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SMALL SCALE WASTE MANAGEMENT PROJECT

Infiltration as Affected by Compaction, Fines and Contact Area of Gravel

by

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INFILTRATION AS AFFECTED BY COMPACTION, FINES AND CONTACT AREA OF GRAVEL

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Traditional onsite wastewater treatment systems utilize gravel, also referred to as aggregate, to support the sidewalls of the soil excavation preventing its collapse, to dissipate energy from incoming wastewater which might erode the infiltrative surface, to provide storage of peak wastewater flows, to support the distribution pipe, and to provide a media through which the wastewater can flow from the pipe to reach the infiltrative surface (EPA 1980). Some have questioned the effect gravel has upon the infiltration rate of wastewater into soil. The supposed problems caused by gravel include the compaction of the soil infiltrative surface by falling gravel during system construction, the presence of excessive fine earth material, or "fines," on the gravel which can wash off and form a restrictive layer on the soil surface, and the "masking" of a portion of the soil infiltrative surface by contact with the gravel (May 1987).

The objective of this study was to evaluate the effect of gravel on soil infiltration rates, and thus on the operation of newly constructed onsite wastewater treatment systems. Specifically, objectives were to evaluate the effect of 1) soil compaction and smearing by falling gravel, 2) the fine earth material carried by gravel, and 3) the masking of the infiltrative surface caused by the contact area between the gravel and the soil.

MATERIALS AND METHODS

Gravel and Fines

Two gravel sizes, referred to here as large and small, were utilized for field experiments. The large gravel had a median particle size of 3.0 cm (1.2 in.) with some pieces up to 5.1 cm (2 in.). The small gravel had a median particle size of 1 cm (0.4 in.). This represents the range of gravel sizes obtained from six suppliers. Except for size, the samples met the requirements of washing and hardness for gravel used in private sewage systems in Wisconsin (Wisconsin Administrative Code 1983). Prior to field experiments, the samples were thoroughly washed in the laboratory to remove fines. Fines were collected from laboratory washings of gravel from numerous sources. The textures of the fines for the gravel obtained from the six suppliers ranged from silt loam to loam and sandy loam. The fines for these samples ranged from less than 1% to greater than 4% by weight. The fines used for this experiment had a sandy loam texture, and were applied at a rate which simulated the total amount of fines that would be expected

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to wash onto the soil surface from 15 cm (6 in.) of gravel that contained 5% by weight fines.

Soils

Two soil types were used for this project. Specifically, the sand C horizon of the Plainfield sand, a mixed, mesic Typic Udipsamment and the structured, silty clay loam argillic horizon of the Plano silt loam, a fine-silty, mixed, mesic Typic Argiudoll were utilized for the field work portion of this study.

Infiltration Measurements

Infiltration measurements were made in six experiments in the silt loam soil, and four in the sand soil. A backhoe was utilized to excavate a trench with a relatively level work surface at the horizon of interest. After each trial, the backhoe prepared a new trench and work surface. After excavation by the backhoe, the work surface was further leveled and raked by hand.

Infiltration rings of 25 cm (10 in.) and 61 cm (24 in.) diameter were used in this experiment. The 25-cm (10-in.) rings were made of steel, while the 61-cm (24-in.) rings were made from PVC pipe. Ring and pedestal locations at the work surface were selected before conducting the experiments to avoid unusual cracks and holes, and the soil surface characteristics for each ring typified the entire treatment area. After ring placement, a cylindrical soil pedestal was carved out beneath each ring, to a depth of at least 30 cm (12 in.). This height ensures one-dimensional downward flow during the infiltration test (Baker 1977). The walls of the pedestals were coated with several layers of dental plaster. Any gaps between the infiltration rings and the pedestal were filled with a bentonite slurry to avoid the channeling of water between the plaster and the pedestal. When possible, pencil-sized tensiometers were installed through holes in the infiltration rings, about 3 cm (1.2 in.) beneath the infiltrative surface. This allowed determination of steady state flow conditions.

