

SECTION X SUBSURFACE WASTEWATER ABSORPTION SYSTEM DESIGN

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SECTION X SUBSURFACE WASTEWATER ABSORPTION SYSTEM DESIGN

A. Introduction

This section provides guidance for design of subsurface wastewater absorption systems (SWAS) under various conditions that control such designs, including:

- soil characteristics,
- ground water conditions,
- wastewater flows and characteristics,
- long term acceptance rates,
- effective infiltrative surface areas,
- linear loading rates,
- vertical separating distance to the seasonal high ground water table,
- travel times from the SWAS to a point of concern,
- flow distribution,
- systems in natural soils, and,
- systems constructed in fill materials.

B. Vertical and Horizontal Separating Distances

1. Introduction

The U.S. EPA indicates that over one-half of the waterborne disease outbreaks in the United States are due to the consumption of contaminated ground water. While some of these outbreaks are caused by chemical contamination, the majority are caused by consumption of groundwater that has been contaminated due to the presence of bacteria and viruses in domestic wastewater that has been discharged onto or into the soil.

In particular, in recent times the U.S. EPA and public health agencies have become concerned with viruses. Viruses are of major concern because of their ability to survive for long periods of time in the subsurface and still remain infectious, and the very small number (as little as one virulent particle in some cases) are thought to cause disease. While there are some bacteria and parasites that can cause infection if ingested in small numbers, of greatest concern are the viruses that may find their way into the ground water.

2. Goals for removal/inactivation of Pathogens

Protozoa and helminths are occasionally found in septic tank effluent but are not usually found in groundwater beneath a SWAS. Because of their relatively large size, pathogens such as helminths (parasitic worms, such as roundworms and tapeworms) and protozoa (*Cryptosporidium parvum* and *Giardia lamblia*, and their cysts or oocysts) are generally removed in the biomat that forms at the soil interface of the SWAS and in the underlying unsaturated soils before reaching the water table, although this might not be the case for very coarse soils.

However, bacteria and viruses are much smaller and, when discharged to a SWAS, can move into ground and surface waters, initiate significant health problems, and promote outbreaks of waterborne disease (VA Division of Health-1990). While pathogenic bacteria are of public health concern, studies have shown that viruses travel further and can exist in a viable state for a much longer time than pathogenic bacteria. Therefore, viruses are of

significant concern with respect to public health considerations. Where adequate removal/inactivation of viruses is obtained, it is probable that adequate removal of other pathogenic microorganisms has also occurred.

The Department had a detailed review and study of the literature conducted on the fate and transport of pathogens in the subsurface (Jacobson-2002). The results of that study indicated that it is reasonable to establish a goal of at least a 5 log₁₀ (99.999%) removal/inactivation of viruses from domestic wastewater discharged to an OWRS before the commingled wastewater/ground water reaches a sensitive receptor, and that a greater removal/inactivation is preferable.

3. Vertical Separating Distance

Recent detailed studies in Florida, Colorado and Massachusetts have confirmed earlier studies that indicated a three Log₁₀ (99.9%) removal/inactivation of viruses can be obtained when domestic wastewater has:

- a.) been pretreated in a septic tank and discharged to a properly designed SWAS,
- b.) percolated through the biomat that forms at the SWAS-soil interface and,
- c.) has moved slowly down through at least three feet of suitable aerobic, unsaturated soil.

Under design flow conditions, additional vertical separating distance may be necessary to provide adequate hydraulic reserve capacity. While the examples contained in this section do not address reserve hydraulic capacity, adequate reserve capacity shall be provided in the system design. This should be discussed with Department staff.

4. Horizontal Separating Distance

While the most significant renovation of septic tank effluent occurs at the biomat that develops at the soil interface with the SWAS and in the unsaturated soil beneath the SWAS, renovation of the percolate from the SWAS continues after it reaches the saturated zone. The effectiveness of renovation in the saturated zone depends on factors such as the type and strain of virus, physical, chemical and biological characteristics of the virus, the physical and chemical characteristics of the soil through which the percolate flows, the temperature of the ground water, and the natural processes that tend to remove or degrade viruses in the subsurface. These natural processes include sorption, ion-exchange, dispersion, and microbial degradation.

