Lesson 13: Environmental Impact of Soil and Water Management

Effects of Soil and Water on Pesticide and Fertilizer Loss

Pesticides and fertilizers are widely used by farmers to help them grow more bountiful crops. The term **pesticides** refers to any substance or chemical applied to kill or control weeds, insects, and other undesirable pests. Pesticides and fertilizers can be lost from the soil by leaching and water runoff and can pollute underground and surface water supplies. Underground water supplies, such as large aquifers, deep wells, and springs, are affected by leaching. Surface water supplies, such as rivers, ponds, and lakes, are affected by water runoff.

Soil properties can be evaluated to determine the potential of the soil to transmit water-soluble pesticides and fertilizers through the soil profile, and the likelihood of contamination of underground water supplies. Soil properties can also be evaluated to determine potential water runoff, which carry soil solids made up of soil particles, organic matter, pesticides, and fertilizer.

Potential Chemical Loss by Leaching and Water Runoff

Leaching and surface runoff are the two main causes of the removal of pesticides and fertilizers from the soil.

Leaching

Leaching is the potential for chemicals to be transported by **percolating water** (water moving downward through the soil) below the soil root zone. Chemicals in groundwater solution are leached from the surface layer and transported vertically or horizontally through the soil. They have a potential to contaminate shallow or deep aquifers, springs, and local water tables. Chemicals that are applied to or incorporated into the surface layer of the soil are subject to leaching. Precipitation—as rain, sleet, or snow—is the major source of soil moisture in which materials are leached from the soil. However, in some areas, irrigation water may be the largest source of moisture during the growing season.

Soil Properties that Affect Leaching

The soil properties that affect surface infiltration and permeability also affect leaching. Soil properties that affect surface infiltration are soil texture, permeability, restrictive layers, soil depth, and shrink-swell potential. The soil properties that affect permeability are soil structure, particle size distribution, bulk density (ratio of dry soil weight to volume), and presence of and depth to a restrictive layer.

Soils with properties that help retain chemicals within the rooting zone present the lowest levels for potential contamination by leaching. These favorable soil properties are deep, moderately well-drained or well-drained soils with moderate to moderately rapid permeability, high organic matter content, and medium soil textures, such as silt loam, loam, silty clay loam, and clay loam.

Runoff

Surface water runoff (precipitation that is lost without entering the soil) has the potential to transport pesticides and fertilizers. Sometimes pesticides and fertilizers are carried off the field by water runoff where they contaminate ponds, lakes, streams, and rivers.

Soil Properties that Affect Water Runoff

The soil properties that affect water runoff are those that affect the rate of runoff and the erodibility of the surface layer. Some of these properties are the same as those mentioned for leaching, such as texture, permeability, restrictive layers, soil depth, and shrink-swell potential. Other properties affecting the rate of water runoff are slope and internal drainage.

The soil properties affecting soil erodibility are particle size distribution (the exact percentage of sand, silt, and clay in the soil texture class), organic matter content, structure, and permeability. When pesticides and fertilizers are applied to bare soil, water runoff and erodibility are the most severe contamination threats. However, large amounts of crop residue on the surface, left by minimum tillage or no-till, are very effective in reducing runoff. Flooding has the potential for catastrophic surface

pesticide and fertilizer loss. Flooding can remove large quantities of pesticides, fertilizers, and solids in a single event.

The most favorable soil properties are those that help to retain pesticides and fertilizers within the rooting zone. The same properties that reduce leaching and water runoff losses will also improve the overall water quality.

Water Holding Structures

Pond reservoir areas hold water behind a dam or embankment. Soils best suited to this use have low seepage potential in the upper 60 inches. The seepage potential is determined by the permeability in the soil and the depth to bedrock or other highly permeable material. Slope also affects the water holding area. A much larger water area can be obtained on gently sloping soils than on steep soils. See Table 13.1.

