Residential Wastewater

Purdue University Cooperative Extension Service

High Water Tables and Septic System Perimeter Drains

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Introduction

Septic systems are becoming more common for new housing developments as Indiana's urban fringe expands into more rural agricultural areas. Due to naturally occurring, seasonally, high water tables in many Indiana soils, most agricultural land has been drained by subsurface tile to lower the water table and improve crop production. In new housing developments, drain tiles are often installed around the perimeter of the soil absorption field to lower the water table. The water collected in the subsurface perimeter drain tile is then discharged downslope to a ditch, creek or stream, or simply to the soil surface downslope of the soil absorption field in an obscure part of the lot.

Perimeter drains are being installed around soil absorption fields with the assumption that these drains maintain an aerobic (oxygen rich) zone below the absorption field trenches, which is required for proper treatment of wastewater effluent. The question remains, "Do perimeter drains lower the water table within a septic system soil absorption field?"

Soil Absorption Fields

Research and experience with conventional septic system soil absorption fields has shown that to effectively renovate effluent, there needs to be approximately 24 inches of Aerated, Moderately Permeable Soil (memory aid: 24 AMPS) between the bottom of the absorption trench and the water table.

A water table is the level to which water will rise in a hole bored into the ground. Below the water table all pores are filled with water; above it some pores contain air. The septic system regulations in all the states that we are familiar with reflect this relationship. In Indiana, the minimum required depth of the aerated soil zone below conventional septic system absorption trenches is 24 inches. Moderately permeable or permeable soil below this depth is required because slowly permeable soil accepts effluent so slowly that it cannot absorb effluent at the rate it is applied and rapidly permeable soils accept effluent so quickly that renovation does not occur.

Soil Oxidation State

Aerated (unsaturated) soil is necessary for two reasons: First, water, and/or effluent, moves much faster through large soil pores than through small pores. When a soil is saturated, effluent occupies all pores — large, medium and small — and moves very rapidly through the large pores, faster than the microbes can renovate it. When the soil is not saturated, effluent still moves through the smaller soil pores, but very slowly, and microbes have time to work on it. Second, a specific set of microorganisms operate in an aerated soil, different from those in unaerated soil. Aerobic microbes function where they have access to oxygen, and anaerobic microbes function where oxygen is depleted, such as in a septic tank.

Wastewater renovation requires both processes — anaerobic in the septic tank and aerobic in the soil absorption field. If the soil absorption field is saturated, it soon becomes anaerobic because the microbes use up all the oxygen. Thus, a saturated soil absorption field operates like a large septic tank, one that extends from the point of application to the water table. The lack of oxygen in the absorption field allows pathogens to survive and multiply in the absorption field, which poses a health hazard.

Reduction is a chemical process that is related to saturation and aeration. Reduction occurs when an atom accepts an electron. It is the opposite of oxidation, and that is when an atom loses an electron. Students remember the relationship by the memory aid OIL RIG (Oxidation Is Loss, Reduction Is Gain in electrons). Microbes produce

Table 1. Order of utilization of principal electron acceptors in soils, equilibrium potentials of these half-reactions at pH 7. (Redox potentials are pH dependent, therefore potentials are shown at a standard pH.)

Reactions	Half reaction	Eh at pH 7 (V)	Redox status	Soil conditions
Oxygen → water	$½O_2 + 2e^- + 2H^+ = H_2O$	0.82	Oxidized	aerobic
Nitrate → nitrite	$NO_3^- + 2e^- + 2H^+ = NO_2^- + H_2O$	0.54	Reduced	anaerobic
Manganese oxides → soluble managanese	$MnO_2 + 2e^- + 4H^+ = Mn^{2+} + 2H_2O$	0.4	Reduced	anaerobic
Iron hydroxides → soluble ferrous iron	$FeOOH + e- + 3H^+ = Fe^{2+} + 2H_2O$	0.17	Reduced	anaerobic
Sulfate → hydrogen sulfide gas	$SO_4^{2-} + 8e^- + 9H^+ = HS^- + 4H_2O$	-0.16	Reduced	anaerobic
Organic carbon → methane gas	$CH_2O = ½CO_2 + ½CH_4$		Highly reduced	anaerobic