Numerous studies have been conducted in an attempt to quantify the rate of virus removal in the ground water. The only factor that has consistently been shown to demonstrate a statistically significant correlation with the decay rate of viruses under saturated flow conditions has been the ground water temperature. Yates et al. (1987) determined from 172 virus experiments conducted at temperatures ranging from 4° to 32°C that the virus inactivation rate could be expressed by the following equation:

$$\text{Inactivation Rate, } \text{Log}_{10} \text{ day}^{-1} = (0.018 \times T) - 0.0144,$$

where T = ground water temperature, °C. The mean ground water temperature in Connecticut, in the zone affected by seasonal fluctuations, can be assumed to be at least 10°C, except in the extreme northeastern and northwestern corners of the state. Inserting that value in the equation above results in an inactivation rate of 0.036 log₁₀ day⁻¹. This indicates that, in Connecticut, viruses can survive for long periods of time in the ground water. If the goal for virus removal/inactivation is selected to be five (5) log₁₀ for sensitive receptors, and a three (3) log₁₀ removal/inactivation is anticipated before the wastewater reaches the ground water, an additional two (2) log₁₀ inactivation would be required as the viruses travel with the ground water. Based on an inactivation rate of 0.036 log₁₀ per day, a travel time of 56 days is indicated between a SWAS and existing and potential sensitive receptors such as:

- a. the outer limit of the cone of depression of a public (community) drinking water supply well,
- b. a surface water body used, or intended to be used, as a source of public (community) drinking water supply,
- c. a private drinking water supply well serving an individual residence.
- d. an impoundment used for aquaculture.

The minimum required travel time to all other points of concern should be not less than 21 days, and a greater travel time is preferable.

It should be noted that some investigators have found that passage of raw wastewater through a septic tank resulted in a reduction of virus concentration in the tank effluent. For example, Higgins et al. (2000) found a 74% (< 1 log₁₀) reduction. On the other hand, other investigators have found little or no such reduction. Thus, while a septic tank may effect some reduction in virus concentration, the amount of reduction is in question.

Therefore, any reduction in virus concentration effected by a septic tank is considered to be a safety factor and any such reduction should not be credited as part of the five (5) log₁₀ reduction goal.

C. Long Term Acceptance Rate (LTAR)

1. General

The Department's criteria for hydraulic design of a subsurface wastewater absorption system (SWAS) are based on consideration of both the hydraulic capacity of the soil in which the system is located, and the long term acceptance rate (LTAR) of pretreated wastewater by the biocrust (biomat) that develops at the soil/SWAS interface (infiltrative surfaces). The determination of the soil hydraulic capacity has been addressed in Section VI- Hydraulic Capacity Analysis. This sub-section addresses the selection of the LTAR of the SWAS infiltrative surfaces.

As indicated in Section II, the thickness and susceptibility of the biocrust to clogging is related to the dissolved and suspended organic matter remaining in the pretreated wastewater (the "organic loading rate"). Excessive organic loading rates will result in conditions leading to a thicker biological/zoogel layer that severely reduces the rate of flow into the unsaturated soil zone and causes anaerobic conditions to persist.

The LTAR may be defined as the infiltrative surface loading rate at which a SWAS will continuously accept effluent for a long period of time, and is dependent upon the soil characteristics, the biomat, and the wastewater characteristics (Anderson, et al.-1991). Healy and Laak (1974) determined the following relationship between the LTAR of a soil and the soil hydraulic conductivity:

$$\text{LTAR} = 5K - [1.2/(\text{Log}_{10}K)].$$

In this formula LTAR is in units of gpd/ft^2 and K, saturated hydraulic conductivity, is in units of ft/minute .

Figure LTAR-1 presents this expression in graphical format. For effluent from household septic tanks, the maximum stable LTAR value allowed by the CTDEP is 0.80 gallons per day per square foot of effective leaching area. This corresponds to a K value of $\sim 28 \text{ ft}/\text{day}$ ($0.0197 \text{ ft}/\text{min}$. or $0.010 \text{ cm}/\text{sec}$).

Siegrist (1987) stated that the rate of discharge from a SWAS to the underlying unsaturated zone should not exceed 3% to 5% of the saturated hydraulic conductivity. He stated that such low discharge rates (hydraulic loading rates) are required in order to maintain adequate soil aeration and the low soil moisture content in the unsaturated zone that will allow intimate contact between the percolate from the SWAS and the soil particles. These conditions are required for removal/attenuation of pathogens and other contaminants in the percolate. The LTAR rates obtained from Figure LTAR-1 satisfy this requirement.

Laak (1970) hypothesized that the service life of a SWAS is related to the sum of the BOD_5 and TSS and that increasing the pretreatment of domestic wastewater prior to discharge to a SWAS would increase the service life of the SWAS. Based on the results of his studies at the University of Toronto (Laak-1966), he suggested an expression for the affect of BOD_5 and TSS in septic tank effluent on the development of the clogging mat at the SWAS-soil interface (Laak-1977). This expression could be used to calculate the increase in infiltrative surface area required for strong wastewater or the decrease in such area where reliable enhanced pretreatment is provided.

