perforated PVC pipes, 3" in diameter, were installed to drain the bottom of each trench section (Figures 4B and 4C). Eight inches of ¾" crushed stone were placed at the bottom of each trench. Then, 4" of ¼" crushed stone were laid over the larger stone in order to prevent sand from clogging the drainage pipes (Figure 4D). Clean medium-coarse sand (6" over sections 1 and 2, 12" over section 3) was then placed over the crushed stone so that the top of the sand was level over all three sections (Figure 4E, Figure 5). The properties of the sand were as follows: nominal diameter D10 ≈ 0.36 mm, coefficient of uniformity ≈ 4.8. At this point, the two trenches were identical to each other.

For the conventional pipe and stone system, a 6" layer of ¾" crushed stone was laid over the sand. A single 60' length of standard 4" diameter perforated PVC pipe was installed and surrounded by another 6" layer of ¾" crushed stone (Figure 4F, Figure 5). For the Enviro-Septic® system, six 10' lengths of Enviro-Septic® pipe were installed in one continuous line within a 16" layer of sand (Figure 4G, Figure 5). The remaining top portion of each trench was backfilled, and grass was planted atop the trenches.

The trench sections were deemed ESP 1, ESP 2, and ESP 3 for the first, second and third 20' of the Enviro-Septic® system and CPC 1, CPC 2, and CPC 3 likewise for the conventional system (Figure 4D). Leachate from each trench section was drained to a separate drainage receptacle located approximately 5' from the ends of the trenches (Figure 4H). Here, the leachate volume was monitored continually, and samples were taken for comparative analysis. Leachate in the drainage receptacles was then pumped to the Stoke municipal sewage treatment area located just downhill from the test site.

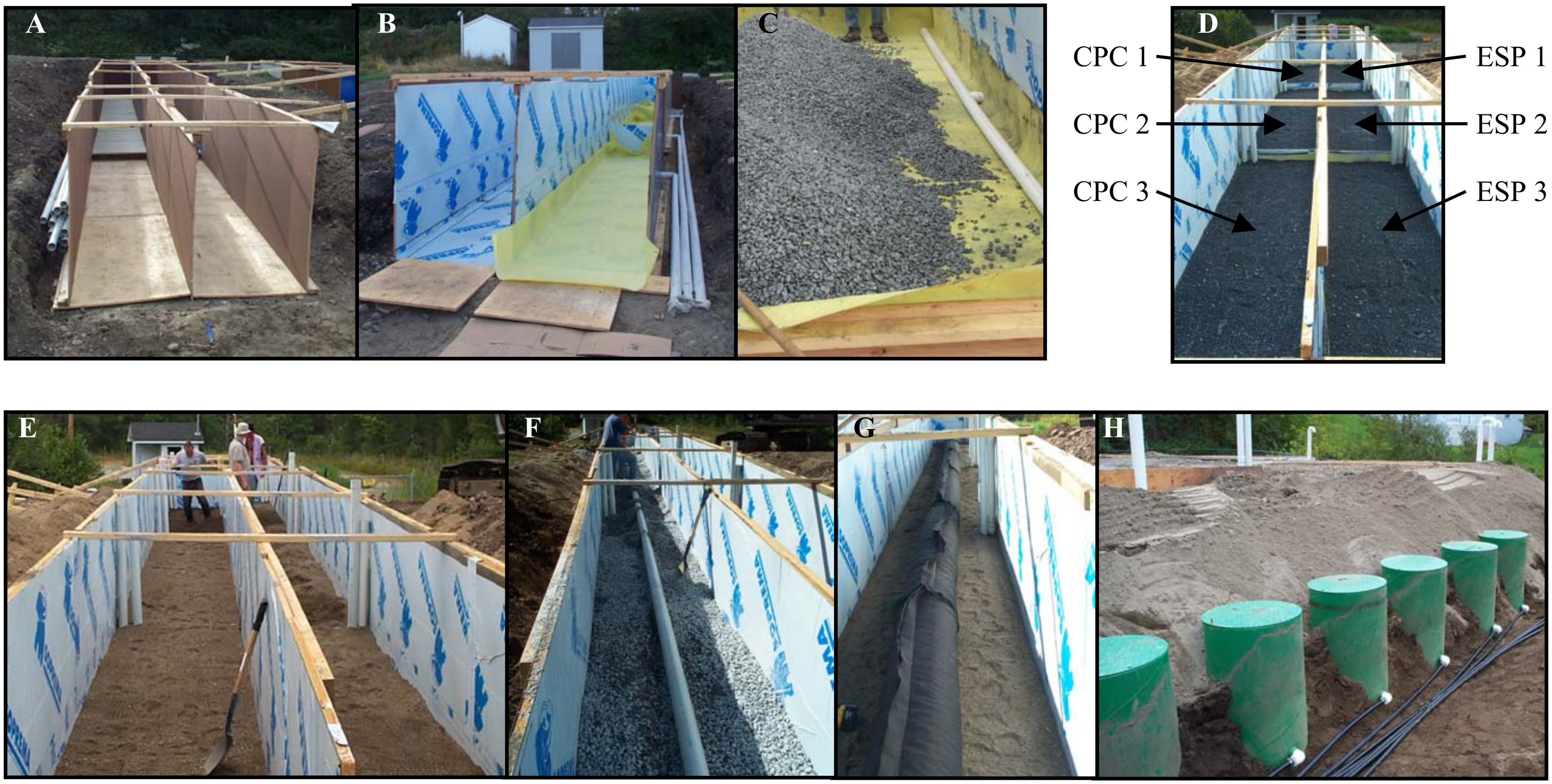

Figure 4. Installing model Enviro-Septic® and conventional pipe and stone leaching systems in Stoke, Quebec. A) Plywood-encased trenches, 60’ long × 3.5’ wide, were divided lengthwise into three sections. Note the final 20’ sections are 6” deeper than the first two 20’ sections. B) A waterproof membrane and plastic canvas were applied to both trenches, and drain pipes attached to each section. C) Stone and 3” perforated PVC pipe allowed leachate to drain from the bottom of each trench section. D) The same amount of stone covered each section’s bottom. The sections, deemed CPC 1, 2 and 3, and ESP 1, 2 and 3, can be seen here. E) A layer of clean medium-coarse sand covered the stone. The two trenches are identical at this point. F) For the conventional model system, a 60’ length of standard 4” perforated PVC pipe was installed in crushed stone. G) In the other trench, sixty feet of Enviro-Septic® pipe were installed within a layer of sand. H) Leachate from each trench section drained to a separate drainage receptacle (green cylinders), where its volume was continually measured, and samples were taken for comparative analysis. Leachate in the drainage receptacles was then pumped (via black hoses) to the Stoke municipal sewage treatment area located just downhill from the test site.

