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SMALL SCALE WASTE MANAGEMENT PROJECT

Soil Acceptance of Wastewaters from Chamber and Gravel Infiltration Systems

by

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SOIL ACCEPTANCE OF WASTEWATERS FROM CHAMBER AND GRAVEL INFILTRATION SYSTEMS[1]

E.J. Tyler, M. Milner, and J.C. Converse[2]

ABSTRACT

Wastewater ponding depths and infiltration rates for chamber and gravel cells approximately 90 cm (3 ft) wide by 180 cm (6 ft) long simulating full-sized wastewater infiltration systems have been determined for more than 4 years. Three chamber systems and three gravel trenches were installed in each a sand and silt loam soil. The actual loading rates of domestic septic tank effluent are 4.2 cm/day (1.0 gpd/ft^2) and 2.5 cm/day (0.6 gpd/ft^2) for the sand and the silt loam soils, respectively. Infiltration rates are periodically determined

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using a constant head infiltrometer in the silt loam soil and by measuring rate of decreasing wastewater ponding height in the sand soil systems.

There is no ponding in the chamber or gravel trenches in the silt loam soil and infiltration rates remain much higher than the long-term acceptance infiltration rate for each cell type. The within cell type variability is great. Ponding of wastewater occurred within the first year of operation in all chamber and gravel cells installed in sand soil and ponding depths fluctuated seasonally with maximum depths during the winter. Ponding depths generally increased each year. Two chambers and two gravel cells have reached the defined failure limit.

INTRODUCTION

A buried structure creating an enclosed open space with a floor of soil to act as a surface for the infiltration of wastewater is referred to as a chamber wastewater infiltration system. The chamber provides a volume for temporary storage of wastewater during periods when wastewater generation exceeds infiltration. The chamber also maintains an exposed soil surface for the infiltration of the wastewater.

The structure used to create the underground chamber must be constructed to support the load of the overburden soil and traffic and have an access for wastewater application to the soil infiltrative surface. The materials for the structure have been concrete or plastic. Chamber wastewater infiltration systems have been in use for many years and are included in some design manuals such as EPA (1).

Since chamber wastewater infiltration systems are without gravel, the basal soil surface is more exposed and the storage volume is greater than for gravel systems. The sidewall of the exposed natural soil is in contact with backfill which is supported by the structure creating the chamber. The structure sides are slotted, allowing ponded effluent to move laterally into the soil. The soil infiltrative surface of gravel systems may be compacted and smeared due to placement of the gravel. Dust carried with the gravel may fall to the infiltrative surface. The different infiltrative surfaces exposed to effluent between gravel and chamber systems may produce long-term differences in wastewater infiltration.

Studies specifically designed to compare chamber systems with those constructed with gravel are rare. In Maine, based on a comparison of bed and chamber systems, it was concluded that chamber systems do not have a higher incidence of failure than bed systems, although the chamber systems were 50% smaller than bed systems for any given soil type (2). In a study comparing french drains (a leach drain filled with gravel) and other types of wastewater disposal systems including a type of chamber, the french drain ponded wastewater to the ground surface, while the other systems did not (3).

The purpose of this paper is to report the current status of continuing research that compares the performance of chamber and gravel wastewater infiltration systems.

MATERIALS AND METHODS

Experimental units were installed at two locations. One site is in a turf area at the Univ. of Wisconsin Arlington Horticultural Farm, about 30 miles north of Madison, Wisconsin. The soil at this site is a Plano silt loam (fine-silty, mixed, mesic, Typic Argiudoll). This soil is a structured silt loam over sandy loam. The other site is also in a turf area and near a mobile home park 4 miles from Wisconsin

Rapids, Wisconsin. The soil is a structureless Plainfield sand (mixed, mesic, Typic Udipsamment).

Twelve infiltration units called cells were constructed at each site in two parallel rows of six cells. The location of each cell type is random. Six of the trenches are approximately 90 cm (3 ft) wide, three were constructed 60 cm (2 ft) wide and three were constructed 30 cm (1 ft) wide. Results from the 60- and 30-cm wide gravel trenches are not reported in this paper.

