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Field Comparison of Rock-Filled and Chambered Trench Systems

University of Minnesota Onsite Sewage Treatment Program

Sara Christopherson[1], Dan Wheeler[1], Jessica Wittwer[1] and Tim Haeg[2]

ABSTRACT

Due to actions of the Minnesota State Legislature, systems utilizing chambers and synthetic drainfield distribution media are allowed to be designed and installed up to 40% smaller than the standard or conventional trench system area, under provisions of a special "Warrantied System" category. If approved for "Warrantied System" sizing, manufacturers can receive reduced sizing guidelines in exchange for offering a five-year performance warranty and technical information. There has been debate among regulators, professionals and manufacturers about the long-term hydraulic longevity of systems that use the reduced-area trenches for final treatment and dispersal. A project was designed to identify whether there is a statistical difference in performance between chambered and rock-filled trench systems. This was achieved by a large-scale survey of over 100 selected onsite systems of both rock-filled trenches and chambered trenches across seven Minnesota counties. Each system type was studied within three major soil permeability categories (fast, medium and slow) utilizing soil texture classes. In addition to a general evaluation of the system and homeowner survey including questions on usage and maintenance frequency, the percentage of the system in use at the time of the site visit was determined. This was possible because a majority of trench systems in Minnesota utilize drop box or sequential distribution which loads the trenches in a particular order so that one trench is loaded to a specific level before the subsequent trenches are utilized. Adjusting both types of systems to a standard size datum, the ponding levels were compared. Surprisingly nearly 60% of the systems visited during the study of the ages 5 -10 years did not have any ponding observed at the end of the first trench segment. When the amount of ponding was compared between rock-filled and chambered systems the data was not able to prove the hypothesis that chambered systems of a similar age as rock-filled systems utilize 25% less area than the rock systems at 10% significance level. To the contrary, the results indicate that rock-filled trench systems were utilizing less soil treatment area than the chambered systems due in part to the smaller area per trench of the chamber systems. More mature trench systems of both types need further investigation and analysis to more fully evaluate this issue.

[1] University of Minnesota – Water Resources Center, Onsite Sewage Treatment Program. 1985 Buford Avenue, 173 McNeal Hall, St. Paul, MN 55108. Email: septic@umn.edu.
[2] Watab Inc. 14234 Fruit Farm Road, St. Joseph, MN 56374. Email: tim@watab.net.

INTRODUCTION

Trench-type drainfields are a simple method of treating wastewater in settings when proper soil and site conditions exist. In gravity dispersal systems, septic tank effluent flows or is dosed to a drop box or a distribution box. Only systems utilizing drop boxes were evaluated in this study, where effluent flows from an outlet pipe in the lowest position in the box to the first trench in a series. In Minnesota, individual sewage treatment systems (ISTS) can utilize various media for temporary storage of sewage prior to absorption by soil, including drainfield rock, chambers, and other approved products. All of these medias have the same objective: to apply wastewater to the soil in a manner that allows movement into or through the soil, resulting in treatment and dispersal of the wastewater. The media also maintains the excavation to expose the infiltrative surfaces and provides storage. Absorption of effluent by the soil is dependent on a complex series of processes. The factors involved include the initial soil characteristics, hydraulic and organic loading, dosing regime, aeration status of the infiltrative surface and soil biogeochemical properties (Kropf et al., 1977).

In Minnesota, drainfields sized according to Minnesota State Rule (Table 1) are considered "standard". Alternatively, drainfields can be installed at a reduced size, using a special classification created by the Minnesota State Legislature at the request of chamber manufacturers. Under this "warrantied system" classification, drainfield trenches built using chambers and expanded polystyrene can be sized with up to a 40% reduction in soil treatment trench bottom area. In order for a technology to be classified as a warrantied system the system manufacturers are required to submit technical performance and design information, financial assurance documentation to ensure performance on warranties, information showing that at least 50 of its systems were operating successfully for at least three years across all major Minnesota soil classifications and a $1,000 application fee.