electrons in the process of respiration, and these electrons have to be accepted by something — they do not just pile up somewhere. Their first choice is to be accepted by oxygen, which results in the production of carbon dioxide and water. Human respiration is the same process. We inhale oxygen, the electron acceptor, and exhale carbon dioxide and water. As long as a soil is not saturated, oxygen moves fast enough through the soil to meet the needs of the microbes. When all oxygen is used up, microbes utilize alternative electron acceptors in a predictable order shown in Table 1. Oxidation and reduction are measured by Eh (Redox potential measured in volts (V)). High Eh values represent oxidation and low values, reduction. Aerobic conditions only exist when oxygen is present. Once oxygen has been utilized, soil conditions become anaerobic which can result in a soil environment conducive to pathogen survival.

Redox potentials vary widely over short distances. In aerobic soils the interior of the soil aggregates may be anaerobic. Oxygen must diffuse through the aqueous phase, and is subject to depletion, before reaching the interior of the aggregate. The change from oxygen sufficiency to deficiency can occur within a few millimeters.

Soil Color

From research we know that the following conditions occur. In late summer evapotranspiration rate has exceeded precipitation for some time, and the soil is very dry because the roots of trees or other plants pumped out much of the available water. Oxygen is in abundant supply throughout the profile. In the fall, precipitation begins to exceed evapotranspiration, and soil moisture builds up. Then Eh starts to decrease, probably because the soil is not uniformly moist. Most is unsaturated, but some small parts of it are saturated and become reduced. The Eh continues to decrease slowly as the soil becomes wetter. When the soil gets saturated, Eh decreases more rapidly, and a few weeks after saturation, Eh becomes low enough to reduce Fe.

Because iron oxides are a major pigment in soils, soil scientists use soil color to qualitatively evaluate the historic average of the oxidation status of soils. Color patterns do not allow us to evaluate the redox status of a soil for any one point in time, but the average over long periods (hundreds to thousands of years).

For example, the three photographs in Figure 1. represent three different drainage classes of 20,000 year old soils. The brownish/orange Miami soil (A) is well drained and is not saturated for any significant length of time during the year. The brownish color of the soil is due to the iron oxide minerals that are homogeneously distributed on the primary mineral surface. In contrast, the Brookston soil (C) is poorly drained, evident by the gray color of the soil. The gray color is due to the primary mineral color which shows up very well after the dissolution of the brown iron oxide

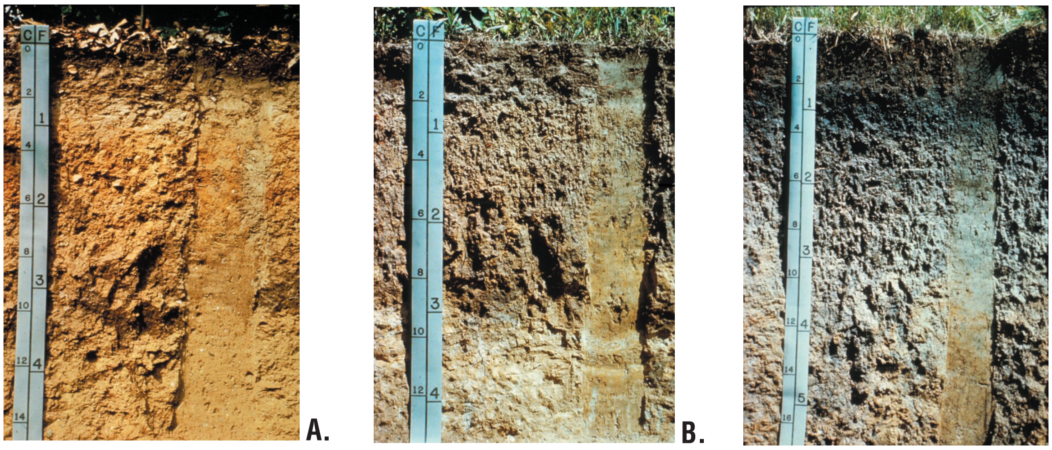

Figure 1. *Soil profile pictures representing a soil drainage sequence commonly found on the Tipton till plain (A. Miami silt loam, B. Crosby silt loam, C. Brookston silty clay loam).*

minerals. The Crosby soil (B) is somewhat poorly drained, evident by the brownish colors mixed with the gray colors.