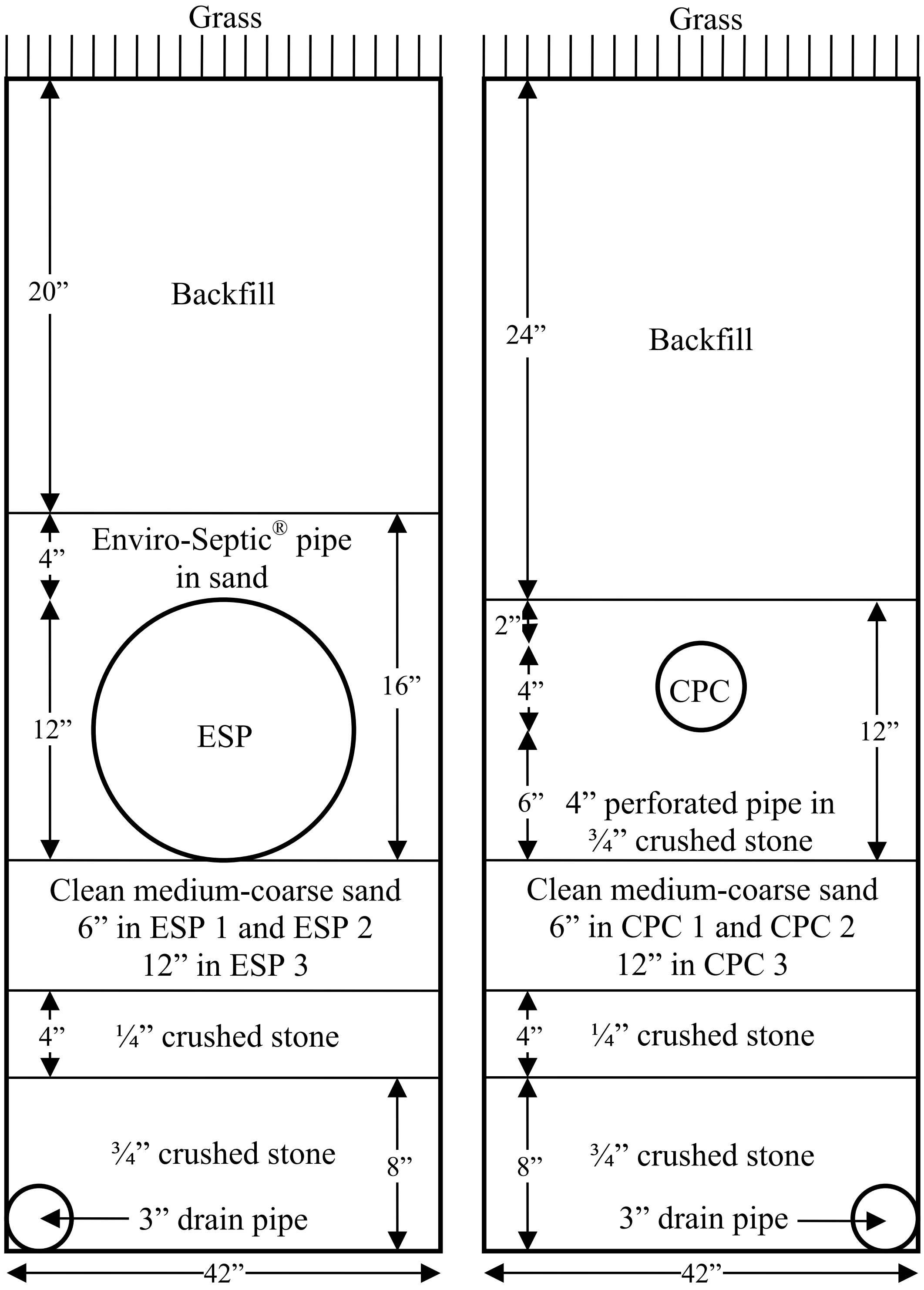

Figure 5. Diagram showing layers of materials and relative locations of drainage and leaching pipes as they were installed in each trench. The box on the left represents the Enviro-Septic® model system; the box on the right represents the conventional pipe and stone model system. Diagram is not to scale.

Loading Septic Tank Effluent into the Model Systems: Sewage from the town of Stoke's sewer was fed into a 6868 gal (26 m^3) septic tank on the test site. Effluent from this large tank was gravity fed to a small 264 gal (1 m^3) waiting tank. Whenever the waiting tank was full, the overflow STE was gravity fed to the Stoke municipal sewage treatment area. Different amounts of STE were pumped to the feeding tank from the waiting tank several times a day. A schedule was set up such that STE was pumped to the feeding tank three times daily: 233 gal (880 L) in the morning, 166 gal (630 L) midday, and 267 gal (1010 L) in the evening. These volumes were chosen because they mimic a ratio of 35%:25%:40% that is typical of residential usage (NSF International, 1999).

When the feeding tank was filled with the set volume, the STE was then gravity fed to a distribution box with equalizers. The STE, however, was not fed to the distribution box all at once. Instead, the draining of the feeding tank was controlled in a manner such that different amounts of STE were released to the distribution box a time, over the course of about an hour. This was done in order to mimic the way a septic tank would receive wastewater from a typical household.

This loading schedule was carried out every day for 171 days, from October 2002 to March 2003. During this time, the volumes of STE leaving the feeding tank were monitored daily to make sure that the pumping/loading system was operating properly. It was determined that an average of 240 gal (908 L), 178 gal (673 L), and 273 gal (1035 L) were actually being delivered to the distribution box in the morning, midday, and in the evening, respectively. This was considered acceptable since the actual volumes were never below the preset volumes. After this 171-day period, an additional pumping of 267 gal (1010 L) to the feeding tank and its subsequent draining to the distribution box was carried out each night.