Three of the six 90-cm (3-ft) wide trenches contain Infiltrator™ chambers from Infiltrator Systems, Inc. The septic tank effluent pipe was connected at one end of each chamber. The chamber cells have open bottom areas, sides with openings that contact the soil and solid end plates. The other three cells were constructed with approximately 10 cm (4 in.) distribution pipe and gravel. End plates were installed in the gravel cells making the number of infiltration surfaces similar between the cell types. All cells have two observation ports that provide access for making measurements. The elevation of the inlet pipe and basal area of each trench was recorded. Exact, as built, dimensions for each cell were used in all calculations.

Household wastewater at the silt loam site is from a single family home with an average biological oxygen demand (BOD) of 81 mg/L and the suspended solids (SS) of 44 mg/L. The BOD and SS of the wastewater is lower than for most domestic wastewaters. At the sand soil site the wastewater is from three mobile homes. The average BOD is 170 mg/L and the average SS is 63 mg/L. The BOD and SS of this wastewater is typical of household wastewaters. Other wastewater characteristics were determined but are not reported here.

At the sandy soil site the design and actual loading rate is 4.2 cm/d (1 gpd/ft^2) and at the silt loam soil site the design and actual loading rate is 2.5 cm/d (0.6 gpd/ft^2) based on the bottom area of the cells. The household wastewater is distributed to the cells by pumping the wastewater into small containers with an overflow. Each container is calibrated to hold 1/8 of the daily design flow for the cell. At unequal time intervals, a pump fills each container to above the overflow. Upon drainage of the excess wastewater to the source, a solenoid valve at the bottom of each container opens, allowing the measured wastewater volume to flow to the appropriate cell. Pumping and valving events are controlled with clocks and events are recorded. The containers, valves, and recording equipment are enclosed in a small heated and insulated structure. Equipment is maintained at least once a month. Most mechanical problems occur with the onset of winter.

At the sandy soil site, cell performance is determined with falling head infiltration rates and wastewater ponding depths. To measure falling head infiltration rate, dosing is stopped and the 24-hour change in wastewater ponding height is measured. Calculations of the infiltration rate are made using the area of both sidewall and bottom contacted with wastewater.

Cell ponding depths are determined periodically by measuring the wastewater elevation and calculating the ponding depth. Ponding depths are reported as millimeters of ponding from the basal infiltrative surface for each cell. Infiltration surface elevations were remeasured once to determine differences due to scouring at the location of the observation ports. For purposes of discussion, the gravel depth from the top of the inlet pipe to the basal infiltrative surface is the assumed failure depth for these experiments. The assumed failure depth is 275 mm (10.8 in.). The chamber system inlet pipe is higher above the infiltrative surface and therefore has a greater capacity than the gravel cells.

Constant head infiltration rates were determined at the silt loam soil cells using an infiltrometer. The rate of addition of water to maintain 5 cm of water in the cell was measured until steady state was reached. Attainment of steady-state condition was evaluated graphically using at least the last three data points. Based on the slope and standard deviation of the points, most data sets were grouped into three levels. Analysis of variance (ANOVAs) were run on each set. Results were the same; therefore no data screening was performed.

RESULTS AND DISCUSSION

Silt Loam Soil

Infiltration rates from all cells in the silt loam soil are higher than the wastewater application rates, and no ponding of wastewater has occurred. Infiltration rates from 1988 to 1992 are presented in Figure 1 for each of the three chamber and gravel cells installed in the silt loam soil. Infiltration rates are often 30 times greater than the expected long-term acceptance rate and the design loading rate. Both Hargett et al. (4) and Siegrist (5) had continuous ponding earlier in system life during experiments in similar soils with similar loading rates. It is possible that the relatively low organic loading of the wastewater is contributing to the delayed reduction in infiltration rates.

