Evapotranspiration Systems

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Fact Sheet

Introduction

Evapotranspiration (ET) is a method of onsite wastewater treatment and disposal that offers an alternative to conventional soil absorption systems for sites where protection of the surface water and groundwater is essential. An ET system is unique in its ability to dispose of wastewater into the atmosphere through evaporation from the soil surface and/or transpiration by plants, without necessarily discharging it to the surface water or groundwater reservoir. However, in certain cases, the ET concept also offers flexibility by combining seepage with evaporation as an alternative option.

An ET system is a feasible option in semi-arid climates and locations where the annual evaporation rate exceeds the annual rate of precipitation and wastewater applied. The different design configurations of this concept are discussed in more detail in the sections that follow.

Process Description

Evapotranspiration is the net water loss caused by the evaporation of moisture from the soil surface and transpiration by vegetation. For continuous evaporation, three conditions must be met. First, there is a latent heat requirement of approximately 590 cal/g of water evaporated at 15° C. Second, a vapor pressure gradient is needed between the evaporative surface and the atmosphere to remove vapor by diffusion, convection, or a combination of the two. Third, there must be a continuous supply of water to the evaporative surface.

Evapotranspiration is also influenced by vegetation on the disposal field. Theoretically, evapotranspiration can remove high volumes of effluent in the late spring, summer, and early fall, especially if large silhouette and good transpiring bushes are used.

There are three main types of evapotranspiration systems: ET, evapotranspiration/absorption (ETA), and mechanical. Each is described below.

The first type, an ET system, is the most commonly used. The main components are a pretreatment unit (usually a septic tank or an aerobic unit) to remove settleable and floatable solids and an ET sand bed with wastewater distribution piping, a bed liner, fill material, monitoring wells, overflow protection, and a surface cover. Vegetation has to be planted on the surface of the bed to enhance the transpiration process.

The septic tank effluent flows into the lower portion of a sealed ET bed that has continuous impermeable liners and carefully selected sands. Capillary action in the fine sand causes the wastewater to rise to the surface and escape through evaporation as water vapor. In addition, vegetation transports the wastewater from the root zone to the leaves, where it is transpired as a relatively clean condensate. This design allows for complete wastewater evaporation and transpiration with no discharge to nearby soil.

Figure 1 on page 2 shows a cross-sectional view of a typical ET bed. Although this design may be acceptable in certain sites, check local and state regulations to ensure approval can be given by that particular agency.

The second type of evapotranspiration system is known as ETA, which is an unsealed bed where evaporation and transpiration are the primary means of disposal, but percolation is also used. This design provides discharge to both the atmosphere and to the subsurface.

The third type of evapotranspiration system is the use of mechanical devices; however this method is still being developed. There are two types of mechanical evaporation systems, both of which require a septic tank for pretreatment, as well as a storage tank. The first is a rotating disk mechanical evaporation unit. The disks rotate slowly so that the moisture on their wetted surfaces can evaporate into the air moving over the unit.

The second type of mechanical ET system is a concentric cylinder unit where forced air enters at the center of the cylinder and moves outward through wetted cloth wraps and is discharged as vapor.

Mechanical systems use a very small

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ETI Environmental Technology Initiative

A Technical Overview

amount of electricity and also require only a minimal amount of maintenance, which could make them an attractive option for individual home wastewater disposal in regions where evaporation exceeds precipitation.