Once at the distribution box, the STE was divided equally among four model leaching systems at the test site (the ESP and CPC systems described here, plus two other systems). Therefore, following March 2003, the ESP system and the CPC system were *each* fed 58 gal (220 L) in the morning, 42 gal (158 L) midday, 67 gal (253 L) in the evening, and 67 gal (253 L) at night. In other words, a minimum of 933 total gallons per day were divided among the four model systems at the test site. Therefore, the conventional and the Enviro-Septic® model systems *each* received a minimum of 233 gal (880 L) per day.

Comparative Analysis of Leachate to Septic Tank Effluent: Leachate leaving each 20' section of each model test system was fed to an individual drainage receptacle. The volume of leachate reaching each drainage receptacle was measured daily. Samples of STE (from the feeding tank) and leachate (from the drainage receptacles) were collected bi-weekly to monthly (May 14, May 28, June 3, July 9, July 29, Aug 27, September 29, November 4, November 18, and December 16, 2003). These samples were analyzed for ammonia, BOD, COD, fecal coliforms, nitrate, nitrite, total phosphorus, TKN, and TSS by Biolab Division Thetford, Robertsonville, Quebec. Statistical averages and standard deviations were estimated using samples collected from *all* functioning sections of the ESP and CPC systems. A Student's *t* test was performed in order to assess the statistical significance of the results.

Results and Discussion

Research Project 1: UNH

Test	Average concentration of STE or leachate		Number of samples	% Removal
TSS	STE	300 mg/L	18[6]	
	ES	8 mg/L	35	98%
	P&S	10 mg/L	36	97%
MPN *E. coli*	STE	126,000 per 100 mL	9	
	ES	2,100 per 100 mL	18	98%
	P&S	5,100 per 100 mL	18	96%
MPN Fecal Coliforms	STE	185,264 per 100 mL	12	
	ES	10,000 per 100 mL	24	94%
	P&S	14,000 per 100 mL	24	92%
COD	STE	450 mg/L	21	
	ES	51 mg/L*[7]	43	89%
	P&S	59 mg/L	44	87%
BOD	STE	240 mg/L	21	
	ES	43 mg/L	41	82%
	P&S	48 mg/L	42	80%
TKN	STE	75 mg/L	21	
	ES	8 mg/L	43	89%
	P&S	11 mg/L	44	86%
Ammonia	STE	61 mg/L	21	
	ES	7 mg/L*	43	88%
	P&S	10 mg/L	44	83%
Nitrate	STE	0.5 mg/L	12	
	ES	54 mg/L	24	NA[8,9]
	P&S	52 mg/L	24	

Table 1. Summary of septic component analysis results from Research Project 1 conducted at the University of New Hampshire.

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[6] The same STE was distributed to each of two ES models and each of two P&S model systems, therefore the number of samples of STE differs from the number of samples of leachate by a factor of two.

[7] * The difference between ES and P&S leachate values is statistically significant at the 95% confidence level ($P < 0.05$).

[8] NA: Not applicable

[9] Levels of nitrate are expected to rise as a result of aerobic microbial metabolism, therefore percent removal is not applicable.

Research Project 2: DBO Expert Inc.

Test	Average concentrations of STE / leachate		Number of samples	% Removal
TSS	STE	125 mg/L	10[10]	
	ES	2 mg/L***[11]	30	98%
	P&S	25 mg/L	22	80%
MPN Fecal Coliforms	STE	3,091,000 per 100 mL	10	
	ES	2,300 per 100 mL***	30	>99%
	P&S	190,000 per 100 mL	22	94%
COD	STE	441 mg/L	10	
	ES	9 mg/L***	30	98%
	P&S	87 mg/L	22	80%
BOD	STE	172 mg/L	10	
	ES	2 mg/L***	30	99%
	P&S	21 mg/L	22	88%
TKN	STE	45 mg/L	10	
	ES	2 mg/L***	30	95%
	P&S	26 mg/L	20	42%
Ammonia	STE	27 mg/L	10	
	ES	1 mg/L***	30	96%
	P&S	17 mg/L	20	30%
Phosphorus	STE	5 mg/L	10	
	ES	1 mg/L***	30	74%
	P&S	2 mg/L	20	59%
Nitrate	STE	0.1 mg/L	9	
	ES	23 mg/L***	27	NA[12]
	P&S	5 mg/L	20	

Table 2. Summary of septic component analysis results from Research Project 2 conducted in Stoke, Quebec by DBO Expert Inc.

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[10] The same STE was distributed to the ESP and CPC model systems, while leachate was collected the three different sections individually. This is why the number of samples of STE differs from the number of samples of leachate. The number of ESP leachate samples varies from the number of CPC samples because until November 2003, wastewater had reached all three ESP sections, but had only reached the first and second CPC sections.

[11] *** The difference between ESP and CPC values is statistically significant at the 99.9% confidence level ($P < 0.001$).

[12] NA: Not applicable

Septic Component Analyses

Results of the septic component analyses from Research Projects 1 and 2 are presented in Tables 1 and 2. The raw data from Research Project 2 are included in Appendix 1. In both projects, the Enviro-Septic® model systems demonstrated greater TSS removal than the conventional systems. In the UNH project, the difference in TSS removal between the systems was small. An average of 8 mg/L TSS exited the ES systems (98% removal), whereas an average of 10 mg/L TSS exited the P&S systems (97% removal). In the large-scale systems of the DBO Expert Inc., project however, ESP leachate contained over ten times less TSS than the CPC leachate (ESP 2 mg/L, 98% removal; CPC 25 mg/L, 80% removal). The difference in leachate clarity between the two systems is visually evident (Figure 6). This difference between the ESP and CPC systems is statistically significant at the 99.9% confidence level ($P < 0.001$); i.e. the probability of the difference being by chance is less than 0.001.