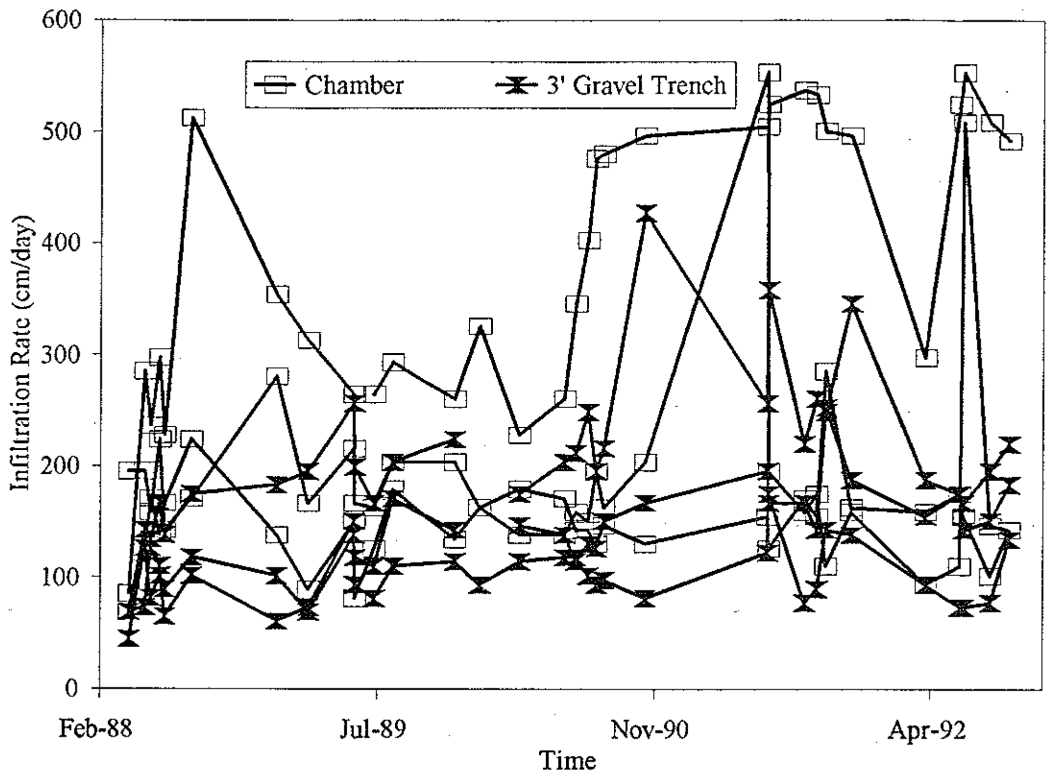

Figure 1. Infiltration rates for three chamber wastewater infiltration cells and three gravel wastewater infiltration cells in silt loam soil.

All data are reported in spite of differences in data quality as determined by sensitivity analysis. However, the relative trend of infiltration rates over time suggests that measurements were generally reproducible. Aberrations may be due to several factors: soil variability, lack of steady state condition during infiltration rate measurement or malfunction in effluent distribution equipment.

Variability of infiltration rate within one cell type is high. As clogging develops and infiltration rates decrease, the variability of the data will likely decrease and an assessment of differences between cell types may be possible. At this time, it is impossible to draw conclusions concerning the long term loading rates.

Sandy Soil

Initially infiltration rates were too high to measure using a 6-L (1.5-gal.) capacity constant head infiltrometer. Cells quickly ponded and remained ponded for major portions of the experiment. The falling head infiltration measurements (Figure 2) produced more reliable data than earlier measurements using the constant head infiltrometer. Therefore, infiltration data are only reported for the falling head infiltration measurements taken after 1990. Missing data occurred when all wastewater within a cell infiltrated during the falling head measurement.

