Project Final Report

The Effect of Selected Treatment Technologies on the Hydraulic Function of Stressed Onsite Septic Soil Absorption Systems - The Results of a Pilot Test Protocol

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Executive Summary

Many communities in the Commonwealth of Massachusetts are engaged in wastewater management planning. This process is often extended in coastal communities because multi-year environmental assessments are required to adequately determine treatment needs. Extended planning periods often result in the needless expenditures of funds to replace septic systems where more centralized options are likely. In order to provide tools to avoid these expenditures, the Massachusetts Alternative Septic System Test Center with support under the Commonwealth of Massachusetts 319(b) Competitive Grants Program endeavored to develop and conduct a protocol to test products that purportedly extend the "life" of a soil absorption system and restore lost hydraulic function. By identifying such products/strategies, communities might allow individuals to forego more-expensive repair options in areas where the elimination of septic systems is imminent and preserve capital that might be used for alternative wastewater treatment options.

Four different technology types capable of being used or retrofitted on existing systems were chosen for testing: addition of purportedly "beneficial" microbes, the introduction of air into the septic tank along with purportedly-beneficial microbes, the introduction of air alone into the septic tank and the introduction of air into the soil absorption system (SAS) directly. Hydraulic function and treatment were compared with a control situation to which no treatment was provided. This report focuses on hydraulic function elements of the SAS, however the consequences of restored hydraulic function to treatment for pathogens was also investigated. This later portion of the investigation was completed by sampling the percolate beneath the SAS following six inches of passage through sand meeting the specification of ASTM C-33.

In order to provide comparable test conditions that simulate a stressed or "failed" condition, a regimen of hydraulic loading up to five times the allowable rate (Long Term Acceptance Rate or LTAR as specified in Massachusetts CMR 15.000[1]) was provided. The stressing period, took approximately ten months. Following this period, the manufacturers' products were applied in accordance with their respective standard installation/application procedures.

Of the four products tested, the introduction of air alone into the septic tank (RetroFAST™) was the most effective means of restoring hydraulic function. Although the SoilAir™, which introduces air directly into the soil absorption system, showed promising ability to restore the hydraulic function during its operation, the test of this product was discontinued due to the inability to isolate these effects from the other test cells. The introduction of air with purportedly beneficial microbes (White Knight™) also demonstrated generally-beneficial results, however the ponding levels within that test cell were variable, sometimes indicating ponding to 50% of the storage elevation of the trench. We also observed the refusal of septic tank effluent into the

[1] 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

leaching trench on two occasions. The manufacturer posits that the wastewater source contained more non-organic components than typical of household wastewater, and that the accumulation of this material restricted the necessary air flow within the treatment unit. The introduction of purportedly-beneficial bacteria alone showed no discernible effect and ponding levels in that trench were similar to the control. It should be noted that this study, which tested only one of over fifty products available that purport to have a beneficial use, may not be indicative of the full range of bacteria/organism additives available on the market.

The reader is reminded that the protocol used in this study may not be an indicator of longer-term performance and maintenance of hydraulic function due to time and resource constraints of the test. Nevertheless the data presented suggests that certain strategies may be beneficial in the short run (up to at least two years) to avoid the large capital expenditure of septic system replacement in areas where alternative solutions to wastewater management are imminent. It should also be noted that the performance of the specific products mentioned may not be indicative of the performance of all products in a class of products/strategies.

The testing protocol used appears to provide a useful means to test restorative products. These researchers believe that the hydraulic loading regimen carried out in this study represents an appropriate test-case scenario for household organic and hydraulic loading for testing the efficacy of such technologies.

Introduction

Soil absorption systems (alternately called leachfields, leaching beds, seepage pits, tile beds and others) are used for the dispersal of wastewater in the onsite septic system. Under most present-day regulations, the soil absorption system (SAS) follows some pretreatment in a solids-retention container referred to as a septic tank. Together, the septic tank, a distribution device and the SAS are the "septic system". The septic tank portion of the system is a biological treatment unit that digests organic matter anaerobically resulting in the reduction of solid material prior to conveyance of liquefied waste and water to the SAS. As part of regular maintenance, undigested waste in the septic tank is periodically pumped out before excessive solids build up and pass through to the SAS. The SAS is also a biological treatment unit that, when properly operating, further digests the septic tank effluent aerobically and allows the resulting liquid to drain away from the area of deposit at a rate equal to or exceeding that of the supply. A schema of a typical septic system is presented in figure 1. Despite the best attempts at maintenance, many SAS may eventually lose the ability to convey septic tank effluent away at the rate at which it is supplied. When this happens, septic tank effluent either surfaces to the ground above the SAS or backs up into the home. This situation is called system "failure".

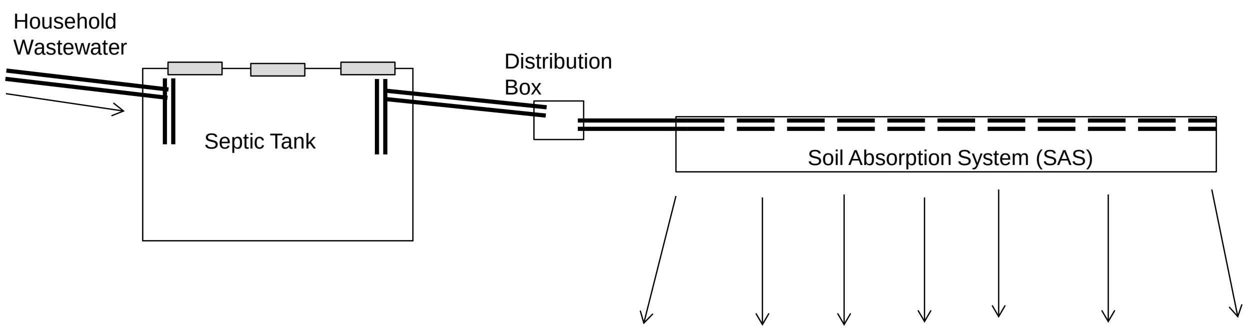

Figure 1. Simplified schema of a typical septic systems showing common components.

A number of products and strategies are commercially available that purportedly restore a failed or a marginally-failed system's ability to continue to function properly. Collectively these products are referred to herein as "restorative" products. The purpose of this study was threefold. Foremost, we endeavored to design and conduct a test protocol. Discussion with staff from the National Sanitation Foundation, an international third-party testing entity, suggested that they had received inquiries regarding this type of test, however to this date no protocol for testing has been developed. Secondly, we endeavored to test examples of four major strategies that purport SAS restoration. These strategies include addition of purportedly "beneficial" microbes, the introduction of air into the septic tank along with purportedly-beneficial microbes, the introduction of air alone into the septic tank and the introduction of air directly into the SAS. These four means were compared to a control SAS to which no strategy treatment or product was applied. Our final objective for this study pertains to areas where replacement of standard septic systems with collected or centralized advanced treatment options is imminent. In that context, we sought to identify temporary options for extending the useful life of septic systems in order to obviate the need for large capital expenditure to replace them (since septic systems in these areas would no longer be used following the availability of other options). Accordingly those restorative technologies with portable and reusable components received prioritized attention.

Description of Testing Locations

Five test locations were constructed for the purpose of testing products that purportedly restore SAS (figure 2.). Each test location was equipped with a 1500-gallon single compartment tank a distribution box and a leaching trench. The septic tank complied with the Commonwealth of Massachusetts Regulation 15.223 (310 CRM 15.000 – Title 5). All three access covers for each septic tank were left accessible to accommodate the range of treatment options and placement. The distribution box following the septic tank was equipped with three discharge ports, one which supplied the test trench and two that allowed the diversion of septic tank effluent to the SAS or to void. Five single leaching trenches were constructed to serve each of the five septic tanks. SAS were constructed in lined 5 ft. wide cells to allow for trenches 30 ft. long x 2 ft. wide with an effective depth of 12". Trenches were constructed of ¾ in double-washed aggregate and perforated pipe. Three observation ports were placed in each trench at approximate distances of 7.5 ft., 15 ft. and 22.5 ft. from the proximal end of the trench. Designations for these observation ports were as follows: most proximal port to the septic tank is "Port A", the center observation port is "Port B", and the distal-most observation port is "Port C". Pictures of the five-cell installation are presented in figure 3. Six inches of ASTM C33 sand were placed beneath each aggregate trench (figure 4). Each test cells drained through a sample collection point prior to conveyance to a wastewater treatment facility. Each septic tank received wastewater from a common source and volumes were verified daily by means of calibrated spill buckets. Following the conditioning phase, described below, each of the four technologies and the control were randomly assigned one of the five testing locations.

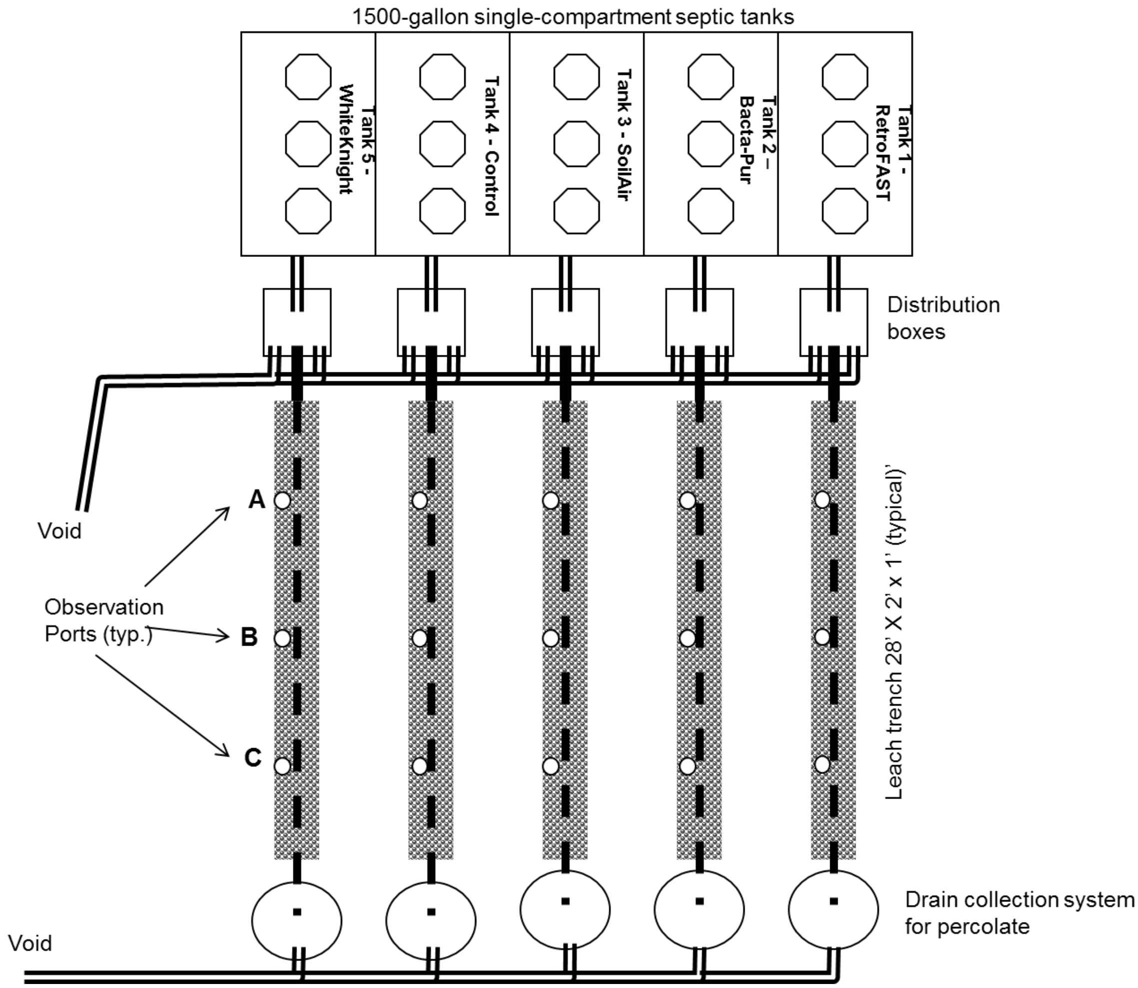

Figure 2. Schema showing test location for products purporting to restore failed septic systems. Four product locations and one control location are shown.

