Rural Wastewater

Soil Hydraulic Conductivity and Septic System Performance

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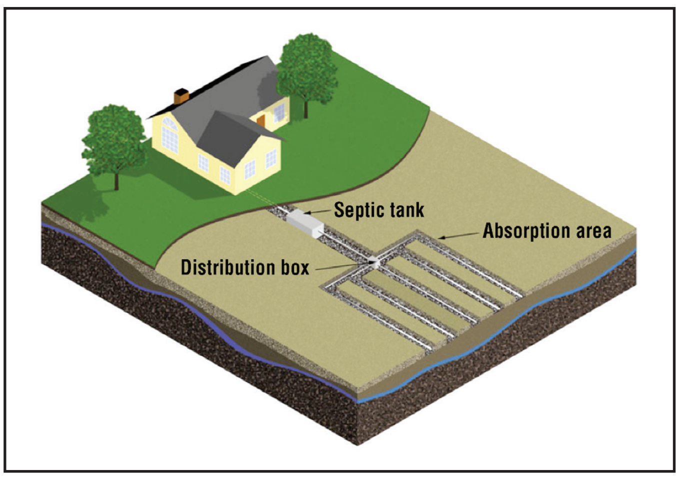
Approximately one-third of all Indiana homes use septic systems, leading to the treatment of more than 51 billion gallons of household wastewater effluent per year. A typical septic system contains a septic tank, distribution box, and absorption field (Figure 1). All components must be functioning properly to effectively remove contaminants from the wastewater and disperse it into the soil.

Central to septic system performance is soil hydraulic conductivity, or the rate water flows through the soil. This publication focuses on hydraulic conductivity in septic system absorption fields, and its importance in the successful treatment of wastewater effluent.



Sharon Katz, Purdue Agricultural Communication

Figure 1. A conventional septic system contains a septic tank, distribution box, and absorption field.

Soil's Role in Septic Systems

The soil absorption field is where final treatment and dispersal of wastewater occurs. Conventional septic system soil absorption fields typically include a series of trenches containing perforated distribution pipes that are surrounded by gravel (Figure 2). In the septic tank, wastewater separates; dense organic matter sinks to the bottom of the tank, lighter elements (fats and grease) float to the top, and the clarified effluent flows into the trenches where it is dispersed into the soil.

Once in the soil, there are three major processes that break down waste products in the effluent:

- chemical
- physical
- biological

Chemical treatment occurs when effluent comes into direct contact with soil material. Nutrients from household effluent, such as phosphates, adsorb to the soil particles, thus preventing them from traveling into groundwater.

Physical treatment occurs when the effluent enters small pore spaces in the soil. The pores act as a filter to remove particulate contaminants (solids) from the effluent.

Biological treatment of wastewater involves microbes in the soil feeding on, breaking down, and removing pathogens and organic contaminants from wastewater.

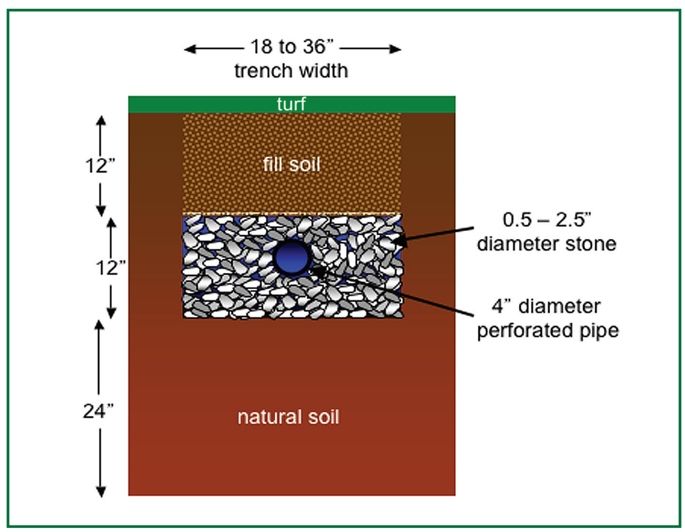
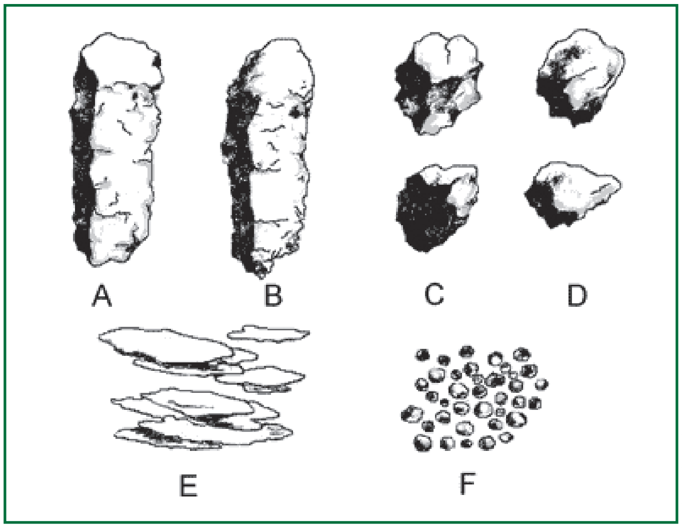