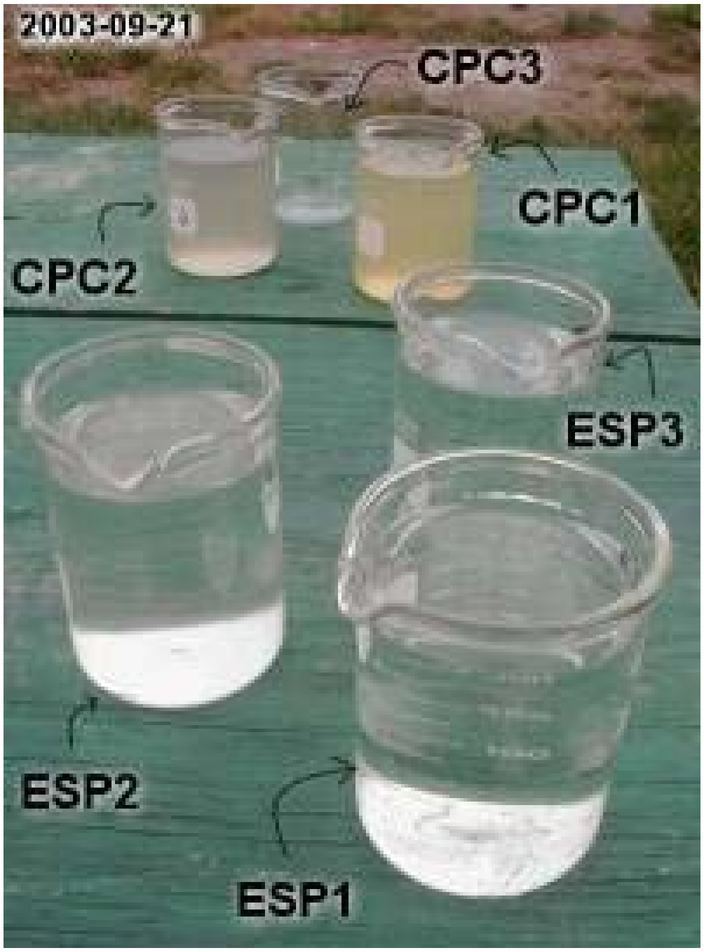


Figure 6. Photograph showing leachate samples from the three different sections of each model leaching system in Stoke, Quebec. The leachate coming out of the Enviro-Septic® system looks clear to the naked eye, whereas the leachate exiting the conventional pipe and stone system is brown in color and cloudy. The beaker labeled CPC 3 is empty because STE had not reached the third 20' section of the conventional system at the time this photograph was taken.

Enviro-Septic® removed fecal coliforms from STE better than pipe and stone systems. Throughout the UNH test, ES leachate contained an average of 10,000 MPN fecal coliforms per 100 mL (94% removal), whereas P&S leachate contained an average of 14,000 MPN per 100 mL (92% removal). This difference is small, but in the DBO Expert Inc., test, the difference is dramatic. Of the average 3 million MPN per 100 mL in the STE, only an average of 2,300 MPN per 100 mL remained in the ESP leachate (>99% removal), compared to 190,000 MPN per 100 mL remaining in the CPC leachate (94% removal). This constitutes a difference of almost two orders of magnitude and is statistically significant ($P < 0.001$). The TSS and fecal coliform results suggest that Enviro-Septic® leaching systems perform significantly better than conventional systems at filtering suspended solids and bacteria from STE, hence supporting Hypothesis 1.

In both research projects, the Enviro-Septic® systems demonstrated greater COD and BOD reduction (Tables 1 and 2) than the conventional systems. In the UNH tests, ES leachate had an average of 51 mg/L COD, whereas P&S leachate had 59 mg/L ($P < 0.05$). In the DBO Expert Inc., results, the COD difference is ten-fold (ESP 9 mg/L, 98% removal; CPC 87 mg/L, 80% removal; $P < 0.001$). The BOD results are similar. The difference between ES and P&S is small in the UNH results, but it is ten-fold in the DBO Expert Inc., tests (ESP 2 mg/L, 99% removal; CPC 21 mg/L, 88% removal; $P < 0.001$).

Results for nitrogen-containing compounds are also significant, with Enviro-Septic® facilitating the decomposition of organic nitrogen compounds and promoting nitrification more than conventional systems. In the DBO Expert Inc., results (Table 2), ESP leachate contained ten times less TKN than CPC leachate (ESP 2 mg/L, 95% removal; CPC 26 mg/L, 42% removal; $P < 0.001$). For ammonia, leachate from the UNH ES systems contained 7 mg/L (88% removal), whereas P&S leachate contained 10 mg/L (83% removal). While this difference is significant at the 95% confidence level ($P < 0.05$), the difference in ammonia values between the DBO Expert Inc., ESP and CPC results are much more pronounced (ESP 1 mg/L, 96% removal; CPC 17 mg/L, 30% removal; $P < 0.001$). The dramatic disappearance of ammonia suggests a high rate of nitrification in the Enviro-Septic® systems. Since nitrate is a product of nitrification, its levels increase dramatically in the Enviro-Septic® systems. While slightly more nitrate was present in the UNH ES system leachate than the P&S leachate (ES 54 mg/L; P&S 52 mg/L), much more was present in the DBO Expert Inc., ESP leachate (ESP 23 mg/L; CPC 5 mg/L; $P < 0.001$). Levels of nitrite in the STE and leachate of the model systems from both research projects were very low (approaching the limits of detection; data not shown), therefore no conclusions were drawn from them.

Finally, Enviro-Septic® systems were more effective at removing phosphorus-containing compounds from STE than conventional systems. From the DBO Expert Inc., results, ESP displayed a 74% removal of phosphorus, compared to a 59% removal by the CPC system ($P < 0.001$).

A decrease in leachate levels of TSS, COD, BOD, TKN, phosphorus, and ammonia, in addition to an increase in nitrate levels, indicate the presence of aerobic microbial metabolism. Such a dramatic decrease of these septic components by the Enviro-Septic® leaching systems suggests that the magnitude of the aerobic microbial ecosystem is extensive. Therefore, these results support Hypothesis 2, that Enviro-Septic® systems accomplish decomposition of wastewater faster and more efficiently than conventional pipe and stone systems by promoting and maintaining a more substantial aerobic microbial ecosystem**.** Although the Enviro-Septic® systems out-performed conventional systems with respect to all the septic compounds analyzed in both the UNH and DBO Expert Inc., tests, the results from DBO Expert Inc., were much more dramatic. This is likely because the model systems in Stoke, Quebec, are larger and, therefore, better representative models of real-life systems.