Water flowed from Mariotte-equipped carboys for the 61-cm (24-in.) rings, or burettes for 25-cm (10-in.) rings, through a plastic tube to the infiltration ring cover plate, and thus to the test pedestal. Each burette or carboy was elevated so as to produce a hydraulic head of about 1 cm on the soil surface (Fig. 1). The actual infiltration measurements were made by applying tap water to the pedestal until steady-state infiltration was reached. Infiltration rate results were expressed in terms of cm/day. An analysis of variance was performed on infiltration rates for each trial.

Each compaction experiment involved nine 61-cm (24-in.) pedestals and rings, three which had undergone compaction by large gravel, three which had undergone compaction by small gravel, and three "control" or undisturbed soils. The compaction of the soil was achieved by dropping the gravel from a height of about 120 cm (4 ft.) onto the soil. After compaction, gravel was carefully removed from the soil to eliminate the contact area effect before the infiltration rings were placed and the pedestal carved. The large rings were utilized to ensure that an adequate number of gravel particles were in contact with the soil surface. This experiment was conducted at 19, 34, and 36% moisture on the silt loam soil, and 8% moisture on the sand soil.

The contact area experiments also involved nine 61-cm (24-in.) pedestals and rings with three replicates each of large gravel, small gravel, and control soils. However, this time the gravel was not dropped but was carefully placed on the soil surface after the infiltration ring had been placed and the pedestal had been carved.

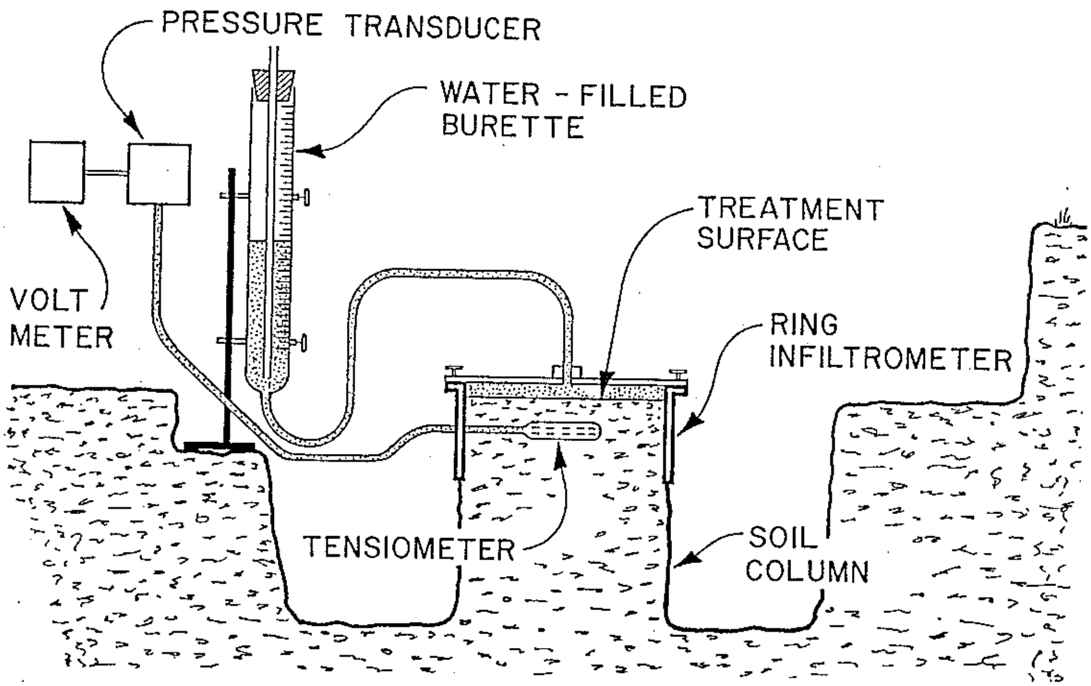

Fig. 1. Schematic Diagram of Apparatus for Measuring Infiltration Rate

The fines experiments involved eight 25-cm (10-in.) pedestals and rings with four replicates each of fines-treated soil and control soil. The fines were added after the infiltration ring had been placed and the pedestal carved.