Figure 2. This cross-section of a conventional septic system soil absorption trench shows a perforated pipe surrounded by gravel. This design increases the area available for effluent to be stored and dispersed in the soil. At least 12 inches of soil must cover the top of the gravel.



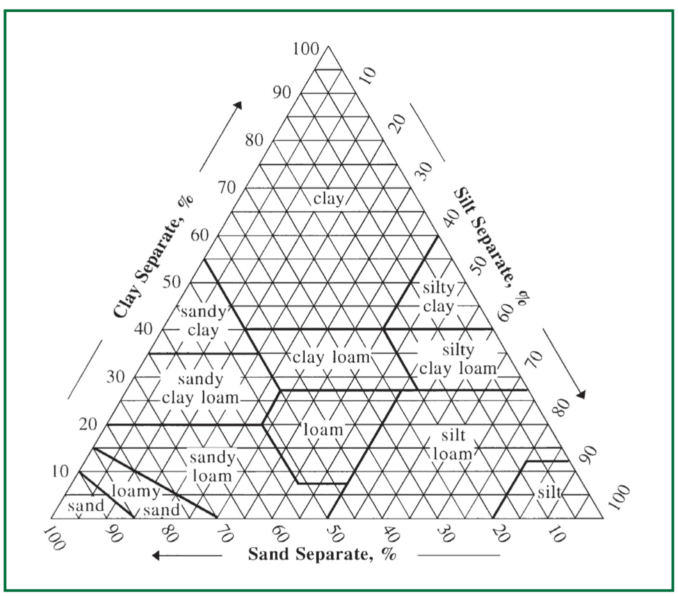
USDA Soil Survey Manual, 1951

Figure 3. *The common types of soil structure: A — prismatic; B — columnar; C — angular blocky; D — subangular blocky; E — platy; and F — granular*

Hydraulic Conductivity of Soil

In order to treat wastewater effluent properly, soil in the absorption field must be able to move water away from the trenches fast enough to prevent the water from rising to the surface, yet slow enough to provide ample treatment of the effluent by the soil.

If the effluent moves through the soil too quickly, the effluent's contact time with the soil particles will not be long enough to break down the pathogens and organic contaminants it contains. If effluent moves through the soil too slowly, the effluent won't be able to drain from the trenches effectively; it will begin to build up and can eventually pond on the lawn's surface. This ponding could lead to direct contact with human pathogens, bad odors, and nutrients running off into surface water bodies.



USDA-NRCS Field Book for Describing and Sampling Soils, 2002

Figure 4. *This textural triangle shows the percentages of sand, silt, and clay that comprise different soil textures.*

A common way to express water movement through porous materials (like soil) is hydraulic conductivity, commonly reported in centimeters or inches per day. Two major soil properties influence soil hydraulic conductivity: structure and texture.

Soil structure is the naturally occurring arrangement of soil particles into aggregates (Figure 3). Aggregates can be formed by biological activity (such as microbes, earthworms, or plant roots), inorganic cementing agents (such as calcium carbonate), climate (such as wetting and drying), and tillage.

Wastewater tends to move through the soil at varying rates depending on its structure. For example, soils with a platy structure, which are characterized by thin, flat plates, tend to slow water flow and may not allow for sufficient hydraulic conductivity. On the other hand, soils with a granular structure, tend to allow water to flow through the soil quickly, decreasing contact time between the effluent and soil particles.

Soil texture also is important for adequate hydraulic conductivity. Texture is the proportion of sand, silt, and clay in the soil (Figure 4). Sand particles range in size from 0.05 to 2 mm, silt particles range from 0.002 to 0.05 mm, and clay particles are less than 0.002 mm in diameter.

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Figure 5. *This image shows an example of a failing septic system. Effluent can be seen surfacing on top of the lawn at left.*

If a soil has a coarse sand or coarse loamy sand texture, the soil will have large pore spaces and the effluent may move through it too rapidly to be treated effectively. However, if the soil has a clay texture, pore sizes will be very small and hydraulic conductivity will be reduced significantly, making the soil unable to effectively move water away from the trenches.

When the amount of wastewater flowing from a home is greater than the soil's ability to transmit and disperse it, the system will overload, resulting in effluent surfacing on the lawn (Figure 5).

