

SMALL SCALE WASTE MANAGEMENT PROJECT

Wastewater Infiltration from Chamber and Gravel Systems

by

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WASTEWATER INFILTRATION FROM CHAMBER AND GRAVEL SYSTEMS

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ABSTRACT

Wastewater ponding depths and infiltration rates for chamber and gravel cells approximately 90 cm wide by 180 cm long simulating full-sized wastewater infiltration systems have been determined for more than 3 years. Three chamber systems and three gravel trenches have been 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/ft²) and 2.5 cm/day (0.6 gpd/ft²) for the sand and the silt loam soils, respectively. In all ponded trenches, wastewater depth is frequently measured. Infiltration rates are periodically determined 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 too great to establish differences between cell types. Ponding of wastewater occurred within the first year of operation in all chamber and gravel cells installed in sand soil and depths fluctuated seasonally with maximum ponding depths during the winter. Ponding depths after the second year of operation are greater in the gravel than in the chamber cells during periods when equipment was functioning properly.

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 (1980).

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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 and 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 50% smaller than bed systems for any given soil type (Hoxie and Frick 1984). 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 was considered unsuitable because wastewater ponded to the ground surface during the time of the experiments while the other systems were considered suitable (Caldwell Connell Engineers Pty. Ltd. 1986).

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

Two sites were selected for installation of the experimental units. One site is located 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 about 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 each. The location of each cell 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 InfiltratorTM 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 also provide access for making measurements. The elevation of the inlet pipe and basal area of each trench was recorded. The exact, as built, measurements for each cell were used in all calculations.

Household wastewater at the silt loam site is from a single family home. The BOD is 81 mg/L and the SS is 44 mg/L (Table 1). 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 BOD is 170 mg/L and

the SS is 63 mg/L (Table 1). This wastewater is typical of household wastewaters.

Table 1. Wastewater Quality Characteristics^a Important to Clogging Mat Development in Onsite Wastewater Infiltration Systems for the Silt Loam and Sand Soil Sites

Character- istics	Silt loam site					Sandy site				
	N	Mean	Std. dev.	Max.	Min.	N	Mean	Std. dev.	Max.	Min.
TS, mg/L	56	728	87	952	476	58	502	136	779	257
VS, mg/L	56	263	62	438	123	58	271	79	457	121
SS, mg/L	56	44	33	147	2	58	63	30	160	21
VSS, mg/L	56	25	13	62	1	58	49	24	132	12
BOD, mg/L	41	81	31	140	29	39	170	35	249	113
COD, mg/L	55	157	46	244	49	57	312	104	576	147
TOC, mg/L	11	41	16	65	17	6	106	32	131	38
O. N, mg/L	57	9	3	16	2	57	12	5	28	4
NH ₄ , mg/L	56	50	11	69	10	57	57	19	87	20
NO ₃ , mg/L	60	0	0	2	0	57	0	0	1	0

^aTS = total solids; VS = volatile solids; SS = suspended solids; VSS = volatile suspended solids; BOD = 5-day biological oxygen demand; COD = chemical oxygen demand; TOC = total organic carbon; O. N = organic nitrogen; NH₄ = ammonium nitrogen; NO₃ = nitrate nitrogen; concentrations of nitrogen compounds are based on elemental N.

At the sandy soil site the design and actual loading rate is 4.2 cm/d (1 gpd/ft²) and at the silt loam soil site the design and actual loading rate is 2.5 cm/d (0.6 gpd/ft²) 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 the 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 both the covered sidewall and bottom area.

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 approximate depth of gravel from just above 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. Numerous data have been collected, as seen in Fig. 1 where infiltration rates for one cell are presented. Infiltration rates are between 46 and 200 cm/day (11 and 48 gpd/ft²). This is well above the design and actual loading rates of 2.5 cm/day (0.6 gpd/ft²) and above the expected clogged and long-term acceptance rate for the soil. Both Hargett et al. (1984) and Siegrist (1987) 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. The BOD averages 81 mg/L (Table 1) or about half of the expected.