The standard system length required is calculated by taking the estimated flow based on bedrooms multiplied by the soil sizing factor divided by the width of the rock trench or chamber. The warrantied sizing is simply 60% of the calculated length or bottom area. When drop boxes are used, the actual loading rate to the first trench in sequence, regardless of distribution media, is often much higher then the design loading rate. This increased loading encourages the formation of a biomat which assists in the treatment process. It was expected that most of the systems visited with ages from 5 -10 years would have an established biomat with some measurable ponding.

Table 1. Soil sizing factors used to design trench systems in Minnesota (MPCA, 2002)

Soil Texture	**Standard Soil Sizing Factor ft^2/gpd (loading rate) gpd/ ft^2**	**Warrantied/ 40% Downsized Soil Sizing Factor ft^2/gpd (loading rate) gpd/ ft^2**	**Permeability Class for this Evaluation**
Course, medium or loamy sand	0.83 (1.2)	0.50 (2.0)	Fast
Sandy loam	1.27 (0.8)	0.76 (1.32)	Medium
Fine Sand and Loam	1.67 (0.6)	1.00 (1.0)	Medium
Silt loam and silt	2.0 (0.5)	1.2 (0.83)	Slow
Clay loam, sandy clay or silty clay	2.2 (0.45)	1.32 (0.76)	Slow
Clay, sand or silty clay	4.2 (0.24)	2.52 (0.45)	Slow

There has been debate among regulators, professionals and manufacturers about the hydraulic longevity of systems that use reduced-area trenches versus "standard" trenches (Hall, 2002). Generally, the argument on the part of proponents of the installation of chamber systems at reduced area has been that the infiltration rate in rock-filled trenches compared to chambered systems is reduced due to an embedment layer composed of rocks impressed with the soil at the infiltrative surface. It is argued that the more open nature of chambers, including its larger volume of storage capacity, more open infiltrative soil surface, lower compaction from installation, and the absence of fines are justification for the downsizing (Siegrist, 1987). Regardless of distribution media, the soil has a limited hydraulic capacity which cannot be exceeded regardless of distribution media. In most cases, the most hydraulically restrictive layer will be the biomat at the soil infiltrative surface and not the underlying soil although in heavy textured soil this many not be the case.

METHODS AND MATERIALS

Project Design

This research was coordinated by the University of Minnesota Onsite Sewage Treatment Program working in conjunction with regulators from local county onsite programs. This study attempted to evaluate the issue of system hydraulic performances between the two distribution medias.

System hydraulic performance was evaluated by:

(i.) determining if the system was sized according to state standards and also met a two foot vertical separation requirement,

(ii.) investigating whether sewage was coming or has come to the surface, and

(iii.) the percentage of system in use as indicated by ponding of effluent. Use was determined in this study by verifying ponding occurrence and ponding depth in order to calculate the percentage of system in use. Systems experiencing no ponding at the end of the first trench segment will have a percentage use of zero.

This project was designed as a large-scale survey of onsite systems across Minnesota. Systems sampled were selected based on system type (rock-filled or chamber) and major soil types utilizing three general soil texture classes as the authors expect there may be differences in system hydraulic performance based on the nature of the soil material(s) encountered. Chambered systems that were designed with both standard and warrantied sizing were included because they would be evaluated for comparison by the percentage of system in use compared to standard sizing.

The evaluation was performed independently of the product manufacturers. The month of May was chosen as a target time period to visit the systems, as this period generally coincides wetter soils and with higher seasonal water tables in Minnesota (Minnesota Climatology Working Group, 2006). This period was chosen to test the systems as it is presents the worse case scenario when ponding of systems would be at a peak level. The study was designed to be conducted in its entirety during a 1-month period in the spring of 2006 to minimize climatic variation among the study sites.