Building Sites and On-site Waste Disposal

Dwellings With Basements

Soil limitations or features that affect the construction of dwellings are:

1. High water table
2. Flooding
3. Shrink-swell potential
4. Slope
5. Depth to bedrock
6. Rock fragments

A **high water table** will likely cause wetness problems around foundations, crawl spaces, and leaky basements.

Dwellings should not be constructed on a site if there is any possibility of **flooding**. Severe flooding can totally destroy houses.

Shrink-swell potential can cause severe damage to foundations and basement walls. See Plates 6 and 19, pp. 50-B and 50-E. The drying and wetting of the soils cause shrinkage when dry, and swelling when wet, exerting great force on roots, roads, foundations, and basement walls. Moderate or high shrink-swell ratings can cause damage to buildings and roads. However, proper design and construction can greatly minimize the possible damage. Shrink-swell is influenced by the amount and type of clay minerals in the soil. Kaolinite clay does not shrink and swell as much as other clays. See Table 13.2.

Slope can cause extra construction costs in excavation and design.

Table 13.1 – Guide for Rating Limitations for Pond Reservoir Area
(For subsoil permeability, use permeability of most limiting layer.)

Property	Slight	Moderate	Severe
Permeability	<0.6 inches/hour	0.6–2.0 inches/hour	>2.0 inches/hour
Depth to hard bedrock	>60 inches	20–60 inches	<20 inches
Depth to soft bedrock	>60 inches	20–60 inches	<20 inches
Slope	<3%	3–8%	>8%

Table 13.2 – Guide for Determining the Shrink-Swell Potential
(Use thickest layer, 10–60 inches, dominant percent of material.)

Soil Texture	Percent Clay	Shrink-Swell Rating
Sandy, loamy sand, sandy loam, loam, silt loam	0–26.99%	Low
*Silty clay loam, clay loam, sandy clay loam	27–39.99%	Moderate
**Silty clay, clay, sandy clay	>40%	High

* Kaolinite/silty clay loam, clay loam, sandy clay loam use low shrink-swell rating.
** Kaolinite/silty clay, clay, sandy clay use moderate shrink-swell rating.

Bedrock is nearly impossible to excavate for basements and foundations unless blasting is used.

Rock fragments cause extra construction costs to remove and/or prepare lawns.

Ratings of slight, moderate, and severe limitations for dwellings are interpretations based on the soil properties that affect construction and maintenance. Determine the correct rating for the site using the accompanying guide in Table 13.3. It should be noted that before any digging is started, on-site inspection and approval may be required by the local health department and/or the local planning and zoning committee. Planning and zoning and health department rules may vary from county to county. See Table 13.3.

On-site Waste Disposal

Any home constructed in an area not served by public sewers must have some kind of on-site waste disposal system. The most common systems are a septic tank with an absorption field or a sewage lagoon.

Septic Tank Absorption Fields

In a household not served by public sewers, wastes first go into the septic tank where anaerobic (not needing oxygen) bacteria decompose the solid and liquid wastes. See Figure 13.1.

Solid wastes sink to the bottom of the tank, and wastewater is drawn off the top for discharge into the absorption field.

The adequacy of these systems depends more than anything else on the properties of the soil. Soil must do three things for an absorption field to function properly: accept the wastewater, treat the waste, and dispose of the water. All three depend heavily on subsoil permeability.

Waste treatment is a biological process, and it requires plenty of oxygen. Wastewater must move through the soil quickly enough to prevent a buildup of saturated conditions, but slowly enough for microorganisms to do an effective job.

Septic tank absorption fields are subsurface systems with a series of tiles or perforated pipes that distribute effluent from a septic tank into natural soil. See Figure 13.2.

Wastewater flowing through the tile lines trickles into the soil, where further treatment and disposal occurs. The center line depth of the tile is assumed to be at least 24 inches. Only the soil between 24 and 60 inches is considered in making the rating. Ratings are for land conditions and do not consider present land use.