Measuring Hydraulic Conductivity

To simulate a properly functioning septic system, the most appropriate method of measuring soil hydraulic conductivity is in the field (Figure 6). In-field testing quantifies soil structural units and dimensional water flow as they occur in nature, rather than being estimated or assumed.

Previously, percolation (or, "perc") tests were used for septic system installation. However, this test does not provide reliable information,

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Figure 6. *Purdue University graduate student Jenny Krenz records water level measurements from Amoozemeters, which measure hydraulic conductivity in the field using the constant head permeameter method.*

during dry summer and fall months, when the soil has a clay texture, and contains cracks, or in soil with a seasonally shallow water table.

There are various methods to assess field hydraulic conductivity, including the auger-hole and piezometer methods. One of the more simple methods is called the constant head permeameter method (also known as the shallow well pump-in method). In this method, a hole of known diameter (usually 2.25 inches) is bored to a known soil depth. The hole is filled with water to a desired level and, as the water flows into the soil, more water is added to maintain a constant water level (Figure 7).

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Figure 7. *This image shows an Amoozemeter set up to measure soil hydraulic conductivity. The Amoozemeter is placed next to an augered hole and the water supply tube and water dissipating unit are lowered into the hole (represented by the boxed area). Tape measures are used to measure the water levels (the blue portion of the box represents the area that would be filled with water) until steady-state conditions are reached.*

When the water in the hole reaches a constant level and the rate of water flow into the soil reaches a constant, steady-state conditions are assumed and the rate of water flow into the soil can be used to determine the soil's hydraulic conductivity at the measured depth (for more detailed information on this method, see Amoozegar and Warrick, 1986).

Glacial Till and Hydraulic Conductivity

Glacial till is an accumulation of an unsorted, nonlayered mixture of sand, silt, clay, gravel, and sometimes boulders deposited by the glaciers that once covered much of the northern two-thirds of Indiana. Frequently, glacial till is dense, restricting hydraulic conductivity through the soil.

Loading Rates

The soil loading rate is an estimate of the gallons of wastewater effluent per day that can be accepted by a square foot of soil. Loading rates are important because Indiana State Department of Health Rule 410 IAC 6-8.1 (see www.in.gov/isdh/regsvcs/saneng/laws_rules/410_iac_6-8_1/410_iac_6-8_1.htm) uses soil loading rates to define which soils are acceptable for septic systems.

According to the rule, soil horizons that can adequately accept wastewater effluent must have a loading rate ranging between 0.25 gallons per day per square foot and (at most) 1.2 gallons per day per square foot.

ISDH Rule 410 IAC 6-8.1 bases estimated soil loading rates on soil texture and structure. The estimated loading rates originated from the following equation:

$$\text{Loading rate} = 0.22 \times (K_{sat})^{0.23}$$

where loading rate is in gallons per day per square foot, and K_{sat} is hydraulic conductivity in centimeters per hour (Taylor et al., 1997).

Comparing Loading Rates and Hydraulic Conductivity

In August 2004, Purdue University researchers, in cooperation with the USDA-Natural Resources Conservation Service, Indiana Department of Natural Resources, Indiana State Department of Health, and Indiana Onsite Wastewater Professionals Association, conducted field measurements of soil hydraulic conductivity in Wells County, Indiana. Measurements were taken on the Wabash Moraine near Bluffton at five

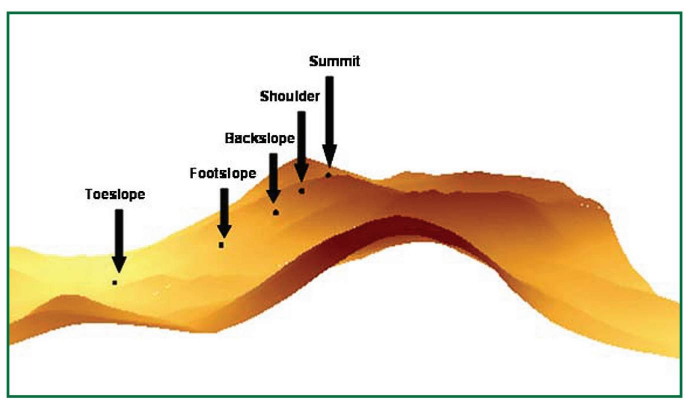

Figure 8. *This illustration shows the five landscape positions of a hillslope: summit, shoulder, backslope, footslope, and toeslope.*

different hillslope positions: summit, shoulder, backslope, footslope, and toeslope (Figure 8). Many of these soils contain dense glacial till.