Statistical Approach

The hypothesis for this project is that chambered systems of a similar age (5-10 years since installation) as rock-filled systems will utilize 25% less area than the rock-filled systems at a 10% significance level. Thus, for similar soils, we anticipate that a chambered system will accept more wastewater per unit area of trench before ponding, and that chambered systems should take more wastewater per inch per unit area of trench.

This project was designed as a large-scale survey of 220 onsite systems across Minnesota. Our minimum sample sizes were determined to minimize the effect of flow variability in our percent usage data. By utilizing flow per capita and standard deviation data (Mayer et al., 1999), we desired to detect a 25% difference in system area used with a probability of 0.90 at a significance level of 0.10. Factoring in this flow variability along with other key variables of system type and major soil category, we determined that for each system type approximately 33 systems must be evaluated stratified by 1/3 of the systems in each major soil category to minimize flow uncertainties.

Basic statistics were computed for all data collected to develop an understanding of data. Comparison of percentage in use data between system types and stratified by major textural category within each system type (Systat 10, 2000). Significance levels utilized for all analyses is 0.10. Assumptions common to the paired t-test analysis include random equal variance and approximately normal distribution. Non-normally distributed data is common in uncontrolled experiments and may result in the skewing of risk levels, which are chosen arbitrarily (Koch and Link, 1980).

The survey areas were chosen based on three conditions:

1. The systems were spread across Minnesota. This was important to limit the data being biased by a particular region, county or professional.
2. The systems were located in counties with a sufficient number of chambered and rock-filled systems ranging in age from five to ten years which utilize drop boxes as the distribution method.
3. The systems were spread across the soil textural classes. For the purpose of this study all soils were placed into categories of slow, medium, and fast. With “fast” representing coarse sand, medium sand or loamy sand; “medium” representing fine sand, sandy loam, and loam; and “slow” representing silt, silty clay loam and sandy or silty clay with approximately a third of both the chambered and the rock-filled systems in each of the three categories.

Based on historical sales data and known soil conditions, counties with the highest probability of a match to the categories studied were contacted. Working with county staff, approximately 1000 systems were identified that met the criteria. After the systems were identified, permission was obtained from homeowners prior to the evaluation period. Homeowners were provided with a clear outline of the project with assurance that enforcement would not occur as a result of the field evaluation of their system. A short homeowner questionnaire was required to be completed prior to the visit provided including the question from Table 3. The data gained from this questionnaire eliminated some systems from the study and provided information on operational and management issues which may affect the amount of ponding in a system. In general, because a large number of systems were surveyed, one would not expect operation and maintenance to vary by system type, so this factor should not affect the survey results. The questions regarding bedrooms and people living in the home were used to determine estimated and calculated flow values.

Estimated daily flow values, used to design all systems in Minnesota were strictly based on the number of bedrooms (150 gal/bedroom). Actual flows were estimated from the number of persons in each residence. The AWWA Research Foundation’s report on Residential Water Use reports a median flow per capita of 60.4 gpd was used with a standard deviation 39.6 gpd (Mayer et al., 1999). The use of this median value is justified by the large number of systems evaluated in this study so the daily flow variability from site to site is averaged out and not considered to be an explanatory variable between the two types of media studied. The number of persons in each residence was multiplied by the reported median flow per capita to obtain the estimated actual daily flow for each residence.

Table 3. Homeowner questionnaire.

Question	**Rationale**
Is the home used on a seasonal basis?	Used to eliminate seasonal residences
How many bedrooms are in the home?	Used to calculate design flow
How many people live in the house?	Used to calculate estimated actual usage
When was the last time your septic tank was pumped?	Used to determine if a relationship exists between recently pumped tanks and usage.
Do you have a garbage disposal?	Used to determine if a relationship exists between presence of garbage disposal and usage.