Prior to building a septic tank absorption field, soil properties and site features need to be considered, especially those that affect the absorption of effluent, affect the construction and maintenance of the system, and those that may affect public health.

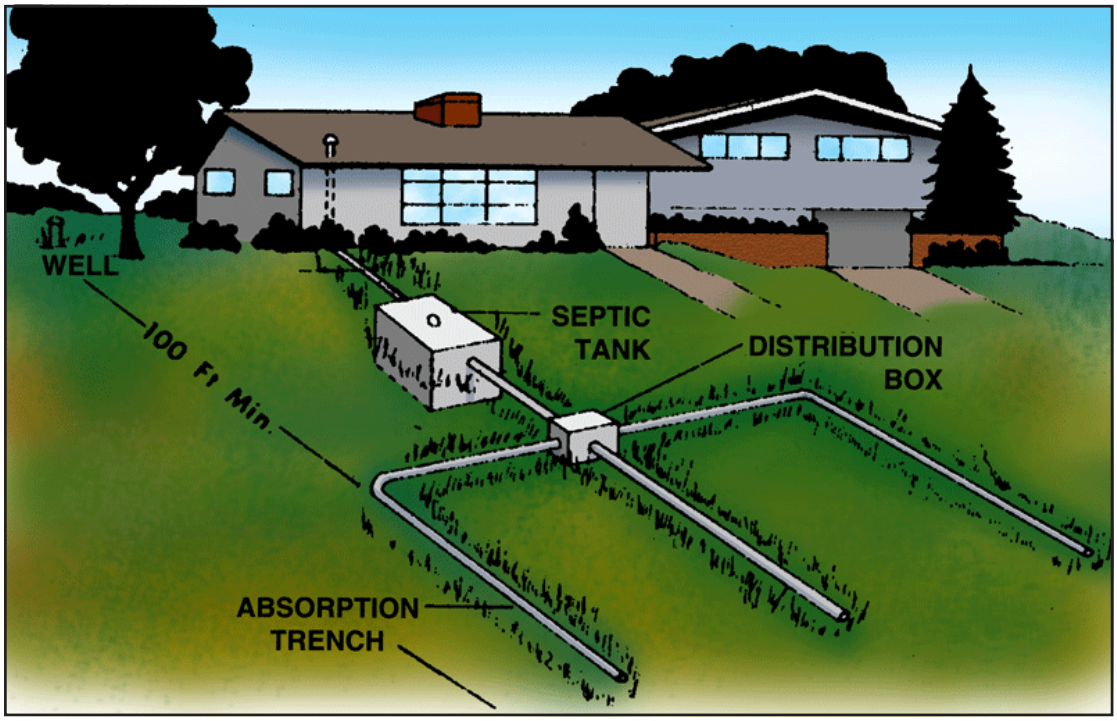
Soil Characteristics that Affect Septic Tank Absorption Fields

Soil properties and qualities that affect the absorption of the effluent are:

Table 13.3 – Guide for Rating Limitations for Dwellings With Basements

Property	Slight	Moderate	Severe
Depth to water table	>6.0 feet	2.5–6.0 feet	<2.5 feet
Flooding	None	——	Any flooding
Shrink-swell (thickest layer 10–60 inches)	Low	Moderate	High
Slope	<8%	8–15%	>5%
Rock fragments (percent >3 inches) (average percent volume to a depth of 40 inches)	<5%	15–35%	>35%
Hard bedrock (must be OK to hold a basement)	>60 inches	40–60 inches	<40 inches

Figure 13.1 – Septic Tank With Absorption Field



1. Permeability
2. Depth to a seasonal high water table
3. Depth to bedrock or to a restrictive layer
4. Slope
5. Flooding
6. Rock fragments greater than 3 inches (to a depth of 40 inches)

Most absorption fields function satisfactorily in deep, well-drained soils with moderate to moderately rapid **permeability**. But if the soil has a slowly permeable layer, or a periodically high water table, septic tank wastewater may surface or not receive adequate treatment, and be the source of a health hazard.