Aerobic Microbial Biofilms and System Treatment Capacity

The role of the perforated pipe in a conventional leaching system is basically to distribute the wastewater to the underlying soils. Although the stone bed offers some surface area upon which waste-treating microbes can grow, it too functions primarily to distribute wastewater. Therefore in a conventional system, the majority of wastewater treatment likely takes place in the sand and native soils below the system. Enviro-Septic® systems are different. The primary function of Enviro-Septic® pipe is to provide an ideal environment for the growth of aerobic microbes, which are highly efficient at treating waste. It accomplishes this by providing extensive surface area for microbial biofilms, and by allowing air, and hence oxygen, to penetrate the system. Sewage treatment plants across the nation employ a similar technology by using attached culture systems to support microbial biofilms and supplying oxygen to them. Since the aerobic microbes grow within the pipe, this is where the majority of wastewater treatment likely takes place. The fact that there was no statically significant increase in wastewater treatment (with respect to all tested parameters except phosphorus) in the section of the DBO Expert Inc., ESP model system with twelve inches of sand compared to the sections with six inches of sand (data not shown) further supports the theory that most of the wastewater treatment happens within the Enviro-Septic® pipe, and not in the soils below it.

In New England, each state provides specific guidelines for septic system design and installation. For example, the allowable loading rate of a system (gallons of wastewater per square foot of soil footprint per day; gal/ft^2/day) is dependent upon 1) the percolation rate (minutes per inch; min/in) of a site's native soils and on 2) the design flow (gallons per day), which is the amount of wastewater that can be expected to be discharged to the system by the facility on site. A designer can determine the necessary size of an individual leach field once the allowable loading rate is established. For conventional stone bed leaching systems, the State of Vermont allows a maximum loading rate of 1.2 gal/ft^2/day in soils with a percolation rate of 4 min/in, but only 0.31 gal/ft^2/day in soils with a percolation rate of 60 min/in (Vermont Agency of Natural Resources, 2002). In New Hampshire, loading rates of 0.71 and 0.20 gal/ft^2/day are allowable for 4 and 60 min/in soils, respectively, for a two-bedroom residence (New Hampshire Department of Environmental Services, 1999). The State of Massachusetts would allow a loading rate of 0.74 gal/ft^2/day for Class I soils with a percolation rate of 4 min/in (Massachusetts Department of Environmental Protection, 1996).

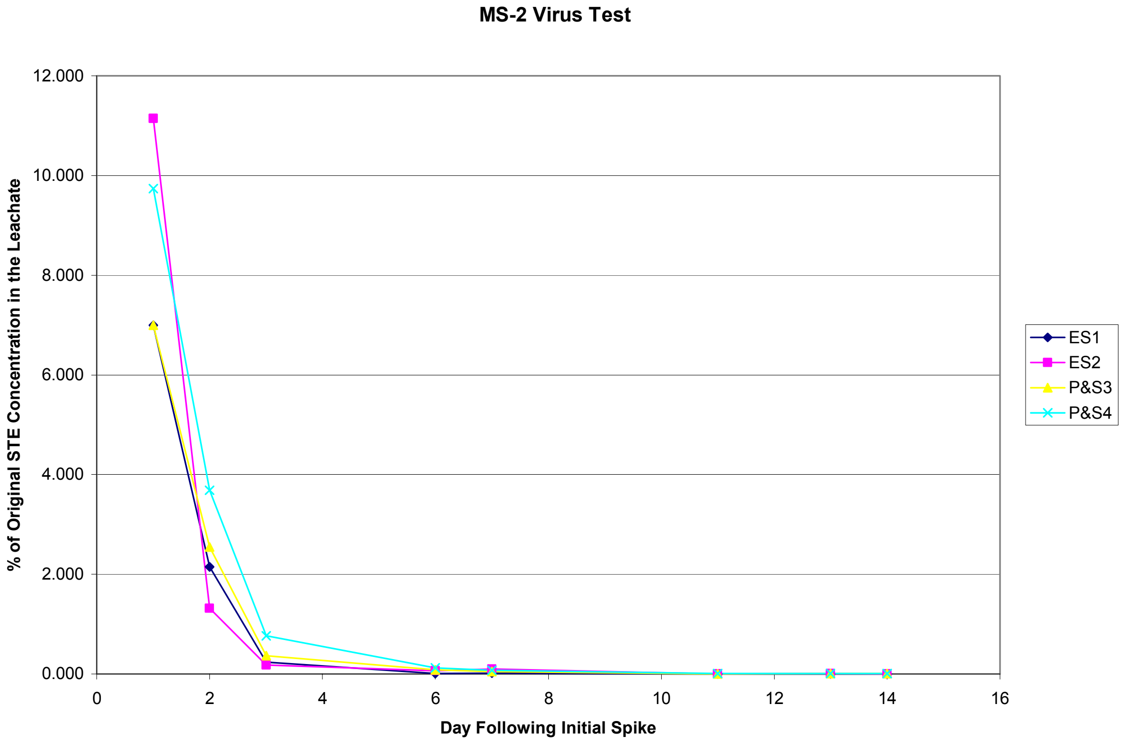
Since Enviro-Septic® systems do not primarily rely on the underlying soils to treat wastewater like pipe and stone bed leaching systems do, it does not make sense to define their allowable loading rates in terms of gallons per square foot of soil footprint per day. Instead, the loading rate could be expressed by dividing gallons per day by the surface area of the microbial biofilms supported by the pipe. In order to determine the biofilm surface area, sensors were installed in the model systems at the Stoke, Quebec test site to determine the levels of liquid inside of them. Over the course of one year, the model ESP system reached a steady state such that the STE remained at a depth at or below four inches inside the pipe. Therefore, a microbial biofilm existed on the bottom 17 inches of the inside circumference of the pipe. Since the system is sixty feet in length, the biofilm surface area is 85 ft^2, and the biofilm loading rate is 2.7 gal/ft^2/day.

A biofilm loading rate of 2.7 gal/ft^2/day is over twice the maximum allowable rate for stone bed leaching systems in Vermont, and it is nearly four times greater than New Hampshire's and Massachusetts' allowable loading rates for stone bed leaching systems in permeable soils. Moreover, Enviro-Septic® systems could function at an even higher biofilm loading rate because the maximum depth that liquid can reach inside Enviro-Septic® pipe is eight inches. Therefore, it could theoretically support a 35% larger microbial biofilm that could treat an 80% greater load volume than the model system in Stoke, Quebec.