At each hillslope position, five measurements were made at four different depths that represented major layers in the soil. The results in Table 1 compare "measured loading rates" (measured field hydraulic conductivity converted to loading rates) to the loading rates assigned by the type of soil structure and texture of each horizon according to ISDH Rule 410 IAC 6-8.1.

For all horizons, the actual measured loading rates are lower than the minimum estimated loading rates recommended by ISDH Rule 410 IAC 6-8.1. The data in Table 1 indicate that at each hillslope position at the study site, there would not be adequate hydraulic conductivity for acceptable septic system performance for any horizon.

Therefore, it can be concluded from this study that factors other than soil structure and texture should be considered when installing septic systems. More studies relating soil morphologic properties to water movement are needed to develop more accurate loading recommendations in northeastern Indiana.

Table 1. *Selected soil morphology and soil hydraulic conductivity measurements (converted to loading rates) and loading rates from ISDH Rule 410 IAC 6-8.1 based solely on structure and texture.*

Horizon	Texture	Structure[a]	Measured K_{sat} Converted to Loading Rate (gpd/ft^2)	Rule 410 IAC 6-8.1 Loading Rate[b] (gpd/ft^2)
Summit				
Ap	silty clay loam	weak, thin platy	0.16	0.60
Bt	clay	weak, coarse prismatic	0.07	0.25
Cdk	silty clay	weak, very coarse prismatic	0.09	0.25
Cdk[2]	silty clay	weak, very coarse prismatic	0.08	0.25
Shoulder				
Ap	silt loam	weak, thin platy	0.14	0.60
Bt	clay	weak, coarse prismatic	0.06	0.25
BCtdk	silty clay loam	weak, coarse prismatic	0.10	0.25
Cdk [2]	silt loam	weak, very coarse prismatic	0.09	0.30
Backslope				
Ap	silt clay loam	weak, thick platy	0.12	0.60
Bt	clay loam	weak, medium prismatic	0.08	0.25
BCtdk	clay loam	weak, coarse prismatic	0.09	0.25
Cdk[2]	clay loam	weak, very coarse prismatic	0.08	0.25
Footslope				
Ap	silty clay loam	weak, thin platy	0.20	0.60
Btg	silty clay	weak, medium subangular blocky	0.07	0.25
BCtdk	clay	weak, very coarse prismatic	0.07	0.25
Cdk[2]	clay	weak, very coarse prismatic	0.06	0.25
Toeslope				
Ap	silty clay loam	weak, thick platy	0.18	0.60
Bt	silty clay	weak, coarse prismatic	0.08	0.25
Cd	silty clay	weak, very coarse prismatic	0.08	0.25
Cd	clay	weak, very coarse prismatic	0.08	0.25

[a] Primary structures are listed in the table. Secondary structures include angular blocky and platy. For example, common structures in these soils included weak, coarse prismatic parting to medium, angular blocky.

[b] ISDH loading rates for Cd horizons are used only for load rate comparisons. These horizons do not receive a loading rate in ISDH Rule 410 IAC 6-8.1.

Summary

Soil hydraulic conductivity must be considered when installing a septic system. In soil with very low hydraulic conductivity, wastewater effluent is unable to move through the soil profile. In soil with very high hydraulic conductivity, the effluent will move through too quickly, and will not be treated properly.

Because measuring hydraulic conductivity in the field is complex and time-consuming, there is little data relating ISDH Rule 410 IAC 6-8.1 loading rate data to actual field measurements. The ISDH's current loading rate table for wastewater effluent is based on results from other states and USDA-NRCS estimates of soil hydraulic conductivity. However, as indicated by Table 1, these loading rates may be high for some soils, so in-field hydraulic conductivity tests are likely to be a better predictor of future septic system performance than the ISDH estimates based on soil morphology.

Remember, just because a soil description indicates that a septic system *can* be installed, does not mean that system will *function* as designed under the current rule.

References

Amoozegar, A. and A.W. Warrick. 1986. Hydraulic Conductivity of Saturated Soils: Field Methods. Chapter 29, *Methods of Soil Analysis, Prt I, 2nd ed.* pp. 735-770, A.S.A. Madison, WI.

Indiana State Department of Health (ISDH). 1990. Rule 410 IAC 6-8.1: Residential Sewage Disposal Systems. *Indiana State Department of Health*. Indianapolis, IN.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and W.D. Broderson (editors), 2002. *Fieldbook for Describing and Sampling Soils*, Version 2.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Taylor, C., J. Yahner, and D. Jones. 1997. *An Evaluation of On-site Technology in Indiana: A Report to the Indiana State Department of Health*. Purdue University.

United States Bureau of Plant Industry, Soils, and Agricultural Engineering. 1951. *Soil Survey Manual*. U.S. Government Printing Office, Washington, D.C.

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