There was a concern that with this method of system selection, property owners with surfacing systems would be less likely to allow access to their sites. There are two reasons this is of less concern. First, these systems are relatively young in age, all designed and installed by licensed professionals and inspected by county inspectors, so the number of surfacing systems should be very minimal. Second, surfacing hydraulic failure was not our only parameter to indicate system performance. Instead we focused on determining the percentage of system in use. Additional parameters collected were possible explanations for differences in usage and may be used to add additional insight into our analyses and outcomes.

Field Survey Protocol

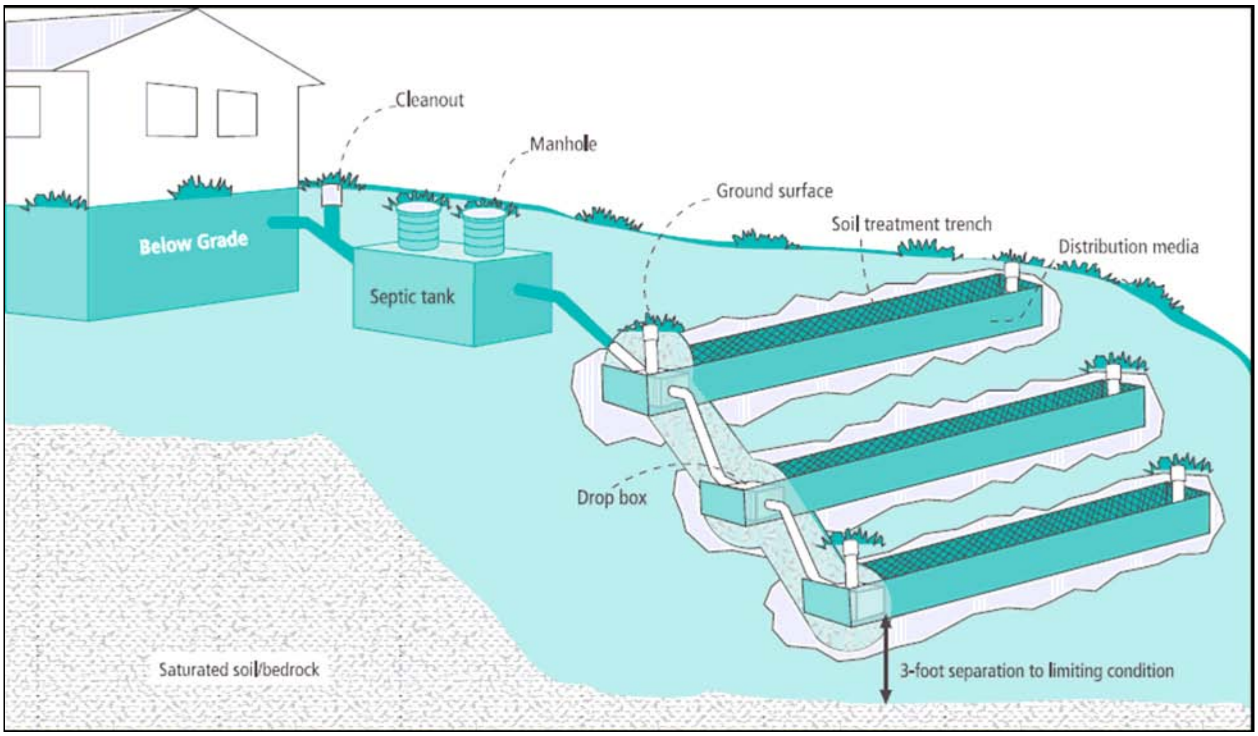
A field survey evaluation form, including the protocol, was designed to serve as a site-specific data collection and compilation guide (See Appendix A). County permit data was used, as available, as a starting point for field evaluation. Typical county permit data available in Minnesota includes the system type, installation date/age, system design, well location, number of bedrooms, design flow, septic tank sizing, use of a pump, type of distribution method, depth to limiting condition, soil sizing factor, system length, depth, and location of trenches, system construction inspection data and as-built drawings. If a subsequent compliance inspection was part of the permit file, it would also be evaluated.