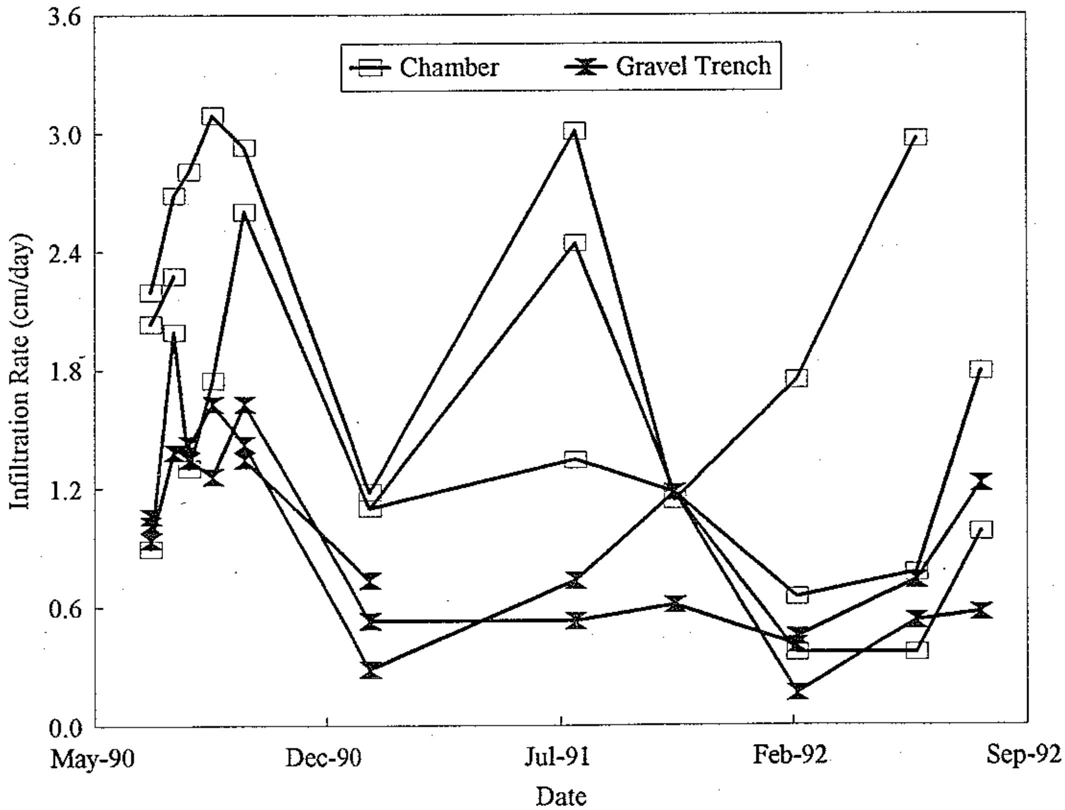

Figure 2. Falling head infiltration rates for chamber and gravel cells in the sandy soil.

Infiltration rates were higher during the late summer and fall and lower in the winter. The reduced infiltration rates during the winter are probably due to increased resistance of the biological clogging mat produced, decreased temperatures and microbial activity. High soil moisture content could also contribute to reduced wastewater infiltration.

Loading rates for the wastewater infiltration cells was estimated based on the basal area. The deeper the ponding, the greater the infiltration contribution of the sidewall. Therefore, the depth of ponding is directly related to reduced infiltration rate. Since the design application rate is 4.2 cm/day (1 gpd/ft^2) based on the basal area, the actual infiltration rate of all surfaces in ponded systems is less than the design loading rate. With an assumed failure depth for ponding of 275 mm, and assuming all infiltrative surfaces performed equally well the actual acceptance rate of the total wetted area of the 90-cm cell with vertical sides is about 2.5 cm/day (0.6 gpd/ft^2). Measured infiltration rates range from less than 0.4 to 3.3 cm/day (0.1 to <0.8 gpd/ft^2). The variation in these numbers and the fact that they are above and below 2.5 cm/day (0.6 gpd/ft^2) suggests that the infiltration rates are not uniform for all surfaces.

Ponding of wastewater was first noted in all cells in the winter of 1987-88 (Figure 3). Therefore, basal infiltration rates are lower than the application rate for all cells. Ponding disappeared or was reduced in the summer and maximum depths were in the spring. Cold season ponding depth is believed to be related to the slower microbial activity, the accumulation of a biological mat and subsequent increased resistance to wastewater infiltration. Ponding depths decrease as bacterial activity in spring and summer reduce clogging intensity. Maximum and minimum ponding depths lag considerably behind the maximum and minimum air temperatures for Wisconsin. It is interesting to note that ponding depth increases at a slower rate than the decline of ponding depths. Wastewater infiltration systems installed in southern climates and loaded at the same rate may not have the depth of ponding observed in Wisconsin.