Trench "Conditioning"

The testing of products that purport to restore SAS presents challenges that differ from standard product tests. Foremost, since these products are designed for use in situations where SAS are stressed or failed, the first challenge was to stress all the SAS in a comparable way that simulates realistic loading scenarios while allowing for the completion of the test within a reasonable period of time. The preparation of the trenches in such a way that they can serve as useful test scenarios herein is called "conditioning". Conditioning in this context involves the systematic acceleration of natural processes that lead to reduced hydraulic function of the SAS. It involves the interplay of biological loading, solids introduction and hydraulic challenges to the SAS.

Because of the many variables involved (including temperature, SAS configuration, wastewater strength variability, etc.) conditioning is not an exact science. The primary goal in side-by-side comparisons of restoration products is to stress all the SAS in comparable ways and in such a manner as to simulate a realistic failure in the field. In this study, we prepared five identical test situations comprised of a septic tank and a 30-ft long stone aggregate trench supplied with wastewater from a common source. The flows designed for the system allowed for retention times in the septic tank that might realistically be expected in field situations (3-5 days). The stone trenches in this study were placed in ASTM C33 sand which, in accordance with CMR 15.242, would receive a hydraulic loading rate of 0.74 gal/day/sq. ft. (~ 92/gal/trench/day). At this specified loading rate, a normal "failure" might not be expected for twenty+ years. With no previous studies to guide a design loading specification that would cause SAS failure, the hydraulic regime presented in table 1 was chosen based on design conveniences as well as values that we hoped would allow the completion of the study in a reasonable (2-year) period.

Date Range	Hydraulic Loading Rate gal/sq. ft./day	Gallons applied per trench	Comment
6-16-2011 to 2-6-2012	3.63	450	Ponding first observed 7-19-11
2-6-2012 to 2-27-2012	2.4	300	
2-27-2012 to 3-7-2012	1.2	198	
3-7-2012 to 4-25-12	0.8	99	
4-25-12 to end of test	0.96	119	Test started 5-7-2012

Table 1. Progression of hydraulic loading challenges to test cells during the testing of restoration products at the Massachusetts Alternative Septic System Test Center 2011- 2013.

Influent wastewater for these tests originated from residential households and a county correctional facility.

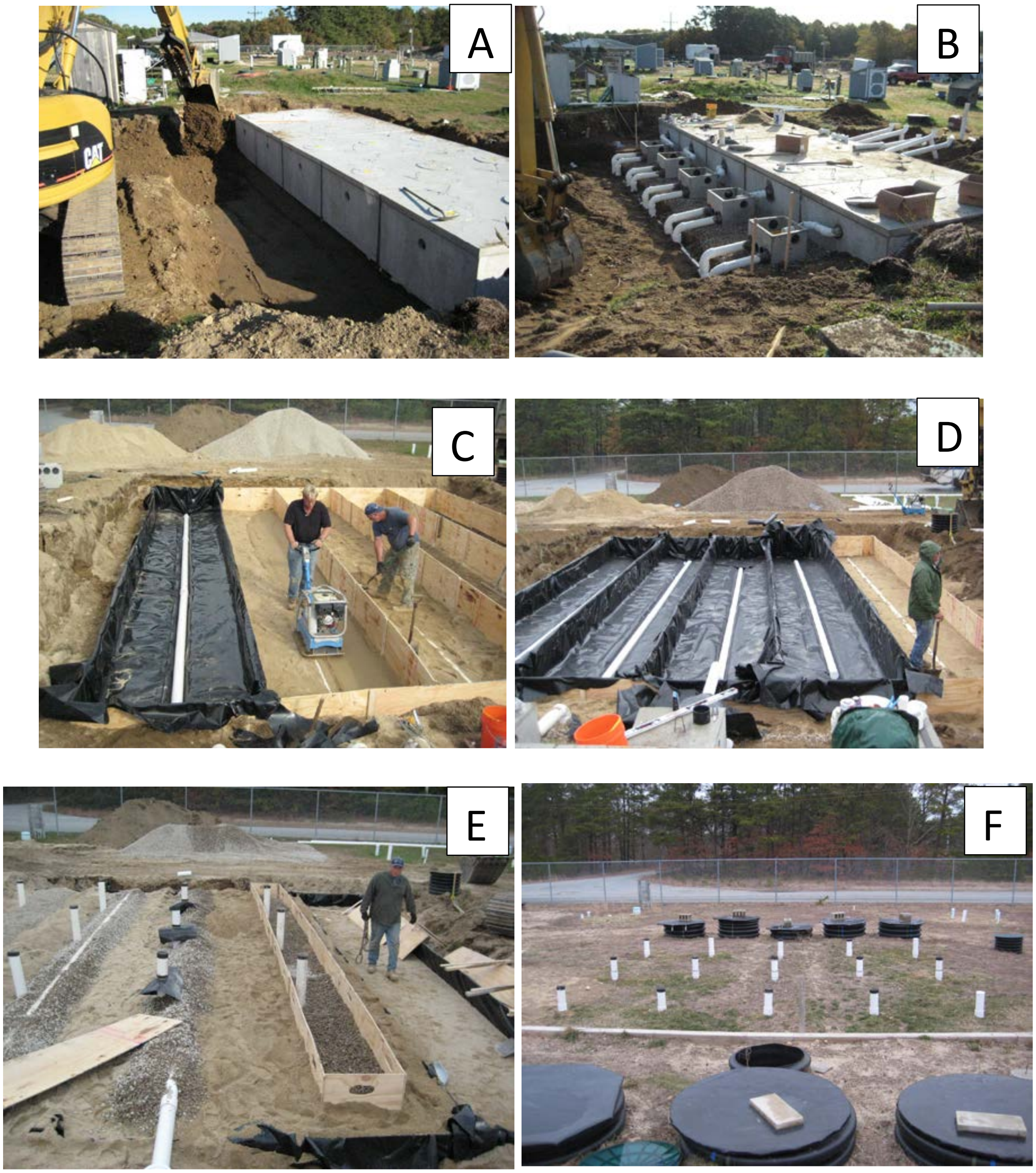

Figure 3. A. Placement of five 1500-gallon single compartment septic tanks (H-10 Loading), B. Placement of distribution boxes and piping to void, C-D Leaching test cells in preparation, E Leach trenches prior to backfilling showing observation ports. F. Leach trenches after backfill and ready for test.

Test Candidates

One purpose of this study was to identify the range of technologies that might be applied to restore SAS. Four strategies were identified and previously discussed. Since more than one manufacturer/vendor of each product was found in three of the cases (microbial addition, air and a combination of microbes and air addition to the septic tank), a single product from each class was randomly chosen from each of these three classes following a statement of interest by the manufacturers. Only one manufacturer of a product that mechanically provides air directly to the SAS was identified and hence no random selection process was necessary. A control test cell, where no restoration product was employed, is used for comparison of product performance.

Test Measures

When an SAS is said to “fail”, it usually means that wastewater is no longer percolating away from the SAS. This situation usually presents as a backup of wastewater to the home or a surfacing of wastewater to the surface of the ground in the area of the SAS. A surrogate measure of SAS failure is excessive “ponding”. Ponding is the accumulation of wastewater above the soil-aggregate interface and can be measured by using observation ports. In this study three observation ports were installed in each trench and ponding was measured five times per week at 1045 – 1100 h. In addition, continuous monitoring with data-logging devices was performed in the middle inspection port. A profile representation of the SAS with sampling ports is presented in figure 4.

The ponding measurements were taken by recording the height of the observation port and then measuring from a benchmark location on the upper rim of the port the liquid surface. Ponding depth was determined by subtraction (total observation port height - liquid height). The standard time of measurement was arbitrarily chosen to occur 1030 – 1100 which coincides with a hiatus in the daily dosing. Design loading was apportioned during the day with 35% of the flow administered between 0600h and 0900h, 25% between 1100h and 1400h, and 40% between 1700h and 2000h. The total daily inflow to each tank was between 300 and 450 gallons (see table 1). Accordingly, the period for ponding measurement was just prior to the second dosing series of the day. In addition to ponding measurements, periodic measurements and assays were conducted at the exit of the septic tank and the percolate or the field.

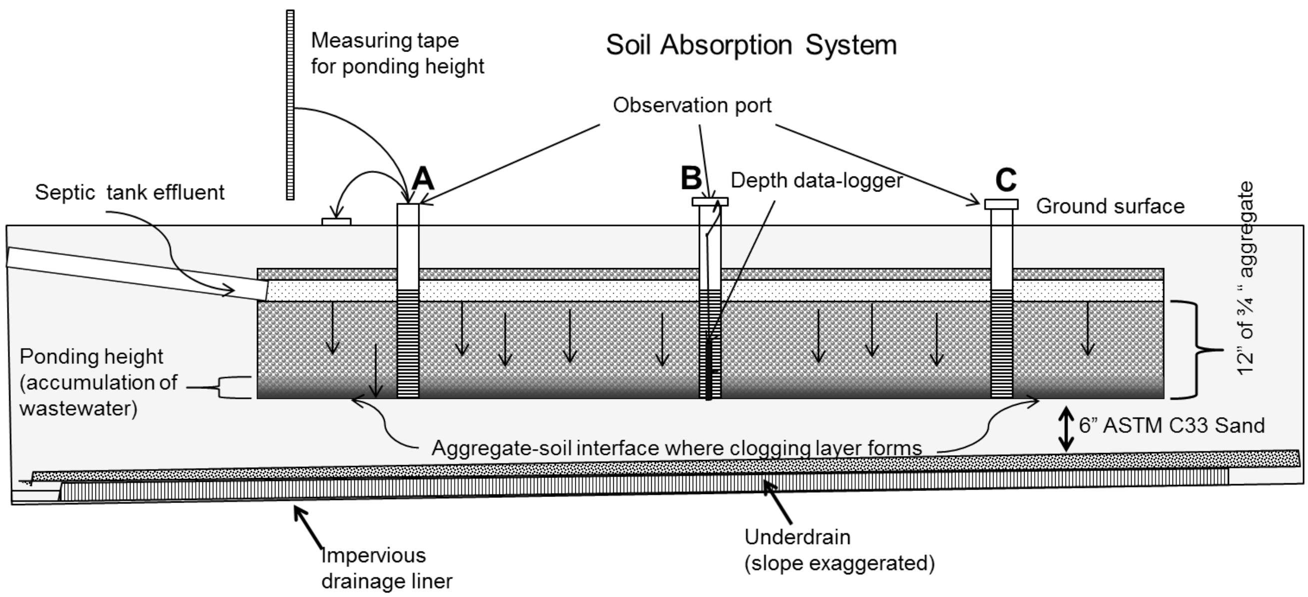

Figure 4. Schemata showing observation port placement and ponding measurement.

Results

Trench Comparability

The endpoint of trench conditioning was arbitrarily chosen based on the ponding level in relation to the effective depth of the trenches. It was decided that at least an 8" ponding level in a 12" effective depth of trench would represent a level of stress appropriate for the application of a restorative technology. This level occurred in all trenches approximately seven months after initial introduction of the supply flow (figure 5).

Flow to the trenches was purposefully interrupted on two occasions (March 3 – 7, 2012 and March 19 – 30, 2012) in order to confirm that all five trenches would similarly respond to renewed hydraulic loads after a period of rest, and that all trenches could be considered similarly stressed. Since all trenches resumed ponding levels within 2.5 inches of each other in similar timeframe, the product testing procedures began in May 2012. Occasional malfunction of the wastewater feed system resulted in brief reduction of ponding levels in some trenches, however on these occasions ponding levels resumed to prior levels within one day.