A licensed private inspector visited each site chosen for the survey. A member of the University of Minnesota research team participated in approximately 30% of the site visits to both establish the initial protocol and provide quality assurance throughout the study. The following parameters were evaluated by the inspector:

a. The size of the system installed was confirmed.
b. Surfacing of septic tank effluent or evidence that the system surfaced in the past was investigated.
c. The number, length and depth of trenches was confirmed.
d. The soil texture and vertical separation was identified with in a soil boring performed outside the area of influence along the mid-point contour of the soil treatment system was performed.

e. The width for rock trenches was assumed to be 36" (typical design variable and bucket width in Minnesota and 29" for chambers (inside foot print of chambers). For design purposes most designers use the excavation width of 36" when sizing chambered systems. The actual infiltration area was considered to more accurate for the purposes of this study.
f. The amount of ponding was recorded for each trench. The drop boxes and inspection wells on the ends of the trenches provide a location for monitoring the use and amount of ponding, height above the trench bottom (see Figure 1). This was done by inserting a probe into the inspection port until the bottom was reach, removing the probe and recording the amount of effluent visible on the probe. If inspection ports were absent, the trench media was manually exposed for ponding measurement. If the trench had no measurable ponding it was recorded as having zero inches of ponding even though portions of that trench were accepting the effluent, but had yet to reach the point of building a biomat resulting in ponding. Due to the use of drop boxes, the subsequent trenches will not receive effluent until the first trench is ponding to its maximum potential.

Figure 1. Trench system layout utilizing drop boxes for distribution.



Determining Percentage of System in Use

Based on the data collected in the field, the percentage of system in use was calculated and compared to the datum of a "standard/conventional" sized system so both full and downsized systems were able to be included in the study. This measurement does not indicate life expectancy as the development of biomat is dynamic and is not likely to be a linear process. The calculation allows for a comparison between the two types of media to test the project hypothesis that a smaller percentage of use will exist in chambers compared to rock-filled trenches.

RESULTS AND DISCUSSION

Survey Area

To meet the conditions of geographic spread, sufficient numbers of each system type and soil textural class, seven Minnesota counties were selected for the study: Hubbard, Goodhue, Cottonwood, Olmsted, Wright, Stearns, and Washington. Other factors that influenced the selection of target counties included the level of interest by local government units to participate and the return of the consent form and questionnaire by homeowners. Once a county was identified as having chambered or rock-filled systems that could qualify for the study, that county's offices were visited for research and duplication of records. At that time, a letter explaining the study, a consent form, and a questionnaire were mailed to owners of potential study sites.

Systems Characteristics

In this study, 116 chambered and 104 rock-filled systems were inspected across seven different Minnesota counties, stratified by 3 major soil textural categories. Each system included in the study had to be occupied year round and have at least 2 feet of vertical separation to the seasonally high water table or bedrock. Over the study period, 31 systems were inspected that did not meet this 2 foot separation requirement and were not included in these results. We also removed rock-trench systems (27 systems) from the database that included more than 6" of ponding (where rock-filled trench depths were greater than 6 inches) in order to compare similar systems to chambers. Surfacing during the field visit or indications of past surface discharge were not observed in any of the systems inspected during the survey. Only one system was fully ponded with very limited additional storage capacity.

All systems meeting study criteria (162 systems total) for this study were between 5 and 10 years of age, with 82% of the systems operating for 6 to 7 years. Seventy percent of the systems had been pumped within the last 5 years and 20% had garbage disposals. A trench with 6" of rock beneath the pipe serves as our datum when determining if a system was downsized. The flow for the home multiplied by our soil sizing factor then serves as a "standard" sized system.