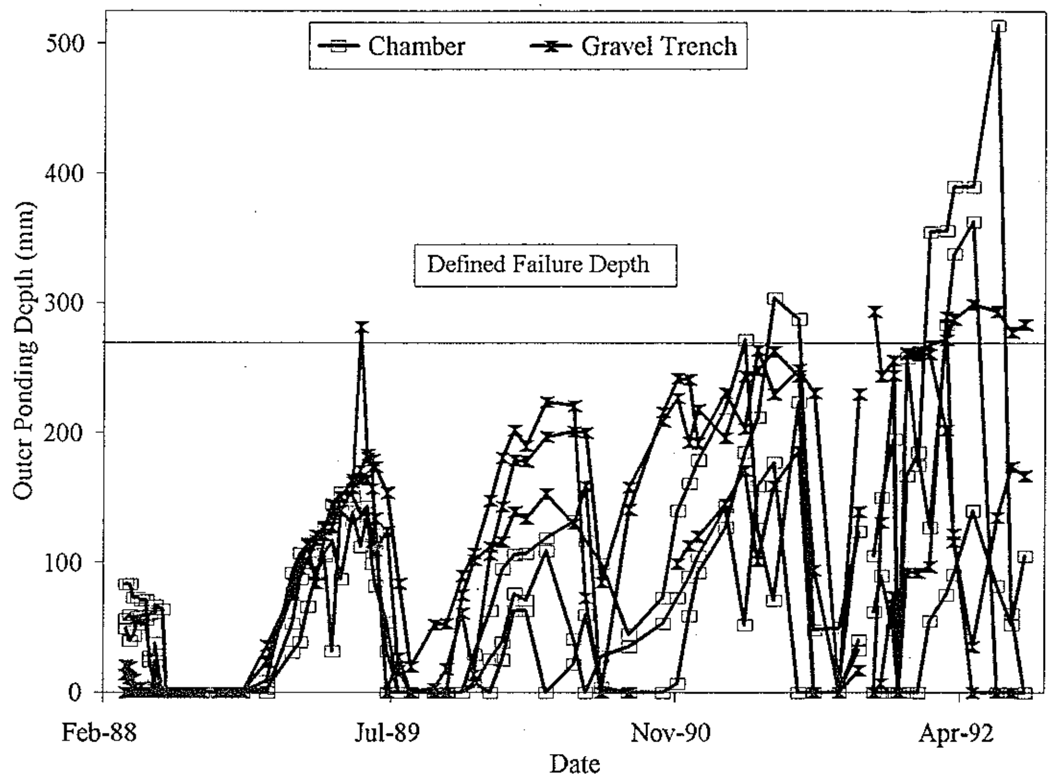

Figure 3. Ponding depths for three chamber wastewater infiltration cells and three gravel wastewater infiltration cells in sandy soil.

Ponding depths between the two cell types varied over time (Figure 3). Initially the ponding depths were deeper in the chamber cells than in the gravel cells. Ponding depths of each treatment were similar during the 1988-89 winter, while 1989-90 ponding in the gravel was as much as 2.5 times greater than that in the chamber cells. Variability increased greatly after 1990-91 due to mechanical problems, making interpretation of the data more difficult.

The assumed failure depth has been exceeded in two chambers and two gravel cells. A chamber was the first to fail in the spring of 1991 and one chamber and two gravel cells failed in the spring of 1992. The other cells were not loaded to design because of mechanical failures. Therefore, the design loading rate of 4.2 cm/day (1 gpd/ft^2) based on basal area is too high for the sand soil cells regardless of system design.

SUMMARY

In the silt loam soil both the chamber and gravel cells continue to accept wastewater above the expected long term loading rate and design loading rate. No ponding of effluent has occurred in these cells. Variability of infiltration rates is high.

In the sand soil, all cells ponded during the first winter of use. Ponding fluctuated seasonally with deeper ponding in the colder seasons. Assumed failure depth of two chambers and two gravel cells in sands has been exceeded.

ACKNOWLEDGMENTS

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