NebGuide
University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
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Residential Onsite Wastewater Treatment: The Role of Soil

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This NebGuide discusses the role of soil in onsite wastewater treatment systems.

The most common onsite wastewater treatment system for rural homes consists of a septic tank and drainfield. The success of an onsite wastewater treatment system depends largely on soil characteristics, as well as system design, installation, and maintenance. This NebGuide will explain the important role soil plays in treating and returning treated wastewater to the environment by way of a traditional or gravelless drainfield.

With these systems, wastewater is reintroduced into the environment, where it will become part of the water cycle and available for further use. Therefore, it is important that wastewater be treated to remove pathogens and other pollutants. For general information on how a septic tank/effluent treatment system works, see the NebGuides *Residential Onsite Wastewater Treatment: Septic Tank Design and Installation* (G1473), *Residential Onsite Wastewater Treatment: Traditional Drainfield Systems for Septic Tank Effluent Treatment* (G1479) and *Residential Onsite Wastewater Treatment: Gravelless Drainfield Systems for Septic Tank Effluent Treatment* (G1480).

What Is Soil?

Soil is typically about 50 percent solid material and 50 percent pore space *(Figure 1)*.

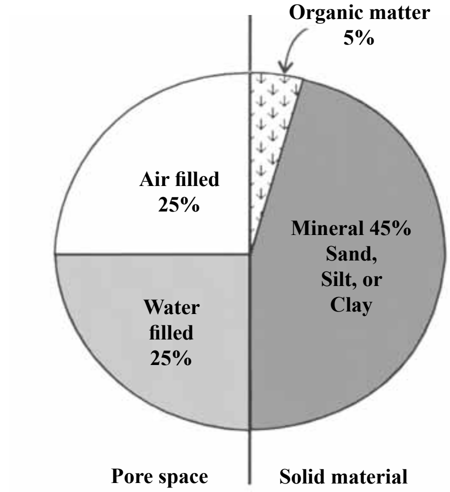

Figure 1. Soil components in typical proportions.

The solid material is a combination of minerals and decayed remains of plants and animals, called organic matter. The texture of a soil depends on the proportions of its different sized mineral particles. Sand particles (0.05-2.0 mm) are visible to the naked eye and feel rough or gritty. Silt particles (0.002-0.05 mm) are best seen with a microscope and feel like flour. Clay particles (smaller than 0.002 mm) are visible with a microscope and form a sticky mass when wet. If a sand particle were magnified to a size 10 inches in diameter, a silt particle at the same magnification would be about 1 inch in diameter, and a clay particle would be about the size of a grain of sugar. Rarely is soil exclusively sand, or silt, or clay. It usually is a combination of all three. Loam is a mixture of sand, silt, and clay; a sandy loam contains a great deal of sand, but has enough silt and clay to make it somewhat sticky. You may also find clay loam or silt loam soils. Ultimately, the texture of a soil affects its ability to hold and transmit water.

What Role Does Soil Play in Wastewater Treatment?

Soil is the most important treatment mechanism for many onsite wastewater treatment systems, including traditional or gravelless drainfields and mound systems. There are two important ways that soil treats wastewater — through the soil's physical characteristics and as a site for biological activity. It treats wastewater by filtering out particles, removing some chemicals and nutrients, and acting as a site for destroying pathogens.

Soil — Physical Treatment

Soil particles provide surface area for wastewater to pass over to be treated. Large particles in the wastewater, including bacteria, are filtered out. Some particles are adsorbed or stick to the soil. Soil particles are negatively charged and will attract and hold positively charged chemicals and viruses. Soils also contain minerals that bind with some pollutants, immobilizing them.

Soil helps treat wastewater by removing some of the nutrients. The two principle nutrients of concern are nitrogen and phosphorus. Nitrogen from the septic tank is usually in the form of ammonia (NH_3). Some is used by soil bacteria or adsorbed by soil particles, but most is converted to nitrate (NO_3) in the aerated soil below the treatment system. Nitrate is water soluble and negatively charged. It is repelled by the negatively charged soil particles, and easily moves with water through the soil, down to the groundwater. At high enough levels, nitrate in drinking water may cause illness in infants and other vulnerable populations. While not as well documented, at higher levels, nitrate may present a health risk for all consumers.

Treatment of nitrogen occurs to a limited extent through uptake by vegetation during the growing season and by a process called denitrification. In this process, following the conversion of ammonia to nitrate, the nitrate encounters a saturated zone in the soil that lacks oxygen. Anaerobic bacteria convert nitrate to nitrogen gas, provided there is a carbon food source such as dead plant material or other organic matter, and the gas escapes to the atmosphere. Because sandy soils often don't have this carbon food source, denitrification rarely occurs in sandy soil.