The field evaluation was conducted between April 26 and June 24, 2006. The time period of evaluation was lengthened due to problems gaining consent from property owners. 33 systems per category was the goal, but due to study requirements and sample time limitations the number was slightly less for several categories as shown in Table 5. The sample set is statistically valid in size.

Table 5. Number of system per soil type and average age and trench length.

System Type	Soil Type and Number of Systems ( )	Avg. Age in years & Standard Deviation ( )	Avg. Trench Length (ft) & Standard Deviation ( )
Chamber	Fast (33)	6.0 (0.5)	46 (20)
	Medium (28)	6.0 (0.8)	52 (17)
	Slow (31)	7.0 (1.5)	66 (24)
Total/Averages	90	6.3 (1.1)	56 (22)
Rock	Fast (22)	6.4 (0.7)	57 (17)
	Medium (22)	6.5 (0.8)	70 (23)
	Slow (28)	6.7 (0.9)	78 (21)
Total/Averages	72	6.7 (0.9)	68 (22)

System Comparison Evaluation

There were a large number of systems where no ponding was recorded (96 total, 57 rock and 39 chamber) indicating the biomat had not yet matured to the point of causing ponding. Generally speaking a biomat is a positive attribute of gravity trenches receiving septic tank effluent as it assists in unsaturated flow through the soil profile. One likely explanation for less rock systems experiencing measurable ponding is due to the fact that it takes longer for the mature biomat to develop in rock-filled trenches because they are generally longer in length as shown in Table 5. Chambered systems are about 30% shorter (SE 5.1%).

T-test comparisons utilizing the entire database demonstrate a higher usage in systems without garbage disposals (12.9% use versus 3.5%, respectively, $p = 0.002$), while there was no difference in usage between recently pumped systems and those less recently pumped (10.4% use versus 11.8%, respectively, $p = 0.688$). To further investigate these differences, we compared within system types. Analyzing the presence or absence of garbage disposals shows the same trends, at significant levels ($p < 0.10$), within both rock and chambered systems. For the pumping frequency, the statistically insignificant results continued.

T-test results indicate no significant differences between systems (chambered and rock) studied comparing overall system size (assuming Minnesota state standard sizing was utilized) or system age. These findings are important when comparing system types in terms of usage. Since there were no significant differences regarding size or age, these properties are not considered influential variables if differences between system types are observed.

Estimated daily flows were determined by multiplying the number of residents from the homeowner survey by 60.5 gallons per day. The mean estimated flows between chambered and rock trench systems did not vary significantly at the 0.10 level (173 and 185 gallons per day, respectively).

T-test comparisons of all rock-filled trenches versus all chambered systems found chambered systems have a higher percent usage (p = 0.000). Investigating the system types by major soil category shows that for each soil textural category, chambered systems use more system area when compared to rock systems (Table 6). The significant differences between system types even when stratified by soil type may be partially explained by trench length.

Table 6. Comparison of percent use by system type and general soil texture class.

	Percent Use (%)		
Soil Category	**Rock**	**Chambers**	**p value**
Fast	8.7	20.8	0.041
Medium	3.1	16.5	0.003
Slow	1.6	9.6	0.001

To investigate the role of trench length as an explanatory variable in this study, we first needed to develop a metric of comparison between systems. Since length of the systems is not comparing the same square footage per unit length, we chose area as our metric. All systems have varying lengths of trenches so we averaged the trench lengths in order to derive our final variable, which is average area per trench. We found average area per trench (square feet) to vary significantly between system types when data is aggregated and between fast, medium and slow soils (Table 7). Chambered systems have shorter trench segments and therefore are more likely to pond sooner. Since our study evaluated system usage by determining ponding, chambers are likely to have a higher use because of their shorter trench segments. It can also be seen in Table 7 that the actual soil sizing factors based on the estimated flows and average area per trench the loading rates to both systems are quite high since all the wastewater is flowing into the first sequential trench. The data indicated that chambered systems are receiving a higher loading rate which encouraged the formation of a biomat and measurable ponding. These results should not be used to predict system longevity.