The combined experiments again involved nine 61-cm (24-in.) pedestals and rings with three replicates each of large gravel, small gravel, and control soils. As in the compaction experiments, the compaction of the soil occurred before the infiltration rings were placed and the pedestals carved. This time, however, the gravel at the infiltrative surface was not removed, as the contact area effect was also part of the experiment. Finally, the fines were added.

RESULTS AND DISCUSSION

Compaction and Contact Area Effects

For both the Plano silt loam and the Plainfield sand soils, no significant difference was found between the infiltration rates for the control columns and the columns which had undergone compaction by falling gravel (Table 1). This was the case for both the dry and moist Plano soils. It was also true for both the large and small gravel on both soils.

In addition, for both soil types, no significant difference was found between the infiltration rates for the control columns and the columns which were being evaluated for the contact area effect. Again, this was true for both the large and small gravel.

These results should not be misconstrued to indicate that either the compaction of soil by falling gravel or the contact area effect may not cause

Table 1. Mean Water Infiltration Rates and Standard Deviations (S.D.) for Falling Gravel Compaction Treatment at Three Water Contents (θ), Placement of Gravel Creating a Contact Area, or Combined Treatments for Two Gravel Sizes or for Fines Only.

Treatment	θ	Control Mean	Control S.D.	Large gravel Mean	Large gravel S.D.	Small gravel Mean	Small gravel S.D.	Significant difference
		(cm/d)		(cm/d)		(cm/d)		
PLANO SILT LOAM								
Compaction	0.19	193	42	263	176	217	108	No
Compaction	0.34	195	66	267	110	132	45	No
Compaction	0.36	1235	355	623	128	1123	210	No
Contact area	0.35	395	92	285	59	313	48	No
Combined	0.36	203	37	88	3	95	15	Yes
				No gravel				
Fines	0.35	710	351	216	79			Yes
PLAINFIELD SAND								
Compaction	0.08	1348	161	1400	318	1352	390	No
Contact area	0.08	1107	65	1280	78	1277	152	No
Combined	0.08	1623	312	705	151	635	36	Yes
				No gravel				
Fines	0.08	2154	738	1441	220			No

infiltration rate reductions in newly-constructed onsite wastewater treatment systems. Rather, the results indicate that the magnitude of whatever infiltration rate reduction, if any, was occurring was not great enough to discern statistically meaningful differences between the control and treated soil columns given the number of replicates and the natural variability in the infiltration rates of the control columns.

Fines and Combined Effects

For the Plainfield sand soil, although there appeared to be infiltration rate reductions for the fines-treated soil columns compared to the control columns, the differences were not statistically significant. However, significant infiltration rate reductions did occur between the fines-treated and control columns in the Plano silt loam soil. If the fines are finer than the soil, it would be expected that the greater the textural difference between the fines and the underlying soil the greater the impact a thin layer would have on infiltration rate (Bouma et al. 1974). In the case of these experiments, the fines were actually a sandy loam material, which falls roughly in-between the silt loam texture of the Plano soil, and the sand texture of the Plainfield soil.

For the combined experiments, where the compaction, contact area effect, and fines effects were all operating, significant infiltration rate reductions occurred between the treated and control columns in both the Plano silt loam and the Plainfield sand soils, although there was no difference exhibited between the columns with small gravel and those with large gravel.

Based on the lack of statistically significant data showing negative impacts on the infiltration rates due to either the compaction of the soil by falling gravel, or the contact area effect, it appears that the presence of fines in the combined experiments is the predominant factor driving these results.

CONCLUSION

These experiments indicate that fines carried by gravel are a potentially greater problem in newly-constructed onsite wastewater treatment systems than either compaction by falling gravel or the contact area effect.

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