Soils that have **seasonal high water tables** interfere with the proper functioning of the absorption field and may cause effluent to surface.

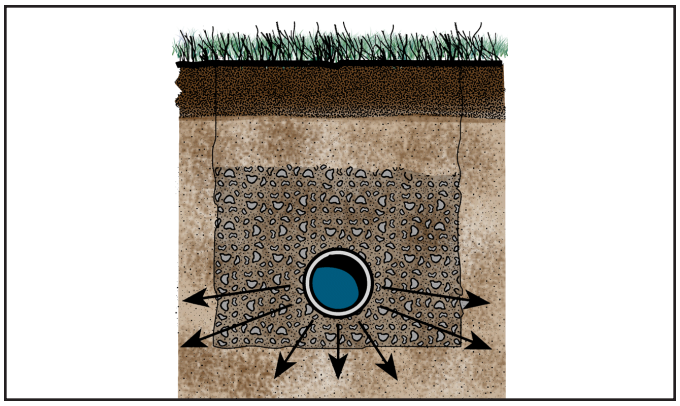
Shallow soils do not have enough volume of soil available for treatment, and the danger of effluent breaking out at the surface is increased.

Slope is a limitation for absorption fields because wastewater may concentrate at the ends of tile lines and either break out at the surface or flow too rapidly downslope in the soil. Soil erosion can also be a problem in sloping soils.

Flood plains generally are not suitable sites for absorption fields because flood waters can become contaminated with sewage wastewater and the system can also be badly damaged.

Rock fragments, along with a shallow depth to bedrock, interfere with the installation of a septic tank absorption field.

Figure 13.2 – Perforated Pipe in an Absorption Field



Soils with slight limitations generally can be used for absorption fields without modifications. Soils with moderate limitations generally can be used for absorption fields, but some special modification generally is needed, for example, increasing the size of the field, installing curtain drains to lower the water table, or adding extra soil to increase the depth. Soils with severe limitations are not suited for conventional septic tank absorption fields. Unique engineering designs may provide alternatives, but generally are too expensive to be feasible. Ratings of slight, moderate, and severe limitations for septic tank absorption fields are interpretations based on soil properties that affect absorption field performance. The rates used are based on the worst circumstances. For example if the depth to rock is 76 inches (slight limitation), but the permeability is very slow (severe limitation), then the site would have a severe limitation, and would probably be unsuitable for a septic tank system unless modifications could be made.

Determine the correct rating for the site using the accompanying guide in Table 13.4, which is based on soil properties and USDA guidelines. It should be noted that before any digging is started, on-site inspection and approval may be required by the local health department and/or the local planning and zoning committee. Planning and zoning and health department rules may vary from county to county. See Table 13.4.

Sewage Lagoons

Sewage lagoons are shallow ponds constructed to hold sewage while aerobic (needing oxygen) bacteria decompose the solid and liquid wastes. Lagoons have a nearly level floor surrounded by cut slopes or berms (embankments) of compacted, relatively impervious soil material. Aerobic lagoons generally are designed so that the depth of sewage is 2 to 5 feet. Relatively impervious soil for the lagoon floor and berms is desirable to minimize seepage and contamination of local ground water.

Soil Properties that Affect Sewage Lagoons

Soil properties, qualities, limitations, and restrictive features used in rating soils for sewage lagoons are:

1. Permeability
2. Slope
3. Flooding
4. Seasonal high water table or internal drainage
5. Depth to bedrock
6. Rock fragments (percentage of cobbles and stones)

Sewage lagoons constructed on soils with moderately rapid or rapid **permeability** may need sealing to function properly and to prevent contamination of the groundwater. Soils with rapid permeability generally are unsuitable because of seepage.

Slope is a limitation only in the construction cost of leveling a site and building the berms.

Flooding is a hazard if there is a possibility of flood waters overtopping the lagoon.