In New Hampshire, the minimum required center-to-center pipe spacing for an Enviro-Septic® system is only 1.5 feet (slope must be 0-10% and percolation rate 1-10 min/in; Enviro-Septic® & Simple-Septic® Leaching Systems Design and Installation Manual, 2003). The ability to space pipes only six inches apart allows for a smaller soil footprint. This is possible because the Enviro-Septic® pipe carries out the majority of the treatment, and the role of the underlying soils is basically to carry the treated wastewater away. Furthermore, soils beneath an Enviro-Septic® system are less burdened than those under a conventional system because treated wastewater is more easily distributed than untreated wastewater.

UNH Virus Tests

For the virus tests conducted at UNH, the STE used to spike the systems contained 2.0-3.8 million PFU/mL live MS-2 viral particles and 200,000-410,000 PFU/mL live poliovirus particles. Over a 14-day period, the rate at which these particles were discharged from the systems steadily declined. By the final day of the test, the concentration of MS-2 in the leachate was approximately 0.005% of the initial STE concentration, and the concentration of poliovirus in the leachate was approximately 0.0006% of the initial STE concentration. The rate at which both types of virus escaped from the leaching systems was essentially the same for both ES and P&S (Figure 7). Therefore it can be concluded that Enviro-Septic® leaching systems perform as well as conventional systems at filtering viruses from STE.



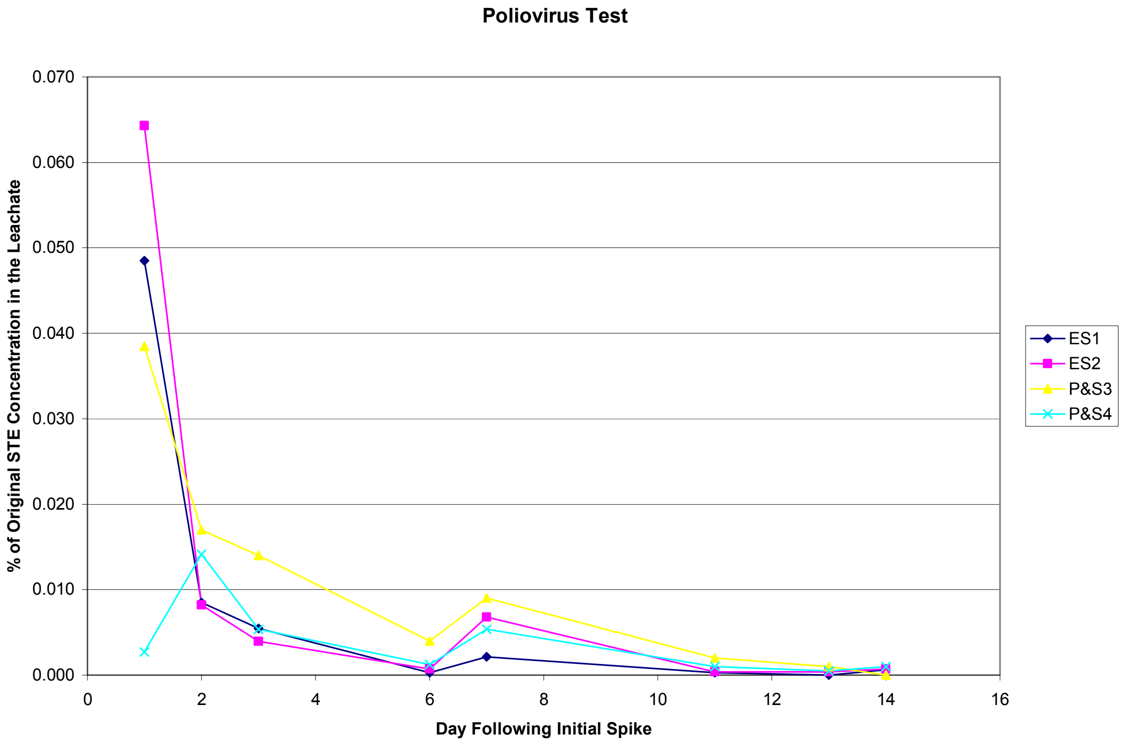


Figure 7. Results of the virus tests. Leachate virus concentrations are presented in terms of percent of the virus concentration in the original spiked STE. There is no significant difference between the ES and P&S systems for filtering viruses from wastewater.

Research Project 2: DBO Expert Inc., Wastewater Flow Tests

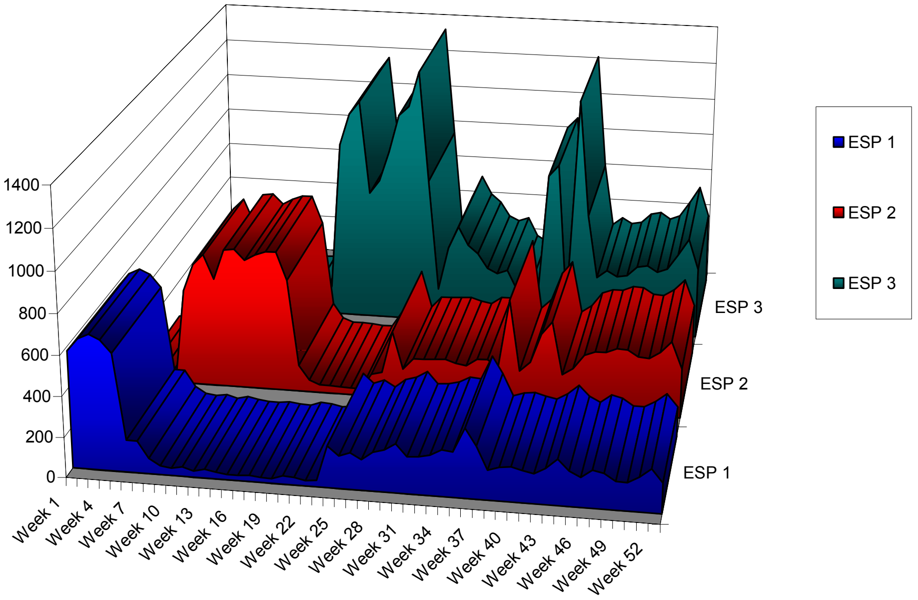
The progress of system function, i.e. the extent of flow of STE through the leaching pipes, has been monitored by DBO Expert Inc., since delivery of STE into the model systems began in October 2002. It was possible to determine when and how much STE reached the second and third 20' lengths of pipe because the bottom of each of the systems' sections were drained individually. The results of this experiment are presented in Figure 8. The data from the ESP system indicate the STE started flowing into the second section of the Enviro-Septic® pipe by Week 6, and that it reached the third section of the system by Week 17. By Week 30, the volumes of STE being treated by the three different sections began to equalize. Interestingly in the conventional system, it took about 36 weeks for STE to reach the second section of pipe and the third section remained non-functional for over a year.