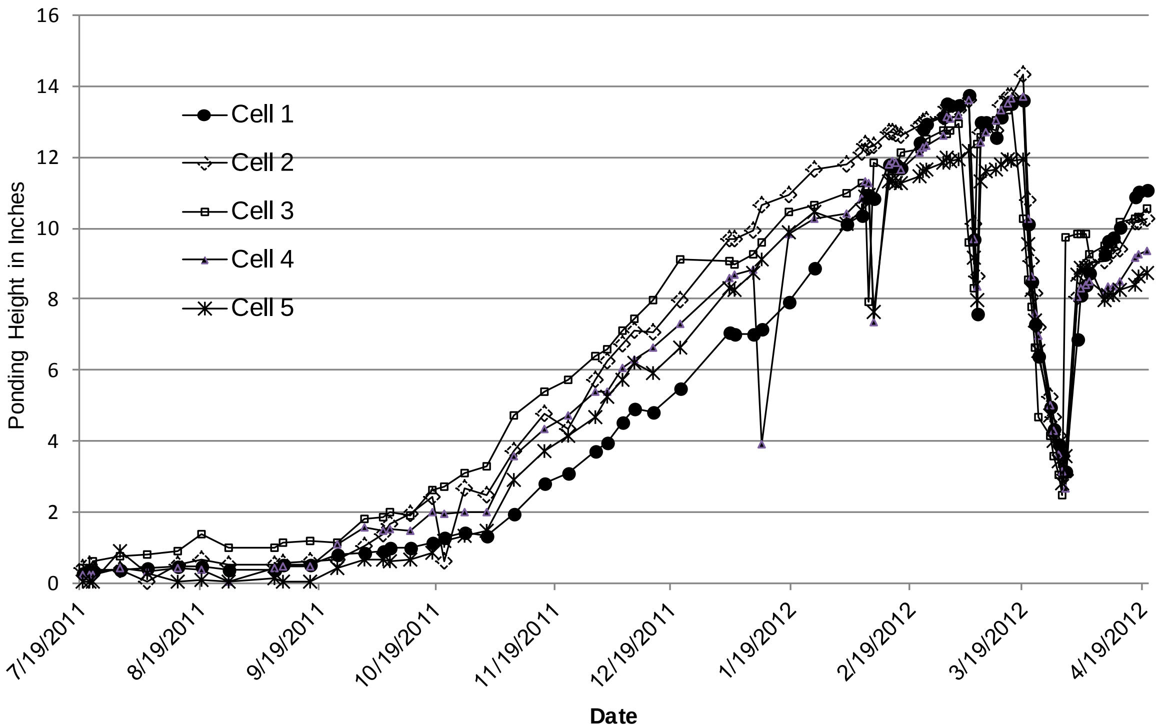

Figure 5. Average of ponding levels in three observation wells in each leaching trench at the Massachusetts Alternative Septic System Test Center July 2011 – April 2012.

Test products were randomly assigned positions among the five trenches. Trenches were assigned the numbers one through five (from west to east in their respective locations) and received the following product assignments:

Cell 1 – Air addition to the septic tank (Biomicrobics RetroFAST™)

Cell 2 – Addition of purportedly beneficial microbes alone to the distribution box.

Cell 3 – Addition of air directly to the leach trench (SoilAir™)

Cell 4 – Control, no additions.

Cell 5 – Introduction of air and purportedly beneficial microbes (White Knight™)

Each manufacturer was asked for deployment procedures. These procedures are summarized in table 2.

Technology	Cell Number	Preparation Procedure	Date Started
Air to septic tank (RetroFAST)	1	Septic tank pumped	5/7/2012
Beneficial bacteria into distribution box (Bacta-Pur)	2	Septic tank not pumped, product added to distribution box per protocol provided	5/7/2012
Air to trench (SoilAir)	3	Septic tank pumped	5/7/2012
Control	4	No Treatment	5/7/2012
Air and beneficial bacteria into septic tank (White Knight)	5	Trench pumped (5/4/12), septic tank pumped and filled 1/2 clean water.	5/7/2012

Table 2. Summary of preparation procedures for technology indicated during the test for soil absorption system restoration products at the Massachusetts Alternative Septic System Test Center. Test Conducted May 2012 – June 2013.

Results – Restoration Technologies and Ponding

The present study reports results from June 2011 – June 2013 (including the conditioning phase previously reported June 2011 – May 2012 discussed above). Following a conditioning phase where the five test cells were equally stressed and showed similar ponding levels, we applied the technologies according to the manufacturers' instruction. The response of each technology and the Control Cell are provided below.

Results - Control (Cell # 4)

The purpose of the Control Cell was to document the effects of natural phenomena (such as temperature and precipitation) on fluctuation in ponding levels in the soil absorption systems. Following the conditioning and pre-test resting phase (June 2011 – May 2012), the ponding in the control trench exhibited a steady increase with some leveling off in July and August 2012 (figure 6). From August 2012 – March 25 2013, ponding levels steadily increased to the point where the system would be considered "failed" due the lack of any residual storage and leaching area; that is there was no remaining bottom or sidewall area in the trench at the soil-trench interface not submersed in septic tank effluent. In the natural or field setting this situation would result in a refusal of effluent to the soil absorption system, a backing up of effluent into the distribution box, and an eventual backing up to the septic tank perhaps into the facility served. We did not observe any backup into the distribution box during the study.

Beginning in January 2012, the ponding levels in the Control Trench indicate a highly stressed condition similar to all other test cells. This condition persisted through to the initiation of the test (figure 6, May and June 2012) and progressed through April 2013 despite reduced hydraulic loading rate (see table 1.). Slight reductions in ponding in the summer of 2012 following the start of our comparisons and reductions during the summer of 2013 are likely due to expected seasonal effects. Other experiments at the Test Center have shown that generally-warmer conditions in summer result in higher digestion of organic material by leaching system flora with a resulting reduction in ponding in many situations (Heufelder et al. 2007). Nevertheless, at the end of this study the Control Trench remained in the stressed state as indicated by at least eight Inches of ponding. We conclude that the Control Trench is suitable for comparison of treatment method effects.

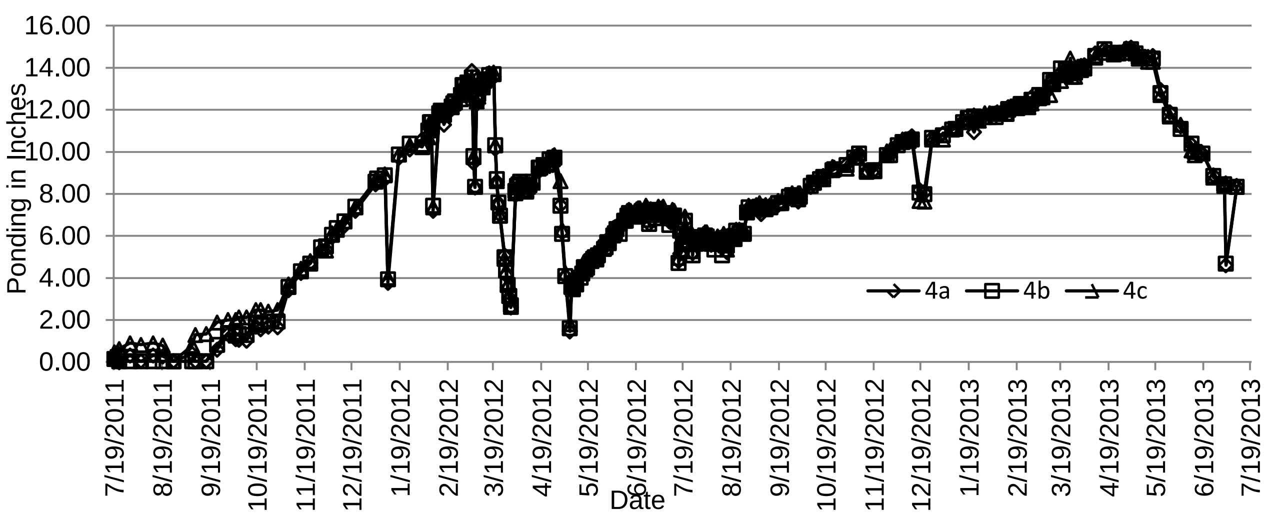

Figure 6. Ponding levels as recorded at observation ports in the Control Cell. 4a, 4b and 4c denote the proximal, middle and distal observation ports as referenced from the septic tank.

Selected measures of the wastewater percolate (wastewater distributed to the leaching trench following passage through the six inches of sand) were taken periodically following the start of the comparison tests. Measures taken include temperature, dissolved oxygen and pH. Raw data for these parameters are presented in appendix 1 and 2. In addition, since we theorized that the restoration of hydraulic capacity might also alter the removal of pathogens, we periodically collected a surrogate measure of such, fecal coliform, in percolate. These data are presented with concurrent ponding data in figure 7.

These data suggest that, despite hydraulic stress, a standard trench maintained an average of a five $\log_{10}$ removal rate with a resulting geometric mean density of 36 (18 – 54, p=.05) CFU fecal coliform/100 ml following six inches of sand percolation. Of particular note is the period when the effluent ponding levels exceeded the effective depth of the stone aggregate. This period exhibited the comparatively higher and increasing number of CFU fecal coliform/100 mL of sample in the percolate, perhaps due to the absence of a biological/organic restrictive layer in this previously-unused vertical portion of the trench.

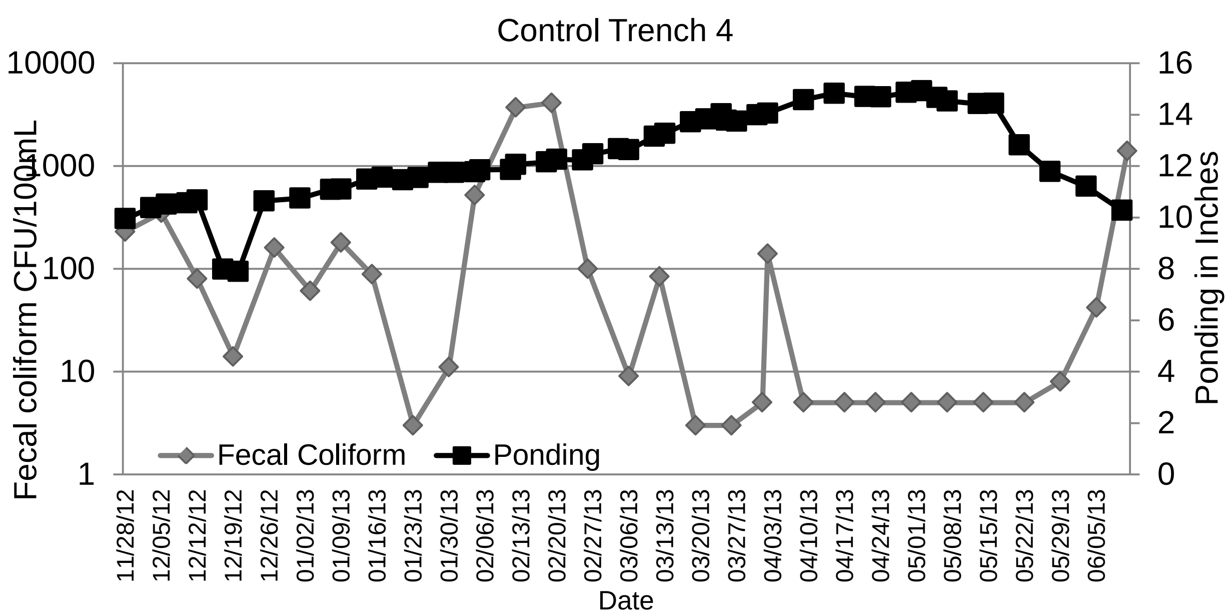

Figure 7. Average ponding levels as recorded at observation ports in the Control Cell contrasted with fecal coliform levels in percolate beneath the Control Trench(4) during the period November 2012 – June 2013.

Results – RetroFAST™ (Test Cell #1)

The RetroFAST™ manufactured by Bio-Microbics is an expandable treatment media module that is retrofitted into a standard septic tank at the outlet end. An above-ground air supply continuously provides process air to the bottom of the media module unit. Prior to the start-up of the test in early May, 2012 the septic tank was pumped in order to facilitate the installation. No other preparations were conducted prior to system operation.