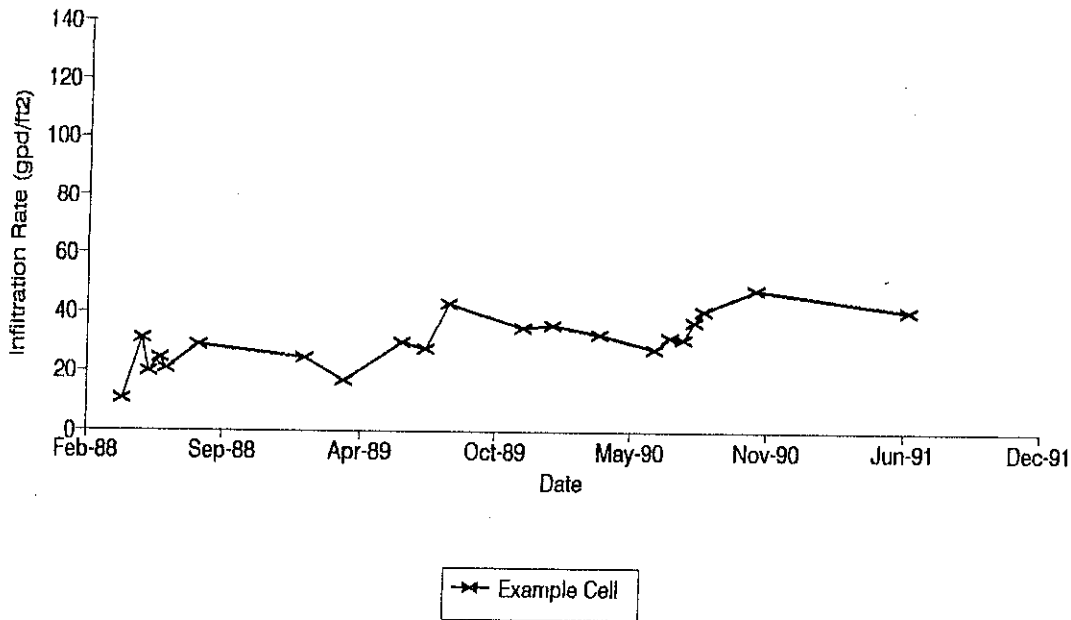


Fig. 1. Infiltration Rates for One Cell
Installed in a Silt Loam Soil

Infiltration rates from 1988 to 1991 are presented in Fig. 2 for each of the three chamber and gravel cells. Infiltration rates are often greater than 30 times the expected long-term acceptance rate and the design loading rate. Average infiltration rates of the three replications for the chamber cells are higher than for the average infiltration rates for the gravel cells. In December 1989, the average infiltration rate of the chambers was

1.3 times that of the gravel cells, while in November 1990 the average infiltration rates for chambers exceeded that of gravel by a factor of 1.7 times.