Nitrate that reaches groundwater is very difficult to mitigate. Dilution with groundwater can have a positive effect. The effectiveness of dilution depends on the amount of nitrate being generated, the amount of nitrate already present in groundwater, and the volume of groundwater available.

Phosphorus is present as phosphate (PO_4), as found in some detergents. It is removed by chemically binding to minerals such as calcium, manganese, and iron, depending on the soil pH. Soils higher in clay have greater capability to bind phosphate. If the wastewater treatment system is functioning properly, and proper setback distances are maintained from surface water, phosphate movement to groundwater or surface water should be minimal. Phosphorus in surface water acts as a fertilizer for algae and other aquatic plants, causing algal bloom in lakes and ponds, upsetting delicate natural balances. This is a particular problem in Nebraska's sandpit lakes, where sandy soil does a poor job of binding phosphates.

Soil — Biological Activity

Soil contains a complex biological community; 1 tablespoon of soil may contain more than 1 million microscopic organisms, including bacteria, protozoa, and fungi, among others. Some of these organisms feed on the organic matter in wastewater. Aerobic bacteria, those that need oxygen, are more effective at breaking down materials in wastewater than anaerobic bacteria, those that don't need oxygen. If the soil is saturated and no oxygen present, anaerobic bacteria predominate and provide little treatment. Therefore, it is important that soil at the site of a drainfield is not waterlogged or saturated with water. The NebGuide *Residential Onsite Wastewater Treatment: Site Evaluation* (G1469) gives information on how to determine if a soil has been saturated.

Generally, soil is a hostile environment for bacteria found in wastewater, due to temperature, moisture, and soil predators. Viruses are smaller than bacteria and are not filtered out by the soil. Instead, viruses have a positive charge and can be held by the negatively charged soil particles. Sandy soils, with their limited negative charges, capture viruses in microbial slime generated by soil bacteria. Some pathogens are held in the soil and die because of changes in temperature, moisture, food, and other conditions. Other pathogens are inhibited or killed by antibiotics naturally generated by soil fungi and other organisms. Still others are preyed upon by soil bacteria and literally eaten.

What Role Does Soil Play in Wastewater Recycling?

Wastewater from soil-based wastewater treatment systems eventually re-enters the water cycle by percolating through soil to groundwater, or evaporating from soil and plants into the air. In the case of a lagoon, water evaporates into the air. Nebraska Department of Environmental Quality (NDEQ) *Title 24 — Rules and Regulations for the Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems* allows a small amount, no more than 1/8 inch per day, to seep from a residential wastewater lagoon into the soil. The texture of a soil — the proportion of sand, silt, and/or clay particles — influences the rate at which water and air move through soil. Water moves faster through sandy soils than through clay soils, sometimes too quickly to provide adequate treatment. If the soil percolation rate is faster than five minutes per inch, a loamy sand liner must be installed in the drainfield to slow water movement. Do not have a drainfield constructed in soil with a soil percolation rate slower than 60 minutes per inch because wastewater will move so slowly through the soil that the system would not be able to keep up with the amount needing treatment. When soils have a percolation rate slower than 60 minutes per inch, a lagoon system is an option for a lot at least three acres in size. If the lot size is not suitable or other factors limit the use of a septic or lagoon system, an alternative soil-based system must be designed by an engineer.

The depth to groundwater is an important consideration in protecting groundwater quality. In areas with a high seasonal water table, effluent can contaminate groundwater, particularly if the soil above the groundwater is sandy or gravelly. In addition, areas with high groundwater levels cannot adequately accept wastewater flow. When all soil pore spaces are filled with water, wastewater may travel too slowly through the soil for the soil to accept all that requires treatment. This can result in wastewater backups in the home or surfacing in the yard.

Nebraska regulations require that there be at least 4 feet of vertical separation between the bottom of the drainfield and groundwater. Similarly, there must be at least 4 feet of soil between the bottom of the drainfield and bedrock. This distance is needed to filter and treat wastewater and reduce the risk of groundwater contamination.

A drainfield or lagoon must be at least 50 feet from surface water. This helps ensure proper treatment before wastewater reaches a stream or lake. Never place a drainfield or lagoon in a flood-prone area. Occasional flooding reduces the efficiency of the system, while frequent flooding may destroy its effectiveness, as well as contaminate surface water.

Identifying Soil Characteristics

Soil survey reports are available on the Internet and may be available at local University of Nebraska–Lincoln (UNL) Extension, U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) offices, or Conservation and Survey Division within the UNL School of Natural Resources. The soil survey report shows soil characteristics such as soil type, soil permeability, depth to bedrock or seasonal high groundwater table and slope, along with limitation ratings for drainfields. For example, a potential building site for a house having a septic tank/drainfield system is outlined on a typical soils map from a soil survey report in *Figure 2*. An enlargement of the building site is shown below the soils map. This site has two different soils — Fillmore silty clay loam (Fm) and Holdrege silt loam (HoB).