During the period May 2012 – June 2013, there was a significant reduction in the ponding level in all areas of the trench compared with the control, with no values exceeding four inches reported (figure 8). These observations suggest that this technology was successful in restoring and maintaining the hydraulic capabilities of the trench. The slight increase during colder weather and declines during the warmer months concur with general observations at the control trench and again may be due to seasonal variations in the rate of biological digestion of the restrictive organic layer in the trenches in general.

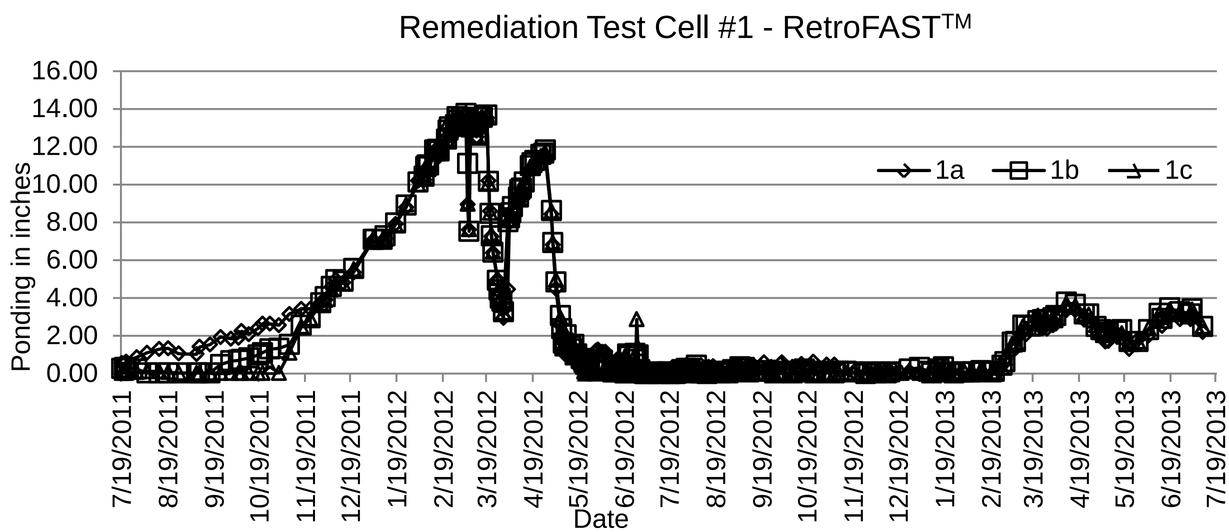

Figure 8. Ponding levels as recorded at observation ports in the Test Cell #1 (RetroFAST™). 1a, 1b and 1c denote the proximal, middle and distal observation ports as referenced from the septic tank.

The highest level of fecal coliform beneath this trench were observed coincident with the lowest ponding level (figure 9), however the relationship between the ponding and fecal coliform entrainment remains unclear. The geometric mean fecal coliform level beneath the trench for this technology was 1160 CFU fecal coliform per 100 mL (1090 – 1230, $p=.05$) which approximates a 3.5 $\log_{10}$ (99.96%) reduction.

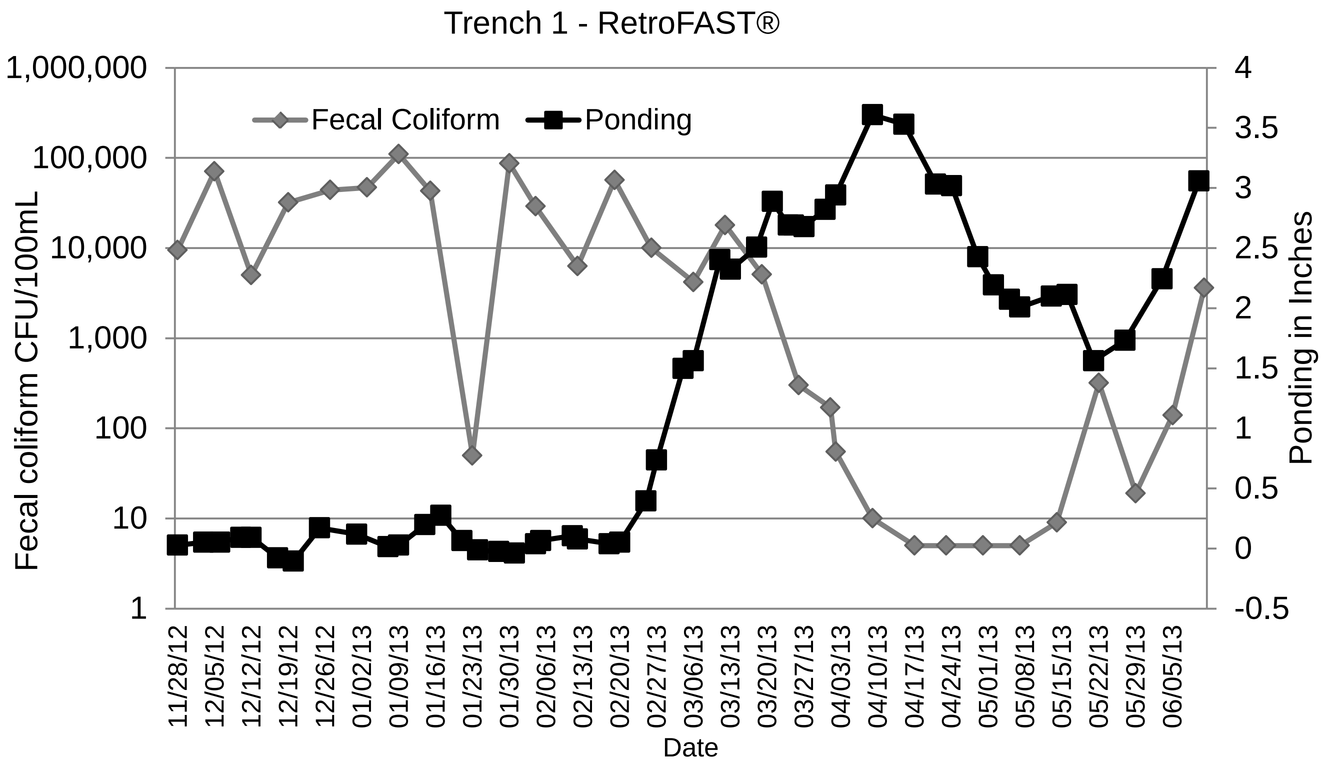

Figure 9. Average ponding levels as recorded at observation ports in the Cell #1 (RetroFAST™) contrasted with fecal coliform levels in percolate beneath the Trench (1) during the period November 2012 – June 2013.

Results – Addition of Bacta-Pur™ (Test Cell #2)

There are over 50 septic system additives allowed for use in the Commonwealth of Massachusetts. Some of the manufacturers of these products claim that their product is capable of restoring a stressed soil absorption system by enhancing the biology of the septic system. After a number of interviews, Bacta-Pur™ was chosen and applied to the distribution box in a manner prescribed by the manufacturer. The addition directly to the soil absorption trench by way of the distribution box is summarized in table 3.

Week	4/30/2012	Flow off until start of test
1	5/7/2012	Test Started 11am, 1L of each added, tank not pumped out
2	5/14/2012	Added 1 L of each of Klean Drain and Klean Septic per protocol
3	5/21/2012	Added 90 ml of Klean Drain per protocol
4	5/29/2012	Added 90 ml Klean Drain per protocol
5	6/4/2012	Added 90ml Klean Drain per protocol
6	6/12/2012	Added 1 liter Klean Septic and Klean Drain per written instructions (e-mail)
7	6/19/2012	Added 90ml Klean Drain
8	6/26/2012	Added 90ml Klean Drain
9	7/3/2012	Added 90ml Klean Drain
10	7/10/2012	Added 90ml Klean Drain
11	7/17/2012	Added 90ml Klean Drain, 1 Liter Klean Septic
12	7/24/2012	Added 90ml Klean Drain
13	8/1/2012	Added 90ml Klean Drain
14	8/7/2012	Added 90ml Klean Drain
15	8/14/2012	Added 90ml Klean Drain
16	8/22/2012	Added 90ml Klean Drain
17	9/6/2012	Added 90ml Klean Drain
18	9/13/2012	Added last 90ml Klean Drain on site

Table 3. Summary of protocol used to treat soil absorption system. Product was added directly to the leach trench through the access in the distribution box.

No other preparation was prescribed. The ponding pattern in this test cell (figure 10) is similar to that of the control test cell (figure 6) and suggests that this treatment had very little benefit in restoring the hydraulic capabilities of the trench. Fecal coliform levels also reflected a similar pattern as the control (figure 11) with a few exceptions (FC = 67 CFU/100 mL, 15 – 119, $p=.05$) resulting overall in a 4.7 $\log_{10}$ (99.99%) reduction beneath the trench.

The purveyors of Bacta-Pur™ have responded to these results (appendix 3). They suggest that the construction method used for the trenches (placing and compacting ASTM C33 sand as a base) encouraged blockages in soil pores and served as a “sure recipe for blockages”. These authors contend that placing a leach trench in fill of this type and compacting the sand in lifts for preventing uneven settling is appropriate and would not cause unusual drainage issues as evidenced by the results from the control and all trenches prior to the initiation of the test period.

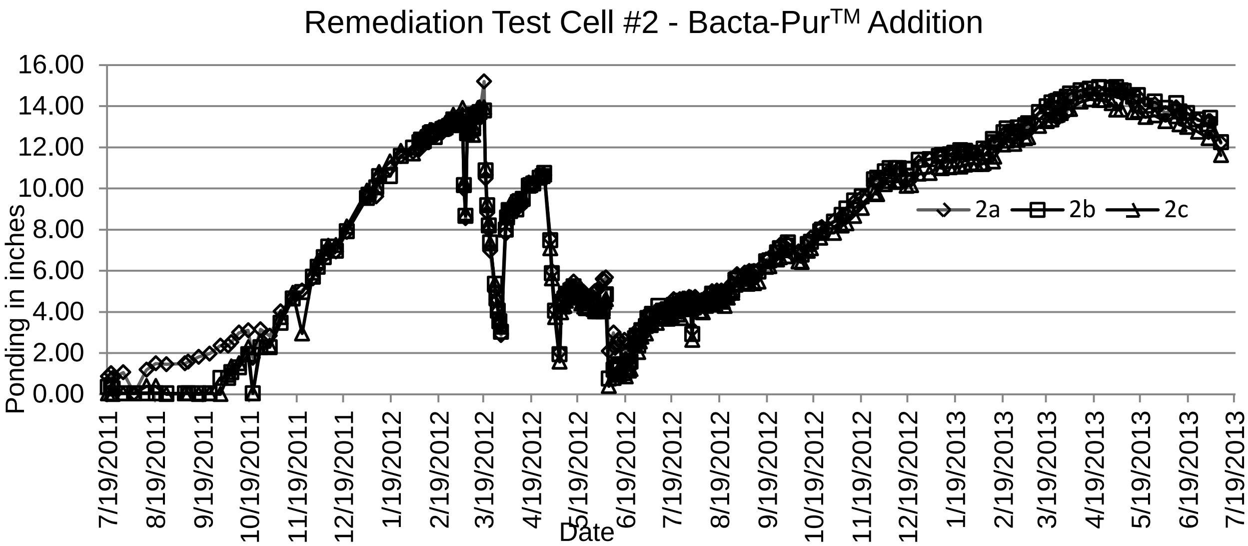

Figure 10. Ponding levels as recorded at observation ports in the Test Cell #2 (Bacta-Pur™ Addition). 2a, 2b and 2c denote the proximal, middle and distal observation ports respectively as referenced from the septic tank.