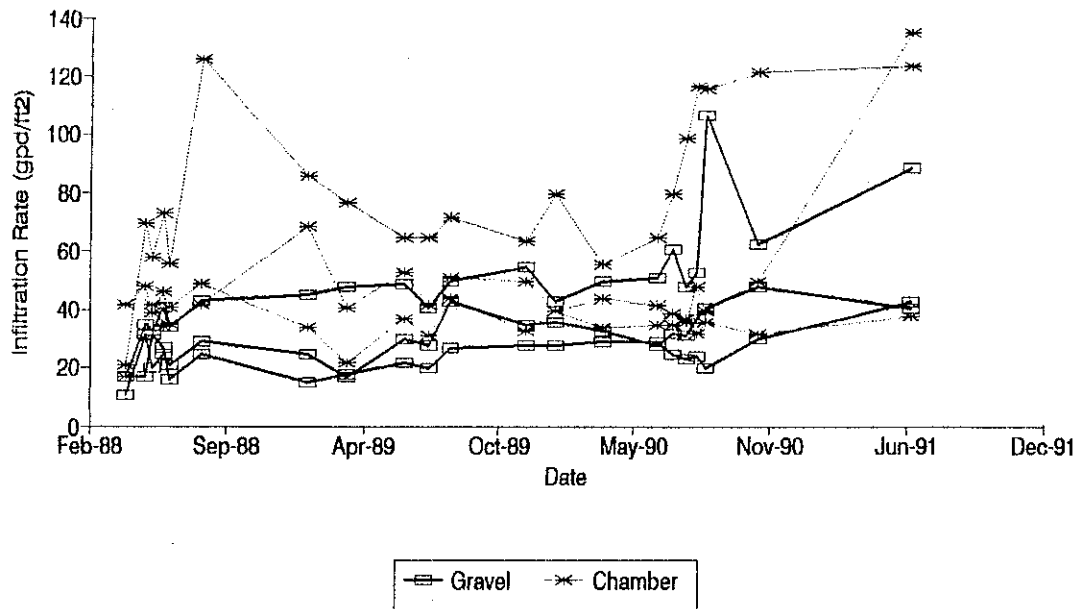


Fig. 2. Infiltration Rates for Three Chamber Wastewater Infiltration Cells and Three Gravel Wastewater Infiltration Cells

As mentioned earlier, 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.

Although there is a trend that the chamber cell infiltration rates are higher than the rates for the gravel cells, the variability of data within one cell type is high and no significant difference between cell types can be established. More replicates are needed to prove significance at this stage of system operation. 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 capacity constant head infiltrometer. Cells quickly ponded and remained ponded for major portions of the experiment. The falling head infiltration measurements (Fig. 3) 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 in 1990 and 1991. Missing data occurred when all wastewater within a cell infiltrated during the falling head measurement.

Infiltration rates were higher during the late summer and fall of 1991 and lower in the winter. The reduced infiltration rate is probably due to

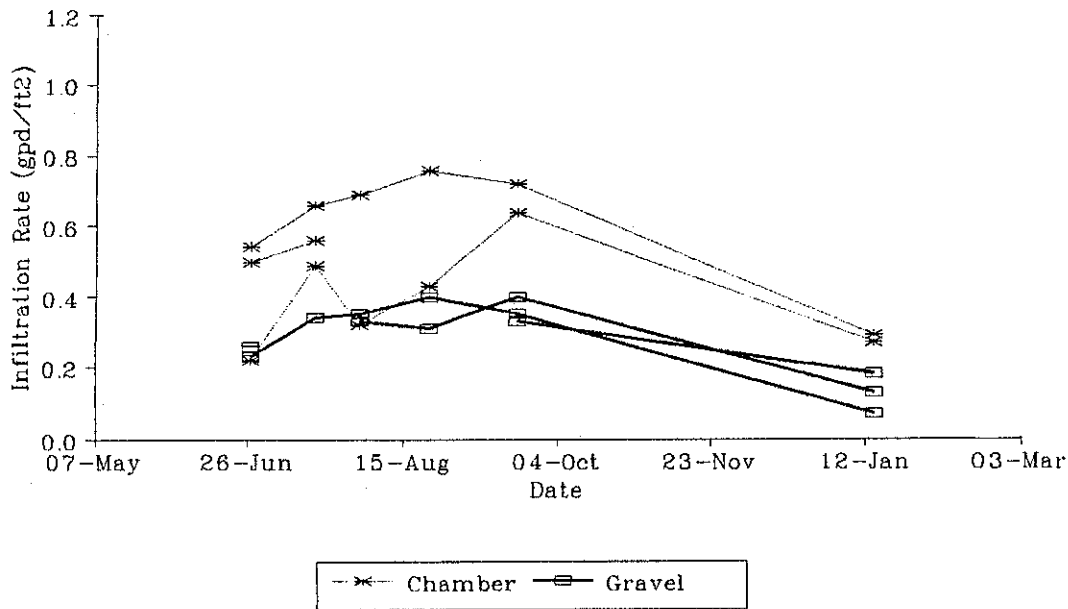


Fig. 3. Falling Head Infiltration Rates for Chamber and Gravel Cells in the Sandy Soil

increased resistance of the biological clogging mat produced during the cold temperatures and decreased microbial activity. There were no significant differences between treatments for the first measurement of June 1990 using the student's-t test at 0.05, while the last two measurements showed significant differences between chamber and gravel cell infiltration rates using the treatment contrast test at 0.01 and the student's-t test at 0.05, respectively. During the last two measurement periods, chamber infiltration rates were higher than for gravel cells. The variation in the establishment of differences between the chamber and gravel cells over time is puzzling. Seasonal variation in infiltration may influence the variability of the measurement. However, there are not enough data to verify the hypothesis.