<u>These results support Hypothesis 3, that Enviro-Septic® systems distribute wastewater better, i.e. over a larger surface area, than conventional systems</u>**.** The improved wastewater distribution of Enviro-Septic® systems may be due to their pipes' design, but it may also be due in part to the medium (sand) in which they are installed. It is probable that sand takes greater advantage of the surface tension of water and hence exhibits greater wicking action than the crushed stone in conventional pipe and stone systems. Since more of the Enviro-Septic® pipe is functioning at any given time, this means that there are more microbial biofilms treating the waste at a time. Furthermore, if Enviro-Septic® leaching systems distribute wastewater over a larger area, then more of the underlying soils are sharing the burden of further treating and distributing it as it percolates through them. This in turn would prevent any one area of the underlying soils from becoming saturated (and hence, less efficient), and may extend the lifetime of the leach field.

Final comments

The results of the experiments described above clearly demonstrate that the Enviro-Septic® leaching system performs as well as conventional pipe and stone systems in all tested aspects of wastewater treatment, and significantly better than conventional systems in most areas of treatment. This can be primarily attributed to the design of the Enviro-Septic® system, which supports aerobic microbial growth, and to the use of sand as a surrounding medium.

Volume (L) of leachate recovered from each 20' section of the Enviro-Septic® model system, Stoke, Quebec



Volume (L) of leachate recovered from each 20' section of the conventional model system, Stoke, Quebec

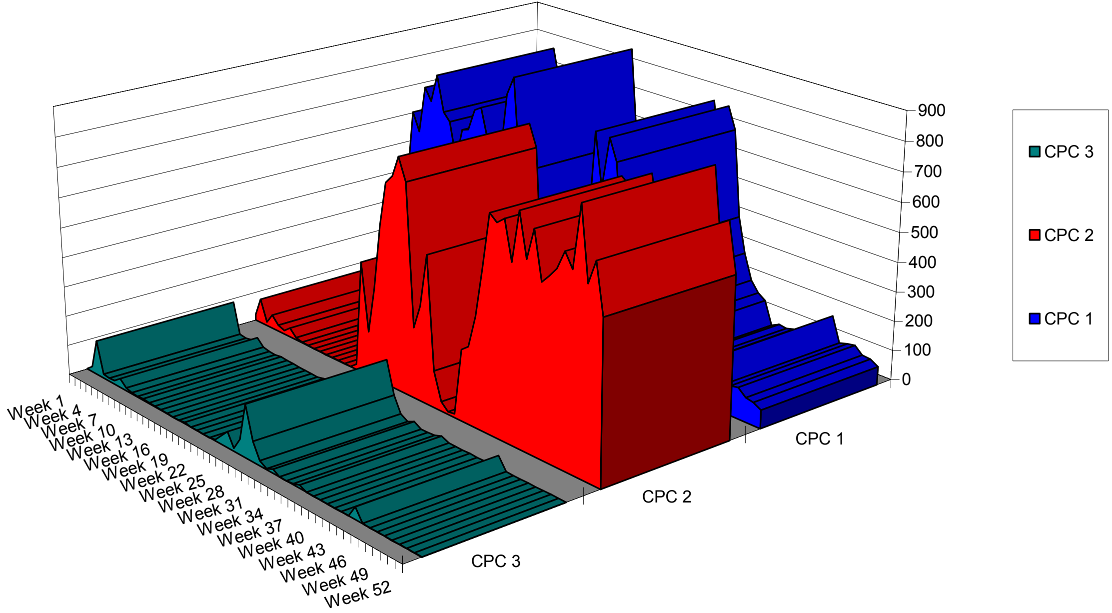


Figure 8. Volumes of leachate that reached the various sections of each model system in Stoke, Quebec, over one year. ESP 1, 2, and 3 refer to the first, second and third 20' lengths of the Enviro-Septic® model system, respectively, while CPC 1, 2, and 3 refer to the first, second, and third 20' lengths of the conventional pipe and stone system, respectively. The volumes include rainwater that infiltrated the systems.

Reference List

Cano, R.J. and J.S. Colomé, *Essentials of Microbiology*. St. Paul: West Publishing Company, 1988.

"Enviro-Septic® & Simple-Septic® Leaching Systems Design and Installation Manual: Sloping, Level, and Multi-Level™ Leaching Systems for Residential and Commercial Applications. 2003." Presby Environmental, Inc., Sugar Hill, New Hampshire, 2003.

Fenchel, T., G.M. King, and T.H. Blackburn, *Bacterial Biogeochemistry. The Ecophysiology of Mineral Cycling*. San Diego: Academic Press, 1998.

Grady, C.P.L., G.T. Daigger, and H.C. Lim, *Biological Wastewater Treatment*. New York: Marcel Dekker, Inc., 1999.

Hallahan, D.F. "The standard septic system: still an effective choice for onsite wastewater treatment." *Water/Engineering & Management* 149 (2002): 33-36.

Heufelder, G. and S. Rask, *The Second Compendium of Information on Alternative Onsite Septic System Technology in Massachusetts*. Environment Cape Cod, 1-69, 2001.

Linsley, R.K., J.B. Franzini, D.L. Freyberg, and G. Tchobanoglous. Water-Resources Engineering. New York: McGraw-Hill, Inc., 1992.

Massachusetts Department of Environmental Protection. 310 CMR 15.000. The State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of On-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage, 1996.

New Hampshire Department of Environmental Services. Water Division. Subdivision and Individual Sewage Disposal System Design Rules, Chapter Env-Ws 1000. Concord, New Hampshire, 1999.

NIST/SEMATECH e-Handbook of Statistical Methods, http://www.itl.nist.gov/div898/handbook/, 2004.

NSF International. "Standard: Residential Wastewater Treatment Systems." NSF/ANSI 40, 1999.

State of Vermont, Agency of Natural Resources, Department of Environmental Conservation. Wastewater Management Division. Environmental Protection Rules, Chapter 1, Wastewater System and Potable Water Supply Rules. Waterbury, Vermont, 2002.