Text and charts in the soil survey indicate that Fillmore soil has severe limitations for drainfields. Fillmore silty clay loam is a deep, poorly drained, nearly level soil in a shallow basin-like depression. It has very low permeability and surface water may occasionally pond. When a drainfield is installed in poorly drained soils, effluent entering the system during wet periods may not drain and may either come to the surface or back up into the house. Because wastewater doesn't travel through this soil easily, Fillmore silty clay loam might be a good candidate for a wastewater lagoon. A percolation test, discussed in NebGuide *Residential Onsite Wastewater Treatment — Conducting a Soil Percolation Test* (G1472), may give a better indication. The other soil identified, Holdrege silt loam on 1 to 3 percent slopes, is a deep, well-drained, very gently sloping soil. It has a moderate permeability and only a moderate limitation for drainfields.

Based on the soil survey report, the best location for a drainfield in this example is on the Holdrege soil. However, other information must be collected before the final determination is made. NDEQ *Title 24* requires that a drainfield must be located according to many different criteria, including separation distances such as at least 50 feet from surface water, 100 feet from a private water supply, 5 feet from property lines, and certain distances from different types of building foundations. There must be at least 4 feet between the bottom of the drainfield and the seasonal high groundwater level. In addition, a reserve site must be identified, which is an alternate site should the original drainfield fail. For this example, depending on the setbacks, the drainfield may need to be near the boundary of the Holdrege and Fillmore soils.

The soil map indicates soil boundaries, but is limited by the scale of the map. An individual soil type may contain small areas of other soil types, called inclusions, that are too small to appear on the soil map *(Figure 2)*. These inclusions may have soil textures and permeabilities that differ from those shown for the larger area. For these reasons, a soil percolation test must be conducted at the proposed drainfield site to measure the water movement rate and determine if a septic

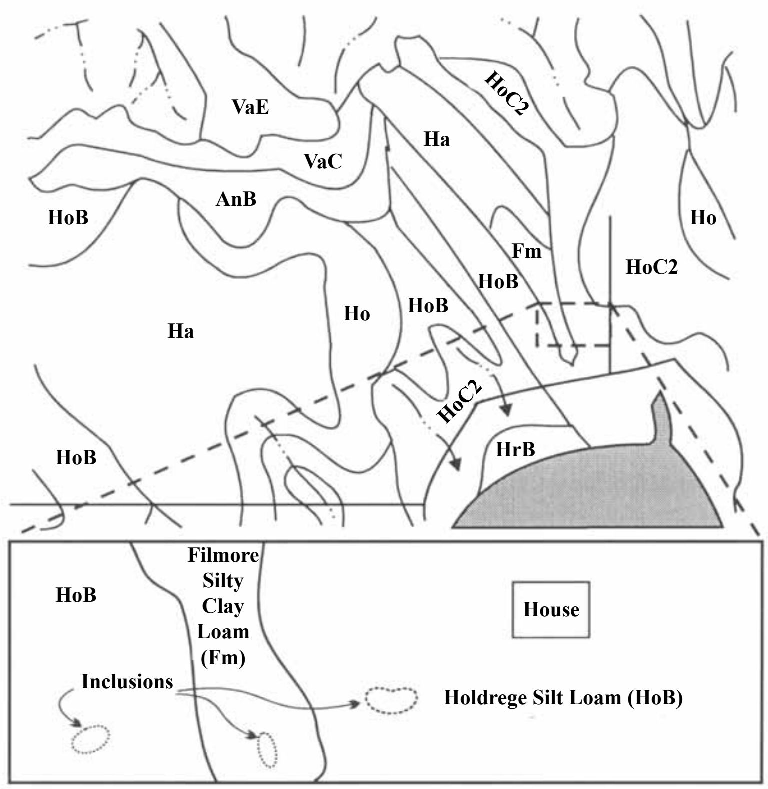

Figure 2. Typical soil map of central Nebraska in upper portion, showing soils found in that region. The enlarged building site at the bottom of the figure shows small areas of differing soils, called inclusions, too small to appear on a soil map.

tank/drainfield, lagoon, or alternative system is appropriate. If the soil has a suitable percolation rate for a drainfield, the percolation test results and wastewater generation estimates, based on the number of bedrooms in the home, are used to calculate the size of drainfield needed. Again, the soils map indicates what might be expected if a drainfield is installed, but generally does not provide enough information to design or size the system.

Summary

Soil plays an important role in effluent treatment in an onsite wastewater treatment system. Soil characteristics, along with a site evaluation, and estimated wastewater generation information are vital for selecting and designing the type of onsite wastewater treatment system best suited for a particular location.

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