Ponding of wastewater was first noted in all cells in the winter of 1987-88. Therefore, basal infiltration rates are lower than the application rate for all cells. Figure 4 illustrates the ponding depths of a single cell. 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. This may be a result of differences in microbial kinetics with the variations in temperature. Others have also noted the seasonal changes in ponding depths (Effort and Cashell 1987; Simon and Reneau 1987). Climate and seasonal changes seem to have a considerable influence on the operation of onsite wastewater infiltration systems. Wastewater infiltration systems installed in southern climates and loaded at the same rate may not have the depth of ponding observed in Wisconsin.

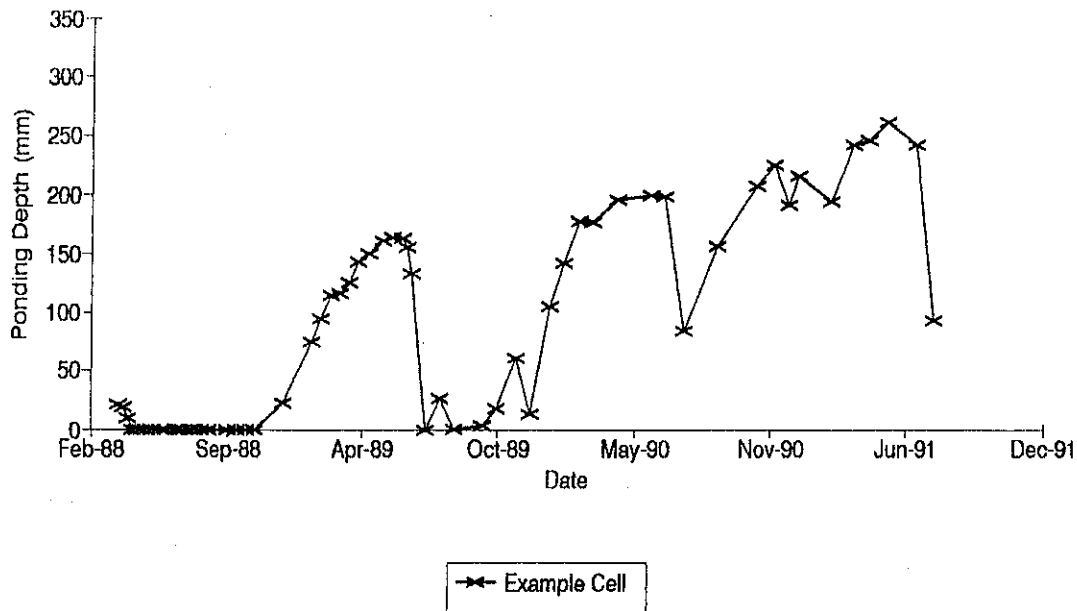


Fig. 4. Ponding Depths for One Cell Installed in a Sandy Soil

Variations in ponding depth not associated with seasonal climate changes may be due to natural variation in the wastewater, soil, the clogging layer and operation of the mechanical equipment. For example, in Fig. 4 the ponding depth varies considerably during fall of 1990 which probably reflects a number of equipment failures. However, these variations are not large enough to affect the final conclusions.

Loading rate 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/ft²) 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/ft²). Measured infiltration rates range from 0.4 to 3.3 cm/day (0.1 to 0.8 gpd/ft²). The variation in these numbers and the fact that they are above and below 2.5 cm/day (0.6 gpd/ft²) might suggest that the infiltration rates are not uniform for all surfaces.

Ponding depths between the two cell types varied over time (Fig. 5). 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 in the 1990-91 data due to mechanical problems making interpretation of the data impossible.