U.S. Environmental Protection Agency. "National water quality inventory: 1996 report to congress." EPA 841-R-97-008, 1998.

U.S. Environmental Protection Agency. "Voluntary national guidelines for management of onsite and clustered (decentralized) wastewater treatment systems." EPA 832-B-03-001, 2003.

Winneberger, J.H.T. *Septic Tank Systems: A Consultant's Toolkit*. Boston: Butterworth Publishers, 1984.

Appendix 1. Raw data from DBO Expert Inc., wastewater component analyses and estimated statistical results.

TSS (mg/L)	5/14/03	5/28/03	6/3/03	7/9/03	7/29/03	8/27/03	9/29/03	11/4/03	11/18/03	12/16/03	n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	67	74	70	112	144	173	131	118	207	151	10	124.70	46.32					
CPC1	7	8	9	45	60	91	20	2	3	40	22	25.14	23.11	79.84	50	3.26	22.84	11.27
CPC2	7	15	9	25	17	34	54	27	15	9								*Signif
CPC3									51	5								
ESP1	1	1	2	1	1	2	2	5	7	3	30	2.30	1.51	98.16				
ESP2	2	2	4	1	2	1	1	1	1	3								
ESP3	3	3	4	2	3	1	1	1	3	5			ave SD					
													12.31					
Ammonia	(mg/L)										n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	15	21	14	23	27	31	29	36	35	36	10	26.70	8.23					
CPC1	4.9	14	2.8	19	30	33	38	39			20	18.64	10.87	30.19	48	3.27	17.65	5.85
CPC2	0.5	13	9.6	19	18	11	24	16	15	15								*Signif
CPC3									25	26								
ESP1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	30	0.99	1.53	96.30				
ESP2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9								
ESP3	2.3	0.5	0.5	1	1.4	0.5	0.5	0.5	3.8	8.2			ave SD					
													6.20					
TKN	(mg/L)										n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	26	31	29	36	39	45	47	67	81	51	10	45.20	17.48					
CPC1	13	20	12	24	33	41	50	56			20	26.40	14.04	41.60	48	3.27	24.35	7.95
CPC2	0.9	18	14	26	22	12	33	24	30	22								*Signif
CPC3									47	30								
ESP1	0.9	0.9	0.9	0.9	0.9	1.5	0.9	0.9	0.9	0.9	30	2.05	2.81	95.47				
ESP2	0.9	0.9	0.9	0.9	0.9	1.8	0.9	0.9	0.9	1.6								
ESP3	5.4	1.1	0.9	5	3	0.9	1	0.9	11	12			ave SD					
													8.42					
BOD5	(mg/L)										n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	98	152	47	211	205	275	190	168	203	172	10	172.10	63.26					
CPC1	8	17	8	57	7	98	4	2	5	4	22	21.36	24.61	87.59	50	3.26	19.10	11.73
CPC2	2	27	12	33	15	14	16	16	19	18								*Signif
CPC3									75	13								
ESP1	2	2	2	2	2	2	2	2	2	2	30	2.27	1.01	98.68				
ESP2	2	2	2	2	2	2	2	2	2	2								
ESP3	2	2	2	2	2	2	2	2	6	6			ave SD					
													12.81					

COD	(mg/L)										n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	213	432	270	448	518	691	541	391	478	431	10	441.30	134.89					
CPC1	18	166	17	154	64	207	121	30	46	37	22	86.77	60.71	80.34	50	3.26	78.24	32.14
CPC2	3	142	46	96	90	92	144	41	63	69								*Signif
CPC3									207	56								
ESP1	3	3	3	3	6	6	3	6	17	6	30	8.53	9.51	98.07				
ESP2	3	3	6	3	3	17	3	3	29	6								
ESP3	6	3	6	19	3	6	17	6	46	12			ave SD					
													35.11					
Phosphorus	(mg/L)										n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	3.6	4.3	3.8	5.4	5.8	6.1	6.2	5.4	5.8	5.6	10	5.20	0.95					
CPC1	1.8	2.9	2.1	0.3	1.7	3.1	0.4	0.3			20	2.15	1.07	58.75	48	3.27	0.82	0.72
CPC2	0.3	2.8	2.5	3.4	2.7	2.8	4	2.7	2.4	1.9								*Signif
CPC3									2.4	2.4								
ESP1	1.1	1.1	1.2	1.7	1.8	1.8	1.4	1.9	1.4	1.9	30	1.32	0.45	74.55				
ESP2	0.9	0.8	0.8	1.7	1.7	1.4	1.8	1.9	1.2	1.5								
ESP3	0.8	0.5	0.4	0.7	1.3	0.9	1.2	1.4	1.7	1.8			ave SD					
													0.76					
Coliforms	(MPN per 100 mL)										n	AVE	SD	%red	d.f.	t 99.9%	difference	t test 99.9%
STE	2600000	2400000	2100000	520000	16000000	1800000	1600000	1600000	1800000	490000	10	3091000	4588605					
CPC1	320000	400000	150000	100000	260000	370000	340	230	1100	40	22	189669	264295	93.86	50	3.26	187410	123083.76
CPC2	9	1100000	170000	550000	54000	4900	4100	37000	160000	51000								*Signif
CPC3									430000	10000								
ESP1	120	2800	390	21000	160	36	36	18	9	120	30	2259	4641	99.93				
ESP2	140	4100	730	180	250	130	2000	150	480	200								
ESP3	99	9	1500	12000	1800	18	90	2900	11000	5300			ave SD					
													134468					
Nitrate	(mg/L)										n	AVE	SD		d.f.	t 99.9%	difference	t test 99.9%
STE	0.05	0.05	0.05	0.05	0.05		0.05	0.18	0.1	0.05	9	0.07	0.04					
CPC1	8.9	4.7	6.8	0.05	0.05		0.05	0.05	0.05	0.05	20	5.28	6.30		45	3.28	18.02	6.44
CPC2	24	4.3	5.3	0.38	4.3		8.5	8.7	12	15								*Signif
CPC3									0.11	2.3								
ESP1	24	25	20	16	16		28	15	23	26	27	23.30	7.00					
ESP2	29	25	26	21	17		28	15	27	17								
ESP3	30	45	33	25	15		27	17	25	14			ave SD					
													6.65					