An "adjustment factor", based on the Laak expression, can be used to determine the leaching surface application rate to be used for high-strength (or low strength) wastewater. This factor is derived from the mathematical expression shown below (Laak-1977), which relates the five-day Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) concentrations in such wastewaters, to the average concentrations of BOD_5 and TSS found in the effluent of septic tanks receiving household wastewater:

$$\text{LTAR Adjustment Factor} = [250/(\text{BOD}_5 + \text{TSS})]^{1/3}$$

In the preceding mathematical expression, the BOD_5 and TSS are expressed in milligrams per liter, and represent the values of these constituents in the pretreated wastewater discharged to the SWAS.

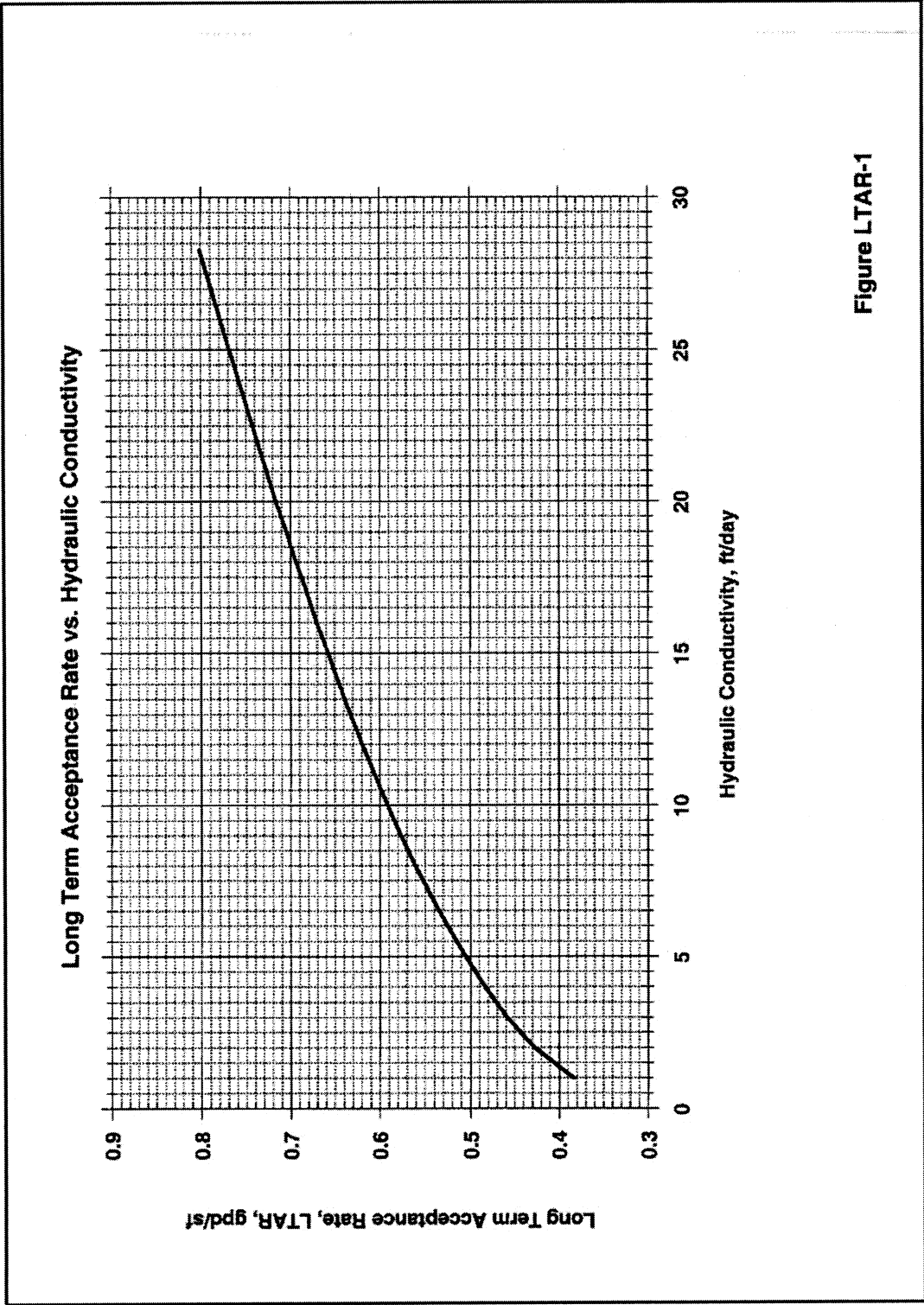


Figure LTAR-1