Student's-t tests at 0.05 were run for ponding depths for maintenance free data collection periods which were found for all but the last ponding season. During the last season mechanical problems precluded comparison. Significant differences between the gravel and chamber cell ponding depths

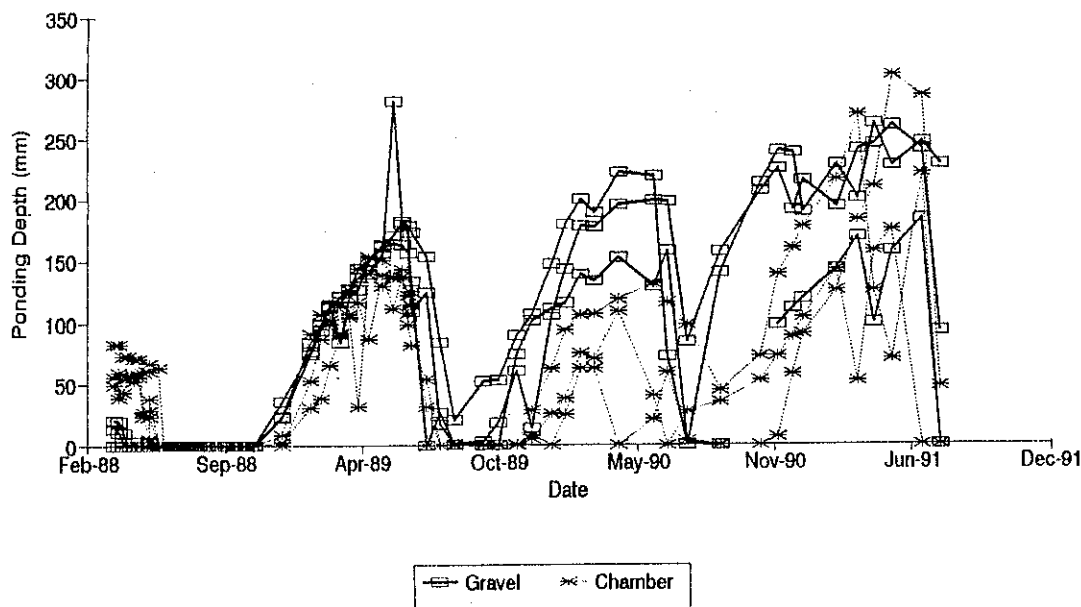


Fig. 5. Ponding Depths for Three Chamber Wastewater Infiltration Cells and Three Gravel Wastewater Infiltration Cells

were found during the first (1988) and third (1989-90) ponding seasons. The latter period of significant difference in ponding depth is probably more significant than the former because it is more closely related to long-term performance. Hopefully, the next season of data will provide important information as to whether the most recent trend was due strictly to mechanical difficulties, system aging or both.

The maximum measured ponding depths are approaching the assumed failure depth. The limit may be reached within the next couple of ponding seasons, depending on the regeneration of sidewall and basal infiltration rate during summer months. It appears that the drained period during the warm months is getting shorter and some cells are continuously ponded. Continuously ponded cells are not likely to reduce basal clogging or sidewall clogging below the depth of continuous ponding. Therefore, the design loading rate of 4.2 cm/day (1 gpd/ft²) based on basal area is too high for the sand soil cells regardless of system design.

CONCLUSIONS

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. Although the average of the chamber infiltration rates exceeds that of the gravel cells, the within cell type variability of infiltration rates for the triplicated experiment is too high to establish differences. More replications would be needed to show significance at this stage of system maturity. When a clogging mat develops, variability may decrease and statistical significance may be established. At this time, it is impossible to draw conclusions concerning the long-term loading rates.

Falling head infiltration rates of chamber cells are significantly higher than gravel cells during fall/winter in sand soil. In the sand soil, all cells ponded during the first winter of use. Ponding fluctuated seasonally with deeper ponding in the colder seasons. The seasonal pattern continues and winter ponding depths in all cells are approaching the assumed failure depth of the cells. After the second ponding season, when equipment was functioning properly, ponding depths in gravel cells have been significantly higher than chambers cells.

ACKNOWLEDGMENTS

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