Table 7. Comparison of average area per trench by system type and general soil texture class.

	Avg. Area Per Trench (sq ft)			**Average Soil Sizing Factor (ft^2/gpd) (Loading Rate(gpd/ft^2))**	
Soil Category	**Rock**	**Chambers**	**p value**	**Rock**	**Chambers**
Fast	181	139	0.008	0.9 (1.11)	0.8 (1.25)
Medium	219	162	0.006	1.2 (0.83)	0.9 (1.11)
Slow	236	206	0.093	1.3 (0.77)	1.2 (0.83)

To further investigate how much of the variability in percent use to attribute to average area per trench, a linear regression was completed of the percent of soil treatment system use by average area per trench stratified by soil textural class. This data found average area per trench to explain

29, 38 and 46% for slow, medium and fast soils respectively of the variation in percentage of system used. So while trench area plays a role in explaining why this study found chambers using a greater amount of a soil treatment area, it is not a complete explanation. Numerous possible explanations exist to potentially further explain the differences including chamber settling, surface compaction due to foot traffic in the trenches and wastewater application methods, quality of sites and installers on sites utilizing downsized chambers and treatment/biomat development which may occur initially in rock trenches before ponding occurs as effluent travels over the rock similar to a trickling filter. Evidence of these occurrences was not identified in this study as the chambers and trench bottoms were not exposed.

To determine which attributes of the systems measured significantly impacted the percent in use SYSTAT was used to perform a multiple linear regression of all the systems included in the study. Evaluating the percent in use type of system ($p = 0.001$), people in the home/usage ($p = 0.000$) and average area per trench ($p = 0.000$) are all important variables which explain approximately 30% of the variability. Within each system type, number of people (chambers $p = 0.007$, and rock $p = 0.000$) and average area per trench (chambers $p = 0.000$ and rock $p= 0.003$) are statistically significant and garbage disposal use is significant only for chambered systems ($p = 0.061$).

Systems were then divided into three size categories based on average area per trench: small (1), medium (2), large (3). Analysis of percent in use was performed with all the systems and number of people ($p = 0.008$) and size category ($p = 0.000$) are explanatory variables. When the data is grouped into rock-filled and chambered the number of people and the size category were significant in both rock filled ($p = 0.001$ and 0.006) and chambered ($p = 0.008$ and 0.000), respectively.

Summarizing percent in use by area categories was determined for each system type as shown in Table 8. The size categories were chosen based on sample size and natural breaks in system areas. As systems increase in average area per trench the percent in use decreases across the two system types. This holds true for each system type with systems with smaller square footage have higher percent use than medium, and medium higher than large. Even within the same size category rock-filled systems have a smaller percentage of system in use then chambered systems. These differences are significant with the exception of category 3 due to the large area of the trenches and the sampling methods.

Table 8. Percent in Use Results with Systems Categorized by Square Footage Categories.

Size Category - Range in ft^2	**Number of Systems**	**Percent in Use**			
		All	**Rock**	**Chambers**	**p value**
1 - (0 – 150)	60	19.6	9.5	24.3	0.011
2 - (150 – 250)	66	7.8	3.9	10.9	0.020
3 - (> 250)	36	1.2	0.6	2.4	0.353

The data collected in this study was unable to prove the hypothesis that chambered systems of a similar age as rock-filled systems will use 25% less area than rock-filled systems at 10% significance level. The data shows the opposite with less ponding in rock-filled systems. Based on the age of systems used in this study this phenomenon may occur because many systems have not yet reached the point of building a mature biomat, which causes ponding. Statistically significant differences were detected by a t-test at the 0.10 level between chamber and rock-filled trench systems when mean percent of system area in use was compared (Table 9). However, it is the rock-filled trenches that are experiencing a lower mean percentage of system use, not chambered systems as stated in our hypothesis. While statistically valid differences do exist, they appear to be small differences and our conclusion from this analysis is that rock-filled trenches and chambered systems act similarly in terms of area used for the age of systems in this study (5-10 years). Therefore, there was no observed advantage of chambered systems over rock-filled systems at this age range in terms of system usage discovered in this study.