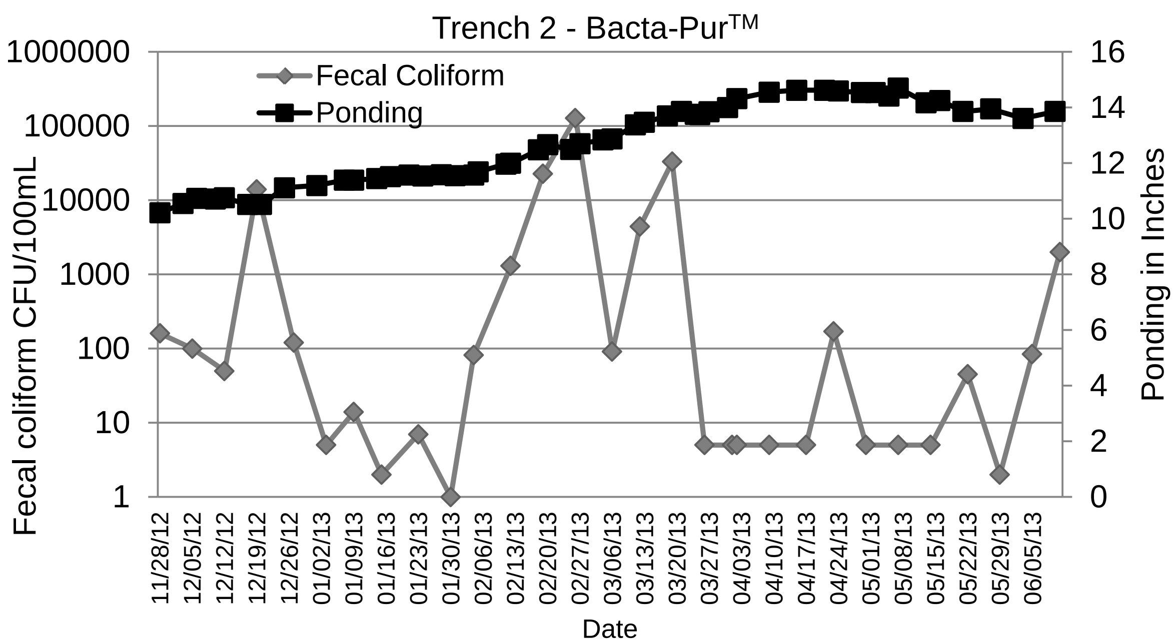

Figure 11. Average ponding levels as recorded at observation ports in the Cell #2 (Bacta-Pur™ Addition) contrasted with fecal coliform levels in percolate beneath the Trench (2) during the period November 2012 – June 2013.

Results – Addition of air to the soil profile – SoilAir™ (Test Cell #3)

SoilAir™ is unique in the field of candidate restorative products, having only one manufacturer of this patented design and strategy. This technology intermittently applies air to the soil profile through existing distribution pipes. Intermittent aeration of soil absorption systems has been shown to enhance the hydraulic performance of hydraulically-failed systems (Amador et. al. 2010). These authors posit that, intermittent aeration of the SAS would be expected to enhance infiltration by promoting aerobic conditions that support microbial oxidation of organic polymers in the biomat. This degradation of organic buildup of materials purportedly reverses the process of restrictive biomat formation.

The retrofit of SoilAir™ to an existing system during normal situations involves the installation of check valves which are placed such that pressurized air flow back through the house venting system is prevented and air is directed only to the soil absorption system. Unfortunately, conditions at the test facility did not allow the requisite pneumatic isolation and resultant differential pressure to build in the test cell. Accordingly the testing of this product was discontinued in October, 2012.

Despite two attempts to isolate the test cell, we and the manufacturer were not able to prevent the introduced air from migrating to the other test cells. This was evidenced by smoke testing the system and observing the air movement to the remaining cells as demonstrated in observation ports. Investigation of construction practices and photographs of the construction detail indicated that the common aggregate base of the distribution boxes (3/4” stone) and the pipe bedding served as the conduit to the other test cells and prevented the intended air supply volume and pressure to the SoilAir™ trench. Despite this shortcoming, from May – October 2012, this product caused a significant reduction in ponding of effluent compared with the control cell for this time period (figure 12); however a more comprehensive evaluation of this product was not possible given our test conditions. Under standard field conditions there would be no concern regarding the migration of pressurized air to adjacent trenches (in fact this would be preferred and designed for in order to renovate the adjacent trenches).

Unfortunately, testing for fecal coliform was only initiated in November 2012, so there are no data to suggest the impact of hydraulic restoration on pathogen entrainment for this technology.

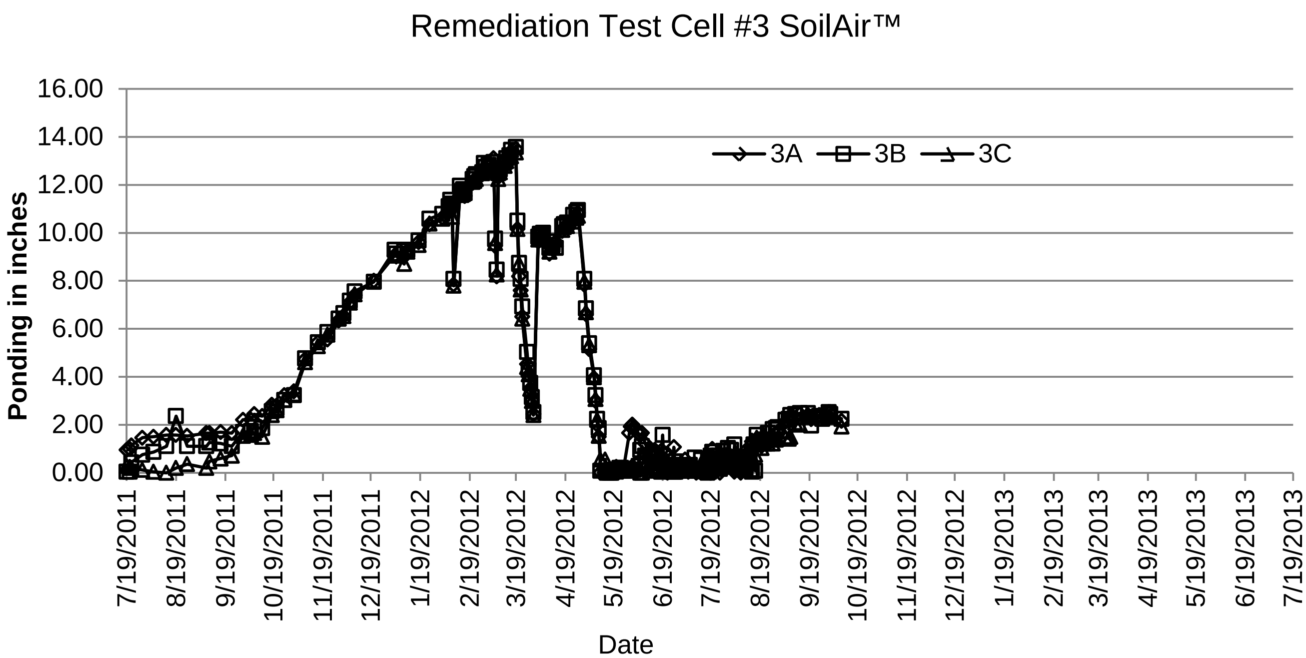

Figure 12. Ponding levels as recorded at observation ports in the Test Cell #3 (SoilAir™). 3a, 3b and 3c denote the proximal, middle and distal observation ports as referenced from the septic tank.

Results – Addition of air and purportedly-beneficial bacteria – White Knight™ (Test Cell #5)

The White Knight™ was chosen to participate by a random selection process among three candidate technologies that introduce air with purportedly beneficial bacteria. The system, comprised of a fine-bubble air diffuser and an inoculant source of purportedly-beneficial bacteria, was installed below the liquid level through the center access cover of a septic tank. The air supply is a linear air pump that operates continuously. Prior to installation, the tank was pumped to allow the installation of the unit and the soil absorption system was pumped down using the inspection ports. Two weeks following start-up the bacteria inoculum was replaced by the manufacturer per standard procedure.

Following the initiation of the test, the leach trench served by White Knight™ was pumped down and then provided the loading indicated in table 1. During this initial period, the trench showed a reduction in the ponding with sporadic (less than10) occurrences where ponding was elevated to levels of six – eight inches (50-75% of full effective depth of the trench- figure 13). In early March 2013 staff at MASSTC noted a refusal of septic tank effluent to the SAS (with a corresponding apparent drop in the ponding level). This was apparently due to a buildup and clogging of the distribution pipe discharge holes and subsequent back up into the distribution

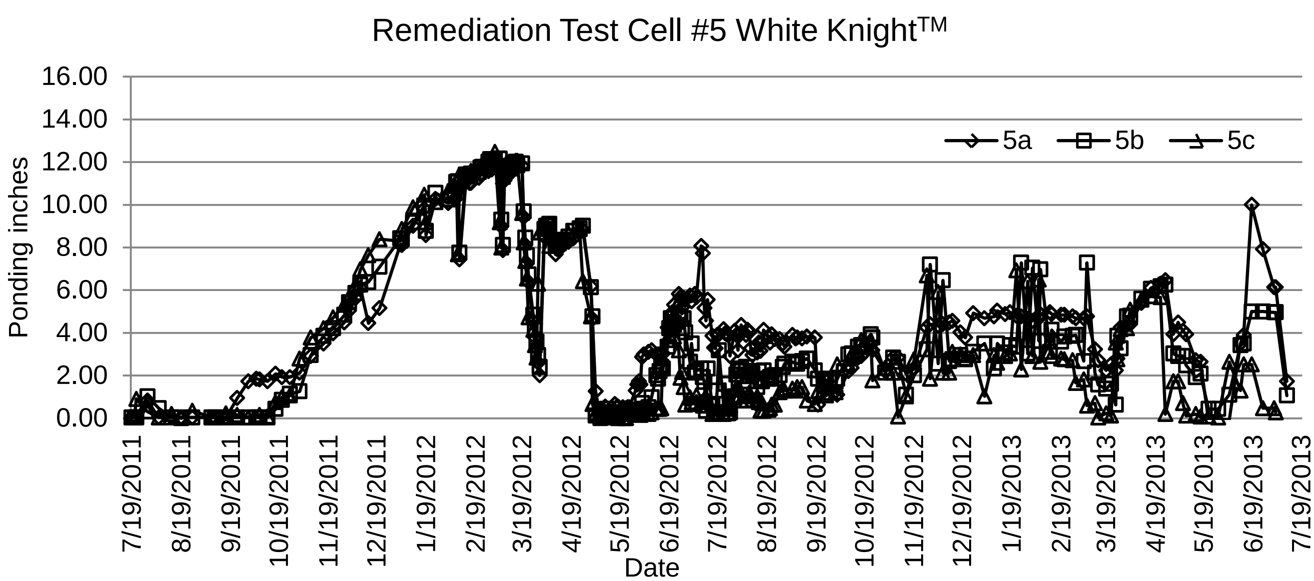

Figure 13. Ponding levels as recorded at observation ports in the Test Cell #5 (White Knight™). 5a, 5b and 5c denote the proximal, middle and distal observation ports as referenced from the septic tank.

box and diversion to the void ports inside the box. The pipe was flushed with clean water and the system allowed to resume discharge to the SAS.

Following an observation that effluent was refused into the SAS again on June 16, 2013 staff notified the manufacturer who arranged an inspection of the system. The unit was removed for the inspection and openings on the unit were found to be clogged with a fibrous material. The manufacturer contends that this material was atypical and was the cause for lack of performance and cause of the subsequent clogging of the discharge line. A report and comment by the manufacturer is included in appendix 4. It is the position of MASSTC that there are alternate theories for this observation since the refusal of the trench was not observed in other trenches, including the control trench. In addition MASSTC has hosted tests on numerous other technologies without this type of incident.

The relationship between the hydraulic modifications caused by this product and the entrainment of fecal coliform in percolate is not clear (figure 14). The geometric mean fecal coliform level beneath the leaching trench following six inches of sand was 74 CFU fecal coliform (55 – 93, *p=.05*) which resulted in an average 4.7 $\log_{10}$ (99.99%) reduction.