A **seasonal high water table** is a limitation, especially on flood plains if seepage causes effluent to get into the groundwater.

Table 13.4 – Guide for Rating Limitations for Septic Tank Absorption Fields
(Use most limiting layer in 24–60 inches.)

Property	Slight	Moderate	Severe
Permeability (24–60 inches)	2.0–6.0 inches/hour	0.6–2.0 inches/hour	<0.6 or >6 inches/hour
Depth to water table	>6 feet	4–6 feet	<4 feet
Depth to bedrock (both soft and hard bedrock)	>60 inches	40–60 inches	<40 inches
Slope	<0–8 %	8–15%	>15%
Flooding	None	——	Any flooding
Rock fragments >3 inches (average percent volume to a depth of 40 inches)	<15%	15–35%	>35%

Table 13.5 – Guide for Rating Limitations for Sewage Lagoons
(For subsoil permeability, use permeability of most limiting layer.)

Property	Slight	Moderate	Severe
Permeability	<0.6 inches/hour	0.6–2.0 inches/hour	>2.0 inches/hour
Slope	<2%	2–8%	>8%
Flooding	None	——	Any flooding
Depth to water table	>5 feet	3.5–5 feet	<3.5 feet
Depth to bedrock (both soft and hard bedrock)	>60 inches	40–60 inches	<40 inches
Rock fragments >3 inches (average percent volume to a depth of 40 inches)	<15%	15–35%	>35%

If the **depth to bedrock** is less than 40 inches, not enough soil material is available to construct berms and leave sufficient soil depth to seal the bottom of the lagoon. Shallow soils with a slope of more than 1 percent add to this problem.

Rock fragments make construction more difficult by limiting the amount of slowly permeable soil material which is available to seal the bottom and berm of the lagoons. Fractured bedrock within 40 inches of the lagoon bottom may create a pollution hazard.

Ratings of slight, moderate, and severe limitations for sewage lagoons are interpretations of the soil properties that affect performance and construction. Determine the correct rating for the site using the accompanying guide in Table 13.5, which is based on USDA guidelines. It should be noted that before any digging is started, on-site inspection and approval may be required by the local health department and/or the local planning and zoning committee. Planning and zoning and health department rules may vary from county to county. See Table 13.5.

Summary

Pesticides are substances or chemicals applied to kill or control weeds, insects, or other undesirable pests. Pesticides can be lost from the soil by leaching and water runoff.

Soil properties that affect surface infiltration and permeability also affect leaching. Soil properties that affect surface infiltration are soil texture, permeability, restrictive layers, soil depth, and shrink-swell potential; soil properties that affect permeability are soil structure, particle size distribution, bulk density, and presence of and depth to a restrictive layer.

Soil properties that affect runoff are those that affect the rate of runoff and the erodibility of the surface layer. Those properties affecting the rate of runoff include texture, permeability, restrictive layers, soil depth, shrink-swell potential, slope, and drainage. Soil properties affecting soil erodibility are particle size distribution, organic matter content, structure, and permeability. Soil properties that reduce leaching and runoff losses also improve the overall water quality.

Soil characteristics affecting water-holding structures, such as pond reservoirs, include permeability, depth to hard or soft bedrock, and slope. Soil characteristics that affect building sites for dwellings are depth to water table, flooding, shrink-swell potential, slope, depth to bedrock, and volume of rock fragments greater than 3 inches. Soil characteristics that affect on-site waste disposal are soil permeability, depth to a seasonal high water table, depth to bedrock, slope, flooding, and rock fragments.

Credits

Soil Survey Division Staff, Lincoln, Nebraska. *National Soils Survey Handbook* (Title 430-VI). Washington, DC: U.S. Department of Agriculture, Soil Conservation Service, 1993.

Soils Interpretation Help Sheet. Missouri Department of Elementary and Secondary Education. Accessed May 8, 2008, from http://www.dese.mo.gov/divcareered/AG/CDE/SoilsInterpretation.pdf.