Table 8. Results of unpaired t-tests comparing system types. P-values were evaluated at a significance level of $p < 0.10$.

System Type	**Age (years)**		**System Size (sq ft)**		**Estimated Flow (gpd)**		**Percent Use (%)**	
	Mean	**p-value**	**Mean**	**p-value**	**Mean**	**p-value**	**Mean**	**p-value**
Chamber	6.3	0.120	853	0.770	173	0.359	15.8	0.000
Rock	6.5		827		185		4.3	

CONCLUSIONS

While direct flow measurements and actual biomat cannot be quantified, our sampling provided non-intrusive methods for collecting data suitable for comparison. Surprisingly, 59.3% of systems included in our study of the ages 5- 10 years did not have any ponding observed during a typical wet time of year for Minnesota climatic conditions. This finding is cause for additional analyses in order to ascertain a suitable explanation, as establishment of a biomat at the bottom of a soil treatment system ensures proper treatment of effluent. Additional data may be required in order to fully understand this unexpected outcome.

Rock-filled trench septic systems between 5-10 years in age were found in our study to be utilizing less soil treatment area than chambered systems. While total area between the two system types did not vary, it is estimated that part of the explanation for why rock systems were found to use less of the soil treatment area is because of the smaller area per trench utilized in many chambered systems (29-46%). Analyses of additional data collected in this study failed to provide further insight into the differences determined. These results should not be used to predict system longevity.

Based on the results of this study, the design parameter used in Minnesota (loading rates and three feet of separation), proper installation and maintenance along with the licensing, permitting and inspection program are resulting in excellent system performance of gravity sequentially loaded trenches. The authors believe the requirements in Minnesota generally result in successful system at relatively low cost due to their proper design and installation. Another large benefit of the trenches in Minnesota is the inspection at both the drop box and end of the trench which allowed us to investigate the amount of ponding and provide a system management component.

FURTHER RESEARCH

This study provides a more detailed protocol to investigate the performance of trench systems. It would be advantageous and informative to either complete this study in a different location with older systems or to rerun this study in 5-10 years to determine if a longer term difference between the system types will exist. This would testing systems for allow longevity and system performance with a higher proportion of systems experiencing measurable ponding.

The development of ponding in gravity trenches needs further investigation. It was assumed when this project was under development that more then 75% of systems with sequential loading would have some measurable ponding at the end of the first trench after five years or more of operation. This lack of biomat development questions our general understanding of biomat formation time lines, identifies our conservative design approach and highlights that shorter trench installation maybe be helpful in the performance of systems.

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APPENDIX A – Field Inspection Form

PONDING STUDY INSPECTION REPORT

Observation #		**Method of Observation:**	
Landscape:		**Depth to Restrictive Soil:**	

FROM MUNSELL SOIL COLOR CHART

DEPTH (inches)	MUNSELL COLOR	SUBSTRATE H / V / C	MOTTLE H / V / C	SOIL TEXTURE	WATER (Y / N)	BEDROCK (Y / N)

TRENCH/MEDIA:

TRENCH #	DEPTH TO BOTTOM	PONDING @ D-BOX	PONDING @ END	MEDIA THICKNESS	TRENCH WIDTH	TRENCH LENGTH	TRENCH AREA
1							
2							
3							
4							
5							
6							
	SEEPAGE?					TOTAL AREA:	
	SURFACE DISCHARGE?					% IN USE:	

OWNER:	COUNTY:
ADDRESS:	PERMIT #:
CITY:	ZIP:
REVIEWED BY:	OWNER HOME?
REVIEW DATE:	OWNER PAID?