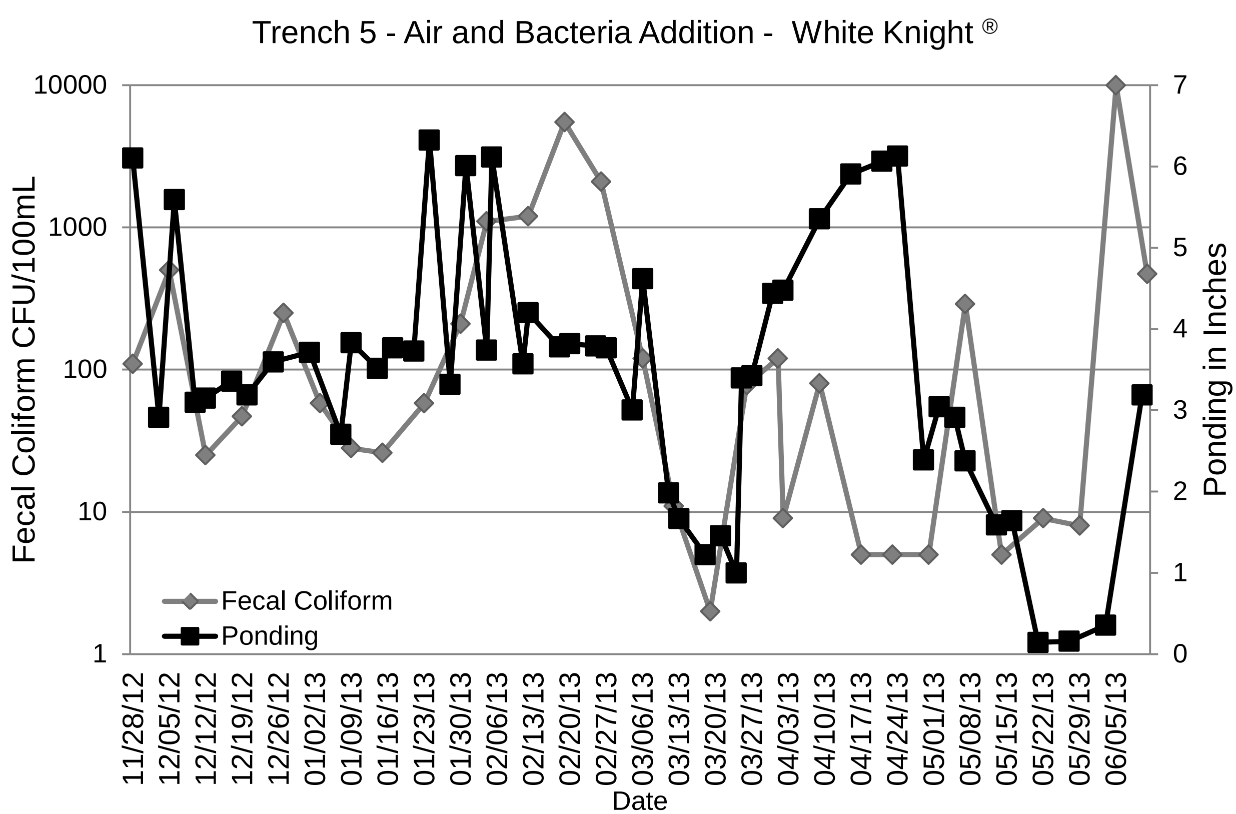

Figure 14. Average ponding levels as recorded at observation ports in the Cell #5 (Addition of air and purportedly beneficial bacteria – White Knight™) contrasted with fecal coliform levels in percolate beneath the Trench(5) during the period November 2012 – June 2013.

Discussion

This study had three goals that, in brief were:

- Develop a protocol for testing restorative products;
- Test products with the protocol concurrent with its development;

- Identify options for retrofitting existing system for the interim period between failure and the implementation of local wastewater plans.

Discussion – Development of a protocol for testing restorative products.

Standardized testing has been a useful tool in identifying candidate onsite septic system products that address various needs. The National Sanitation Foundation (NSF) in Ann Arbor Michigan has developed testing protocols for secondary treatment units (STD 40), nutrients (STD 245), soil absorption system products (STD 240) and many others. There are presently no standards for testing restorative products purporting to renew the hydraulic function of stressed soil absorption system.

The first challenge of protocol development is standardization of method. In short, the relevant questions are:

- How should the test cells be pre-conditioned so that a meaningful test indicative of longer-term performance can be conducted?
- At what point is the condition of a control and test cell (tank, distribution box and leachfield) considered stressed to the point where the test should begin?
- What criteria should be used to indicate the comparability of the control and test cells prior to the initiation of the test?

With no authoritative guidance, the loading regime in table 1 was conducted using information collected during a pilot protocol development for gravelless trench products which similarly used standard pipe-in-stone systems for control trenches (Heufelder et. al 2007). It was theorized that stressing the system would take place in six months at approximately four times the LTAR as specified in Massachusetts regulation. It was further theorized that a gradual reduction to a loading rate to that which is reasonably close to the LTAR (0.74 gal/day/sq ft) should be completed before the application of the technology. These conditions were determined by reasonable extrapolation from observations of the comparable ponding in each replicate as well as observations made in previous protocol-development projects. The results appear to have been adequate approximations that allowed us to complete a protocol test.

In summary, the tests cells were conditioned in approximately one year. It remains debatable whether this conditioning properly simulates a “natural” stress on a system. It is the opinion of these authors that this time period balances the time burden of proving the efficacy of a product with the assurance that the test can extrapolate to the performance of a product under field conditions. Although this test protocol would lead to the conclusion that any future tests would be of at least a two-year duration, these authors believe that two years would be a minimum timeframe to complete a meaningful protocol for the evaluation of restorative products.

One essential item in any protocol is that of a control. While NSF protocols concerning soil absorption products require at least six control cells, these authors believe that this requirement applied to restorative products would be cost prohibitive. The costs for a test using the protocol described herein would be approximately $30,000 excluding the costs of the test unit and installation itself. If replicates were required, the approximate cost of each tank/dbox/trench complex would be approximately $15,000. These authors believe that the test protocol conducted resulted in information sufficient to determine the efficacy of the systems tested.

Discussion – Test Results

The data suggest that, with the exception of the microbial additives alone, each of the systems tested resulted in some restoration of hydraulic capacity. The RetroFAST™ - treated trench showed the most substantial change, maintaining a ponding level of less than four inches for the duration of the test period and exhibiting less than two inches of ponding for the majority of the test period. The White Knight™ trench maintained ponding levels generally less than six inches and displayed a higher variability and range than the RetroFAST™. The SoilAir™ system trench showed ponding levels generally less than 3 inches, however the loss of air from the SoilAir™ cell and subsequent termination of the test for reasons stated herein, did not allow for an accurate assessment of this technology. The addition of bacteria alone did not appear to have any substantial effect on ponding (compare figure 5 with figure 9).

The comparisons of ponding depth in a trench and fecal coliform entrainment in percolate were inconclusive. Resulting percolate levels of fecal coliform were highest in the RetroFAST unit trench during the lowest ponding levels, although these levels still represented a 3.5 $\log_{10}$ (99.97%) reduction. This compares with the White Knight™ (4.7 $\log_{10}$ or 99.99% reduction) or the control (5 $\log_{10}$ reduction or 99.999% reduction). No fecal coliform samples were taken at the SoilAir™ system due to the early termination of the test.

In considering these results, the reader is reminded that the leach trench cell construction included a layer of only six inches of sand beneath the trench (figure 3). In Massachusetts, a standard trench design would require 60 inches of sand beneath the soil absorption trench above a limiting condition or groundwater. Accordingly, in standard conditions, the apparent greater entrainment of fecal coliform observed coincident with lower ponding levels is likely less significant. Examination of data from previous testing in 2000 – 2001, for instance, found no significant difference ($\alpha = .05$) between fecal coliform densities collected from pan lysimeters situated one foot beneath a standard pipe-in-stone trench receiving septic tank effluent and the same design trench receiving treated effluent from a MicroFAST™ unit.

In summary, these tests reveal at least two candidates (RetroFAST™ and WhiteKnight™) for restoring hydraulic function following the hydraulic stress of the system that results from hydraulic and organic overloading. The manufacturer of the WhiteKnight™ system has provided a statement as to why the leach trench refused septic tank effluent on two occasions, opining that the wastewater characteristics of the MASSTC are markedly different from typical household situations (appendix 3). The SoilAir™ system showed initial promise, restoring hydraulic function for at least four months, however due to the inability to resolve issues regarding pneumatic isolation, a complete evaluation was not possible. No significant difference was found between the percolate beneath the system treated with only bacteria product and the control cell. These tests suggest that certain remediation technologies may be applied to at least temporarily delay the replacement of a stressed septic system.

Discussion – Applicability

One issue that concerns the public as well as wastewater managers during the planning and implementation process is that of timing. In the interim between deciding to serve an area with municipal sewer and its actual operation there will inevitably be a number of failed individual onsite septic systems within the proposed service area. In order to preserve economic resources it would be advantageous to have a series of interim measures that allow wastewater disposal options while the implementation of a plan is taking place. Certain of the technologies (and perhaps others not investigated) offer this ability to forego installing septic systems that will soon be abandoned. In discussing the costs involved in deciding whether to apply any of these specific technologies, there are certain confounding factors. Permitting and other regulatory fees differ from municipality to municipality, as do the operation and maintenance costs and general construction cost rates. Accordingly here we chose to present only equipment costs for each of the units. Purveyors of the RetroFAST indicate that the costs for unit components range from ~$1,540 (house serving three persons) - $2,261 (for a house serving five persons). Upon completion of its need and subsequent abandonment of the onsite system, the blower and control panel can be moved to another location as could the media and liner following a cleaning procedure. The power usage of this unit is approximately 6 – 7 kWh/day. The White Knight™ indicates that the price for equipment is $ 2,175. The power usage of this unit is approximately 1.5 – 2 kWh/day . The unit and components are portable and can be moved following a cleaning procedure. The SoilAir™ system component costs are approximately $2,900. Power usage in this unit is approximately 5-6 kWh/day. All components of the SoilAir™ are portable and reusable.

As a final note, it may be argued that the testing of only one purportedly-beneficial bacteria product is not representative of the range of possible candidates or the range of successes that we might have observed. Of the four classes of candidate treatment technologies tested in this study, this technology class had the least representative selection process (one selection out of 50 or so candidates as opposed to one out of four or so candidates for other technologies). More research should be conducted on these types of additives since, if they indeed can restore hydraulic function in a stressed system, they hold the possibility of being the easiest to apply.

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Appendix 1

Raw Field Data Collected at Test Cells during the Performance of a Test Protocol for Products Purporting to Restore the Hydraulic Function of the Soil Absorption System Component of Septic Systems