Perimeter Drain Discharge

Figure 2 shows the outlet of a perimeter drain where it drains to a small stream. Let us assume that the reddish color is due to an iron mineral precipitate in which Fe is oxidized (Fe^{3+} - the superscript 3+ represents the charge on the iron ion). It precipitated when soluble reduced Fe (Fe^{2+}) in the tile drain water mixed with stream water that contained oxygen. In order for the Fe^{2+} to be in the tile drain, a series of sequential environmental conditions most likely exist: The soil became saturated, all the oxygen in the soil was used for microbial respiration (the soil became anaerobic), nitrate and manganese in solution were reduced, and then Fe was finally reduced. Thus, the soil in the absorption field became anaerobic (like a septic tank) well before Fe was reduced, flowed through the tile drain, and was oxidized in the stream.

Apparently the perimeter drain is not achieving its designed purpose, at least for some time period — we do not know how long. The lack of an aerobic zone is conducive to pathogen survival and puts the ground and/or surface water at risk. The presence of iron oxides precipitating near the outlet of a perimeter drain is indicative of reducing conditions in the septic system absorption field and probable contamination of surface waters with pathogens.

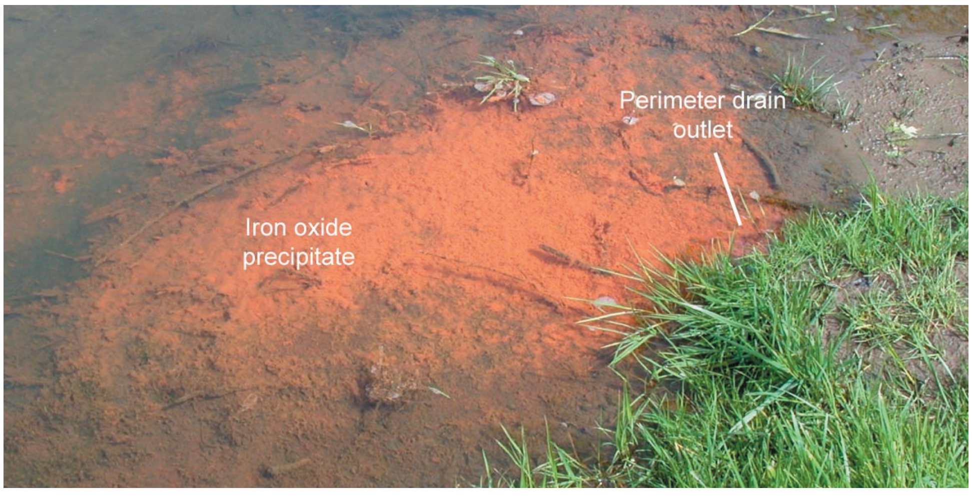

Figure 2. *Iron oxide precipitation at the septic system perimeter drain outlet in a neighborhood drainage channel.*

Summary

More and more of Indiana's poorly and somewhat poorly drained soils are being developed. As a result, septic systems utilizing perimeter drains are more common. Unfortunately, there is little evidence that these perimeter drains are lowering the water table and maintaining an aerobic zone below the absorption field trenches for the entire year. Surface observation of septic system absorption fields has long been the test to determine if a septic system is functioning properly. To ensure water quality is being protected, it is necessary that Indiana takes a more holistic approach to designing septic systems and begins to investigate the water quality discharging from perimeter drain outlets.

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