KEY

Tank 1 and Field 1 – serving the RetroFAST™ Unit

Tank 2 and Field 2 – serving the standard system with Bacta-Pur™ additive

Tank 3 and Field 3 – serving SoilAir™

Tank 4 and Field 4 – serving the Control System

Tank 5 and Field 5 – serving WhiteKnight™

Blanks indicate that no data were taken

	Tank 1			Tank 2			Tank 3			Tank 4			Tank 5			Influent		
Date	**pH**	**DO mg/l**	**Temp °C**	**pH**	**DO mg/l**	**Temp °C**	**pH**	**DO mg/l**	**Temp °C**	**pH**	**DO mg/l**	**Temp °C**	**pH**	**DO mg/l**	**Temp °C**	**pH**	**DO mg/l**	**Temp °C**
05/22/12	7.73	5.29	16.89	6.72	1.03	15.96	7.00	1.03	15.69	6.62	1.20	15.83	7.39	1.99	16.02	7.70	1.46	16.18
05/24/12	7.99	6.91	17.51	6.90	1.16	16.34	7.18	1.09	16.33	6.78	1.24	16.35	7.51	4.29	16.43	7.08	0.28	16.25
05/29/12	7.98	5.13	18.87	6.92	1.40	17.54	7.17	1.36	17.29	6.88	1.46	17.22	7.77	4.47	17.61	7.11	0.12	16.81
05/31/12	7.81	5.01	18.94	6.98	1.39	19.02	7.27	1.29	18.96	6.89	1.42	18.79	7.68	4.51	18.68	7.18	0.07	16.49
06/05/12	7.98	4.54	18.2	6.95	0.78	17.41	7.25	0.79	16.97	6.89	0.86	17.29	7.62	2.19	17.62	7.35	0.11	17.39
06/12/12	7.75	4.64	19.34	6.88	0.93	18.55	7.01	0.11	19.67	6.79	0.89	18.46	7.54	2.45	18.74	7.05	0.40	18.45
06/20/12	7.80	4.96	19.52	6.91	1.06	18.44	6.81	0.41	18.88	6.89	0.89	18.38	7.32	1.01	18.81	7.45	0.05	19.08
06/28/12	7.78	4.48	21.42	6.91	0.78	20.22	6.71	0.11	24.44	6.80	0.63	20.18	6.69	1.26	20.65	7.21	2.01	20.22
07/03/12	7.91	2.83	22.11	7.01	0.55	20.85	6.77	0.27	22.83	7.12	0.50	20.98	7.01	1.92	21.32	7.17	0.11	19.45
07/10/12	8.10	3.64	22.59	7.15	1.03	21.33	6.98	2.45	21.17	7.14	1.05	21.3	7.34	3.84	22.18	7.48	0.25	19.77
07/17/12	7.84	2.88	23.96	7.20	1.43	22.68	7.07	0.42	23.44	7.16	0.89	22.41	7.50	1.45	23.01	6.66	0.50	21.73
07/24/12	7.91	3.68	23.61	6.85	1.03	22.72	6.74	0.75	23.14	6.86	0.68	22.57	7.33	2.90	22.92	7.08	0.07	21.53
07/31/12													7.52	2.07	22.57	7.33	0.09	21.6
08/07/12													7.61	1.36	23.64	7.35	2.10	22.88
08/14/12	7.91	2.80	24.65				6.89	0.16	23.73	7.06	1.21	23.51	7.59	2.59	23.88	7.61	3.18	13.68
08/22/12	7.82	2.72	23.99	7.02	1.25	23.22	6.78	0.01	22.92	6.95	0.73	23.16	7.63	1.14	23.41	7.54	0.87	23.05
08/29/12	7.69	1.31	23.65	6.92	0.17	22.37	6.74	0.04	21.03	6.85	0.79	22.97	7.54	0.04	23.7	7.34	2.07	23.16
09/05/12	7.52	1.20	23.41	6.87	0.24	22.44	6.59	0.12	22.89	6.80	0.44	22.72	7.62	1.29	23.51	7.29	1.62	23.24
09/11/12	7.68	5.21	22.75	6.83	0.82	22.56	6.89	0.45	21.82	6.92	0.77	22.37	7.64	1.22	22.34	7.08	0.43	21.72
09/18/12	7.76	4.32	22.04	6.69	0.67	21.6				6.80	0.57	21.58	7.68	1.39	21.78	7.08	1.52	21.71
09/25/12	7.69	2.97	20.37	6.81	0.70	20.39	7.00	0.10	17.7	6.99	0.89	20.5	7.68	1.93	20.72	7.11	1.37	20.59
10/02/12	7.66	4.97	20.69	6.64	0.87	20.1	6.96	0.21	19.84	6.92	0.49	20.05	7.57	2.13	20.14	7.12	1.21	20.85
10/10/12	7.33	4.71	19.68	6.78	1.23	19.2	6.92	0.34	19.13	6.98	0.71	18.96	7.41	2.61	19.13	7.03	0.78	19.93
10/17/12	7.48	5.28	18.65	6.84	0.86	18.33				6.93	0.90	18.26	7.64	3.61	18.44	7.12	1.12	18.88
10/24/12	7.42	3.91	18.01	6.87	1.38	17.14				6.96	0.92	16.91	7.53	0.21	17.32	6.91	1.47	17.89
11/01/12	7.44	4.85	17.86	7.01	1.20	17.1				7.06	1.12	16.87	7.59	2.36	17.08	7.72	0.89	17.56
11/07/12	7.60	6.15	14.39	7.30	2.68	13.44				7.22	3.60	12.6	7.42	3.81	14.12	7.27	1.08	16.27
11/14/12	7.34	6.21	14.64	6.97	1.14	13.98				6.87	1.33	13.37	6.96	3.61	13.75	7.37	2.51	15.04

11/20/12	7.13	6.24	13.73	6.87	1.09	13.46				6.83	1.07	13.13	6.54	3.37	13.14	7.46	1.17	14.63
11/27/12	7.23	6.24	11.88	6.99	1.06	11.37				6.91	1.91	11.61	7.24	3.77	11.74	7.37	2.39	13.03
12/05/12	7.39	6.71	13.51	6.78	0.95	12.55				6.69	0.86	12.25	7.08	3.41	12.29	7.20	0.23	13.94
12/12/12	7.33	5.98	12.48	7.01	1.21	11.66				6.97	1.57	11.36	7.41	4.00	12.03	7.06	0.12	13.07
12/19/12	7.07	6.18	11.92	6.74	1.06	11.13				6.63	1.30	10.46	7.11	4.31	10.93	7.07	1.19	12.06
12/28/12	7.08	5.82	10.01	6.91	11.10	9.61				6.82	4.42	9.42	7.35	4.92	9.35	7.11	0.89	11.21
01/03/13	7.17	7.60	7.77	6.79	1.23	8.02				6.83	1.49	7.84	7.31	6.71	7.94	6.91	2.01	9.81
01/09/13	7.30	7.30	8.12	6.94	3.59	7.33				6.99	4.02	7.15	7.38	6.46	7.65	6.89	1.61	8.44
01/15/13	7.22	7.21	10.38	6.65	0.82	9.14				6.68	0.96	8.86	6.98	5.38	8.88	6.68	1.04	10.03
01/23/13	7.13	6.58	8.05	6.23	0.27	8.31				6.70	0.50	7.68	7.45	8.67	7.6	7.03	1.40	8.97
01/30/13	7.31	9.03	7.58	6.77	1.27	7.18					1.67	6.79	7.36	7.04	6.37	7.19	3.31	8.64
02/04/13	7.28	8.11	7.12	6.81	1.11	7.08				6.79	1.42	7.2	7.32	6.92	7.16	7.32	2.81	8.19
02/12/13	7.14	8.22	6.81	6.79	1.03	6.92				6.85	1.27	6.87	7.21	6.82	6.92	7.48	1.21	8.06
02/26/13	7.21	8.49	5.89	6.59	2.72	5.12				6.84	3.71	4.89	7.14	6.19	5.12	7.11	0.98	6.98
03/06/13	7.39	9.99	7.93	6.45	1.09	6.99				6.33	0.93	6.5	7.14	7.25	6.76	6.85	2.49	7.36
03/12/13	7.21	7.48	8.05	6.49	1.23	6.94				6.54	1.39	6.63	7.07	6.13	6.6	6.92	4.03	7.66
03/19/13	7.48	7.76	7.86	6.47	1.14	7.12				6.62	1.00	6.81	7.30	5.48	6.89	7.01	5.05	7.51
03/26/13	7.27	7.46	7.6	6.53	1.28	6.83				6.70	1.88	6.56	7.27	6.23	6.94	6.61	1.27	8.4
04/02/13	7.54	7.96	9.75	6.75	1.77	8.59				6.57	3.72	7.14	7.33	5.55	8.42	7.06	2.12	9.53
04/09/13	7.49	6.92	9.49	6.81	1.78	9.51				6.72	2.81	9.49	7.41	4.96	9.22	7.14	1.82	9.79
04/17/13	7.27	6.59	11.18	6.52	1.00	9.82				6.40	1.22	9.67	6.94	1.77	9.89	6.94	2.01	10.27
04/23/13	7.31	6.28	11.44	6.50	2.39	10.21				6.45	2.20	10.11	6.98	3.35	10.68	7.02	2.97	10.51
04/30/13	7.28	5.26	12.49	6.44	2.67	11.31				6.34	2.53	11.37	7.04	3.27	11.57	6.94	2.07	11.36
05/07/13	7.17	4.66	13.93	6.02	1.19	12.4				6.15	1.34	12.56	6.83	0.75	12.88	6.89	1.20	13.32
05/14/13	7.25	5.97	15.01	5.97	2.09	13.72				6.03	1.87	13.57	6.95	1.29	14.09	7.01	0.49	13.77
05/22/13	6.96	5.01	17.18	6.17	1.60	15.49				6.19	1.57	15.51	6.98	2.88	16	6.98	1.94	15.81
05/29/13	6.94	6.19	16.88	6.29	1.18	15.32				6.17	1.25	15.12	6.84	3.25	15.51	6.84	0.94	15.57
06/05/13	7.35	5.30	18.76	6.35	1.31	17.4				6.34	2.47	17.06						
06/11/13	7.27	5.19	18.48	6.39	1.48	18.19				6.44	1.12	18.24						
		Tank 1			Tank 2			Tank 3			Tank 4			Tank 5			Influent	

	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C
Mean	N/A	5.61	N/A	N/A	1.44	N/A	N/A	0.58	N/A	N/A	1.45	N/A	N/A	3.52	N/A	N/A	1.39	N/A
Median	N/A	5.24	N/A	N/A	1.26	N/A	N/A	1.03	N/A	N/A	1.16	N/A	N/A	1.99	N/A	N/A	1.46	N/A
Min Value	6.94	1.20	5.89	5.97	0.17	5.12	6.59	0.01	15.69	6.03	0.44	4.89	6.54	0.04	5.12	6.61	0.05	6.98
Max Value	8.10	9.99	24.65	7.30	11.10	23.22	7.27	2.45	24.44	7.22	4.42	23.51	7.77	8.67	23.88	7.72	5.05	23.24
Count	55	55	55	54	54	54	20	20	20	54	55	55	55	55	55	55	55	55

	Field 1			Field 2			Field 3			Field 4			Field 5		
Date	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C	pH	DO mg/l	Temp °C
05/22/12	6.11	4.09	16.14	6.11	5.40	16.33	6.93	6.11	16.34	6.11	4.75	15.98	6.12	4.16	15.83
05/24/12	6.46	4.63	16.55	6.32	5.28	17.25	7.36	5.68	17.25	6.35	4.81	16.37	6.25	3.96	16.01
05/29/12	6.22	4.06	18.12	6.18	4.90	17.9	7.29	5.63	18.35	6.33	4.23	17.61	6.14	3.66	17.24
05/31/12	6.12	3.89	18.72	6.21	4.38	18.68	7.41	5.27	18.92	6.28	4.19	18.61	6.18	3.79	18.71
06/05/12	5.91	4.48	17.75	6.12	4.97	17.99	7.30	6.27	17.37	6.31	4.38	17.79	6.05	3.76	17.4
06/12/12	6.60	4.15	18.18	5.95	4.99	18.59	6.49	6.20	18.46	6.10	4.17	18.23	6.29	4.39	18.34
06/20/12	6.65	4.72	18.41	6.25	5.04	18.58	6.30	6.56	18.6	6.15	4.29	18.42	6.04	4.36	18.16
06/28/12	6.31	4.53	20.38	5.90	4.47	20.28	6.17	5.95	20.76	6.01	4.26	20.46	5.82	4.55	20.13
07/03/12	6.28	4.05	21.04	5.71	4.08	21.31	6.27	5.87	21.72	6.08	3.86	21.12	6.37	4.69	20.86
07/10/12	6.67	4.55	21.87	6.37	4.07	22.18	6.75	7.02	21.97	6.29	4.03	21.98	6.60	4.77	21.77
07/17/12	6.19	3.64	22.92	5.92	4.04	23	6.28	6.61	23.05	5.85	3.85	22.86	6.42	4.83	22.93
07/24/12	6.18	4.60	22.81	6.21	5.32	23.02	7.04	6.36	22.92	6.02	4.32	22.9	6.51	5.46	22.27
07/31/12													6.54	4.66	22.55
08/07/12													6.25	3.81	23.32
08/14/12	6.52	4.27	23.65	5.92	4.95	23.75	6.58	5.58	23.85	5.84	3.77	23.67	6.00	3.71	23.38
08/22/12	6.41	3.86	23.12	6.24	4.21	23.37	6.73	4.79	23.24	6.05	3.56	23.34	6.04	3.59	23.3
08/29/12	6.34	4.91	22.7	6.08	5.78	23.14	6.79	7.36	23.03	6.01	4.47	23.09	5.85	4.25	23.17
09/05/12	6.29	4.80	22.7	6.11	5.42	22.89	6.77	6.42	23.03	6.24	4.38	23.12	5.85	4.34	23.42
09/11/12	6.45	3.87	22.44	6.17	6.19	22.5	6.38	6.87	22.19	6.03	4.61	22.53	6.09	5.47	21.33
09/18/12	6.38	5.35	20.94	5.77	5.89	21.45	6.11	6.66	21.08	5.72	4.77	21.47	5.73	4.53	21.2
09/25/12	6.44	4.70	20.29	6.14	6.47	20.53	6.59	7.49	20.11	5.97	5.08	20.49	5.95	4.86	20.36
10/02/12	6.35	4.96	19.68	5.87	6.97	19.76	6.63	7.99	19.5	6.14	5.17	19.81	6.18	4.49	19.72
10/10/12	6.33	6.16	19.06	6.02	7.66	19.03	6.46	7.50	18.97	6.13	5.56	19.41	6.24	4.85	19.29
10/17/12	6.83	6.15	17.6	6.25	5.48	17.87				6.27	4.20	17.79	6.29	3.71	17.77
10/24/12	6.77	6.59	16.85	6.06	4.91	17.46				6.04	4.39	17.43	5.98	4.31	17.21
11/01/12	6.07	5.86	16.55	5.88	6.52	16.58				6.01	4.47	16.53	6.16	6.16	16.09
11/07/12	6.74	6.80	13.35	6.18	5.00	14.78				6.21	3.51	14.67	6.33	6.66	14.43
11/14/12	6.28	7.87	12.88	6.10	5.32	13.47				6.02	3.63	13.07	6.40	6.39	12.97

11/20/12	6.10	8.03	12.5	6.00	4.93	12.5		5.99	3.88	12.31	6.65	8.38	11.04
11/27/12	5.95	7.96	10.62	5.83	5.21	11.06		6.10	3.78	11.06	6.64	6.33	10.78
12/05/12	6.15	7.75	10.8	6.08	4.35	11.15		6.18	3.45	10.91	6.55	5.94	10.9
12/12/12	6.07	7.78	10.94	6.10	5.15	11.33		6.01	4.50	11.02	6.16	5.99	10.18
12/19/12	5.84	7.23	9.49	5.89	4.35	9.83		5.33	5.49	8.68	6.00	5.85	9.35
12/28/12	5.79	6.42	9.28	5.89	4.21	9.42		5.24	5.01	9.51	6.08	5.89	9.21
01/03/13	6.11	6.23	6.82	5.98	4.34	6.47		5.44	5.12	6.81	5.98	5.72	6.74
01/09/13	5.71	9.63	6.23	5.73	5.20	6.4		5.97	3.81	6.47	5.96	5.63	6.3
01/15/13	5.93	9.05	6.61	5.42	6.89	6.58		5.69	5.25	6.8	5.65	6.05	6.67
01/23/13	4.98	8.81	4.78	5.12	6.15	4.62		5.39	5.99	4.58	5.60	6.02	4.83
01/30/13	5.88	9.32	4.75	5.39	5.79	5.44		5.53	5.70	5.2	5.55	5.96	5.41
02/04/13	5.89	8.67	5.54	5.41	5.66	5.61		5.53	5.88	5.16	5.62	5.42	5.12
02/12/13	5.69	9.32	5	5.65	6.89	4.67		5.74	5.06	4.83	5.63	6.21	4.71
02/26/13	5.99	9.59	4.47	5.79	6.71	4.65		5.71	6.20	4.51	6.11	4.78	4.6
03/06/13	6.00	9.60	5.86	5.27	8.02	5.51		5.07	7.48	5.39	5.65	6.62	5.57
03/12/13	6.11	8.76	5.43	5.67	7.42	5.33		5.55	7.37	5.29	5.80	8.66	5.31
03/19/13	5.84	8.37	5.49	5.45	5.32	5.59		5.07	6.88	5.28	6.05	13.99	3.51
03/26/13	6.30	7.94	5.93	5.50	6.40	5.88		5.32	6.98	5.69	6.19	7.42	5.72
04/02/13	6.20	7.38	7.07	5.43	6.69	6.81		5.20	6.55	6.58	6.02	5.99	6.97
04/09/13	6.09	6.82	8.41	5.58	6.89	8.39		5.37	6.44	8.41	6.19	5.88	8.19
04/17/13	5.49	6.88	9.07	4.92	6.86	8.98		4.84	6.09	8.85	6.94	1.77	9.89
04/23/13	5.35	6.17	10.16	5.40	5.38	10.06		5.22	5.60	9.91	5.82	6.31	9.73
04/30/13	5.43	6.25	10.92	4.79	5.63	10.95		4.65	5.61	10.69	4.31	7.90	10.35
05/07/13	4.99	7.27	12.05	4.20	6.32	12.09		4.10	5.18	11.76	5.09	6.00	11.63
05/14/13	3.92	6.81	13.06	4.11	5.87	13.29		4.14	5.09	13.06	5.13	11.02	11.78
05/22/13	5.10	6.39	15.26	4.35	5.77	14.93		3.96	6.06	14.52			
05/29/13	4.73	6.20	15.47	3.66	6.24	15.18		3.80	6.36	14.93	3.89	7.31	14.73
06/05/13	5.17	5.16	17.87	4.35	6.10	17.41		4.36	7.04	16.76	5.66	5.51	
06/11/13	5.08	3.86	18.19	4.78	5.12	17.93		5.19	5.06	17.72			
		Field 1			Field 2		Field 3		Field 4			Field 5	

	pH	DO mg/l	°C	pH	DO mg/l	°C	pH	DO mg/l	°C	pH	DO mg/l	°C	pH	DO mg/l	°C
Mean	N/A	6.31	N/A	N/A	5.59	N/A	N/A	6.39	N/A	N/A	5.01	N/A	N/A	5.58	N/A
Median	N/A	6.23	N/A	N/A	5.40	N/A	N/A	6.36	N/A	N/A	4.81	N/A	N/A	5.47	N/A
Min Value	3.92	3.64	4.47	3.66	4.04	4.62	6.11	4.79	16.34	3.80	3.45	4.51	3.89	1.77	3.51
Max Value	6.83	9.63	23.65	6.37	8.02	23.75	7.41	7.99	23.85	6.35	7.48	23.67	6.94	13.99	23.42
Count	55	55	55	55	55	55	21	21	21	55	55	55	55	55	54

Appendix 2

Raw Fecal Coliform Collected at Test Cells during the Performance of a Test Protocol for Products Purporting to Restore the Hydraulic Function of the Soil Absorption System Component of Septic Systems

KEY

Tank 1 and Field 1 – serving the RetroFAST™ Unit

Tank 2 and Field 2 – serving the standard system with a Bacta-Pur™ additive

Tank 3 and Field 3 – serving SoilAir™

Tank 4 and Field 4 – serving the Control System

Tank 5 and Field 5 – serving WhiteKnight™

REMD INF – Common influent wastewater

	FIELD 1 EFF	FIELD 2 EFF	FIELD 4 EFF	FIELD 5 EFF	REMD INF
11/28/12	9,500	160	230	110	3,900,000
12/05/12	71,000	100	350	500	4,000,000
12/12/12	5,000	50	80	25	5,900,000
12/19/12	32,000	14,000	14	47	5,200,000
12/27/12	44,000	120	160	250	5,500,000
01/03/13	47,000	5	61	58	4,000,000
01/09/13	110,000	14	180	28	3,000,000
01/15/13	43,000	2	88	26	4,100,000
01/23/13	50	7	3	58	3,800,000
01/30/13	87,000	1	11	210	4,100,000
02/04/13	29,000	82	520	1,100	5,900,000
02/12/13	6,300	1,300	3,700	1,200	2,100,000
02/19/13	57,000	22,700	4,100	5,500	7,900,000
02/26/13	10,000	128,000	100	2,100	2,900,000
03/06/13	4,200	91	9	120	1,900,000
03/12/13	18,000	4,400	84	11	2,900,000
03/19/13	5,100	33,000	3	2	2,400,000
03/26/13	300	5	3	78	2,400,000
04/02/13	55	5	140	9	2,800,000
04/01/13	170	5	5	120	
04/09/13	10	5	5	80	1,300,000
04/17/13	5	5	5	5	670,000
04/23/13	5	170	5	5	1,700,000
04/30/13	5	5	5	5	1,800,000
05/07/13	5	5	5	290	3,100,000
05/14/13	9	5	5	5	4,700,000
05/22/13	320	45	5	9	7,300,000
05/29/13	19	2	8	8	6,400,000
06/05/13	140	84	42	10000	11,000,000
06/11/13	3,600	2,000	1,400	470	5,800,000

Appendix 3

Manufacturer Response to Test Results

Bacta-Pur™

Received by email. – "George" refers to Principal Investigator George Heufelder

"George,

Bacta-Pur® has been used for decades to unblock leachfields, trickle filters and biofilters; where the blockage is due to organic material. Bacta-Pur® is purely biological and does not remove non-organic or non-biodegradable material.

Biofilter media is a balance between surface area and open area. Design of a biofilter includes estimation of the back wash frequency, based on the loading and the ration of surface area to open area. Fine material such as sand has very large surface area but little open area.

If I understand the design of your test system correctly, the drain pipe was buried in sand, which was compacted prior to adding crushed stone and the influent line from the septic tanks. Compaction is used to fill in the interstitial spaces with the fines in the sand. This reduces open area. I am not familiar with construction methods in Massachusetts, but I have never seen a leachfield constructed with a base of sand and certainly not compacted sand. This is a sure recipe for rapid blockages.

Best wishes,
IET-Aquaresearch Ltd / Bacta-Pur — Since 1984
Building Sustainable Ecosystems: Environment, Economies & Societies
Our Common Universal Heritage: The Earth and its habitants
Karl
Karl F. Ehrlich, Ph.D.
www.bactapur.com "

Appendix 4

Manufacturer Response to Test Results

White Knight™

"Guardians of Water Quality®"
281 Co. Rt. 51A, Oswego, NY 13126
1-800-560-2454 / 315-343-8521 / Fax 315-343-2941
www.knighttreatmentsystems.com

September 10, 2013

To: Mr. George Heufelder
Barnstable County Department of Health and Environment

From: Mark C Noga, President
Knight Treatment Systems, Inc.
281 Cty Rt 51A,
Oswego NY 13126

Re: KTS Draft Report Comments, Project Number 01-05/319

Dear Mr. Heufelder:

Thank you for the opportunity to comment on the fore mentioned draft report.

As discussed during our June 13, 2013 investigation into the malfunction of the absorption trench's ability to readily accept wastewater and the unexpected ponding observations, it was discovered that the White Knight Microbial Inoculator Generator™ column within the tank had become fouled resulting in a loss of efficiency by the extraordinary amount of shredded inorganic material found in the wastewater influent as evident by the photos below.

White Knight MIG™ Column Fouling

Stringy Debris Removed Moved From Column

The installation of the White Knight MIG ™ also included a modified 4" Diameter Orenco Bio-tube™ Effluent Filter, $1/16^{th}$ inch filtration, at the outlet which had also become fouled.

Effluent Filter Fouling **Debris Washed Off Effluent Filter**

The mat like material observed on the sewer line inspection camera (photo below), that was previously sent down the line to investigate the trench's inability to readily accept the wastewater when first noticed, appeared to consist of fine inorganic fibers and other inert debris particles that had found their way thru the effluent filter. Thus it is our position that these deposited materials rather than organic clogging are what have impacted the trench's ability to properly function hydraulically.

Fibrous Debris on Sewer Camera Head Following Line Inspection

In retrospect, had KTS realized that a significant contributing source of the project's incoming wastewater is an active correctional facility, as correctional facilities are notorious for large volumes of uncommon inorganic / synthetic constituents, that would be passed thru a comminutor / grinder process, KTS would have taken additional steps to protect the treatment train and its equipment from the large volume of these materials which are not typical of an individual homeowner's residential waste stream.

Respectfully,

Mark C Noga

Mark C. Noga, President
Knight Treatment Systems, Inc.