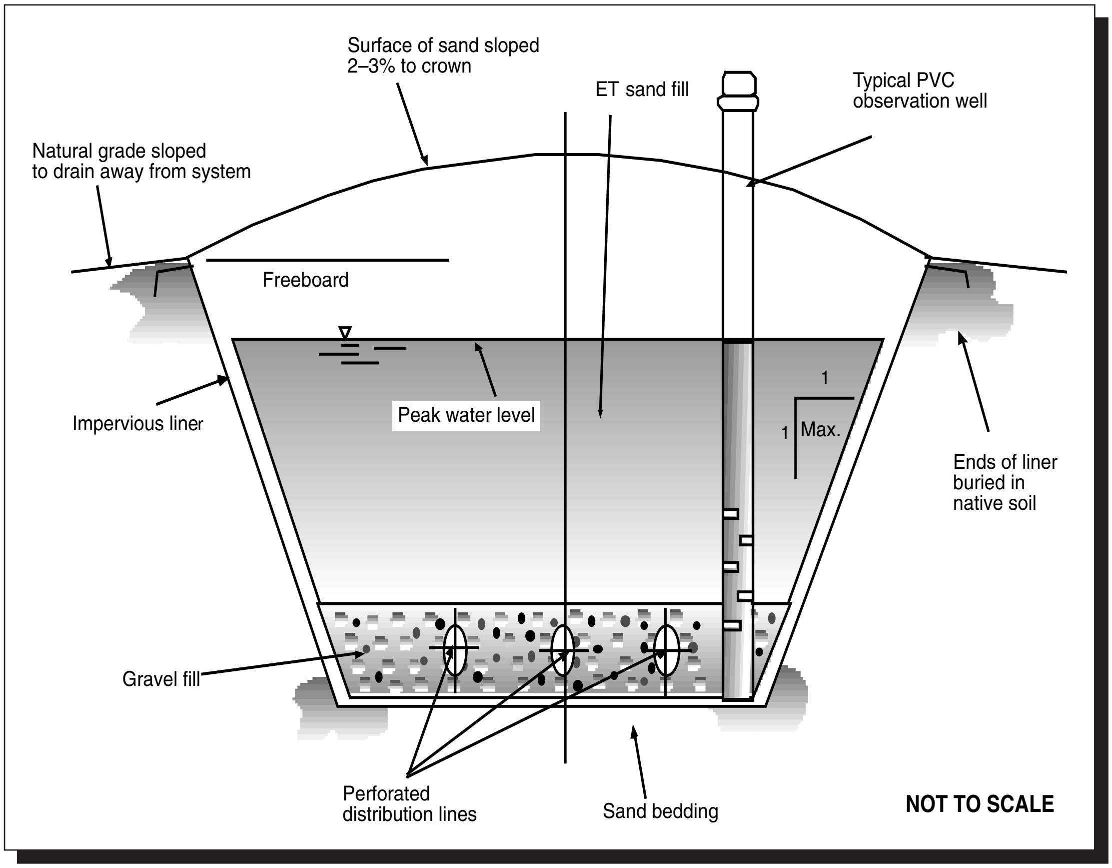

Figure 1: Cross Section of a Typical Evapotranspiration Bed

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Advantages and Disadvantages

Listed below are some advantages and disadvantages of ET systems:

Advantages

- ET systems may overcome site, soil, and geological limitations or physical constraints of land that prevent the use of subsurface wastewater disposal methods.
- The risk of groundwater contamination is reduced with ET systems that have impermeable liners.
- Costs are competitive with other alternative onsite systems.
- ET systems can be used to supplement soil absorption for sites with slowly permeable, shallow soils with high water tables.
- These systems could be used for seasonal application, especially for summer homes or recreational parks in areas with high evaporation and transpiration rates, such as in the southwestern U.S.
- Landscaping enhances the aesthetics of an ET system.

Disadvantages

- ET systems are governed by climatic conditions such as precipitation, wind speed, humidity, solar radiation, and temperature.
- These systems are not suitable in areas where the land is limited or where the surface is irregular.
- They have a limited storage capacity, and are thereby unable to store much winter wastewater for evaporation in the summer.
- There is a potential for overloading from infiltration of precipitation.
- The bed liner must be watertight to prevent groundwater contamination.
- ET systems are generally limited to sites where evaporation exceeds annual rainfall by at least 24 inches (i.e., arid zones).
- Transpiration and evaporation can be reduced when the vegetation is dormant (i.e., winter months).
- Salt accumulation and other elements may eventually eliminate vegetation, and thus transpiration.

Performance

There are several variables that determine the size requirement of any ET system. The flow rate of domestic wastewater is site-specific. Accurate estimates (daily, weekly, or monthly) of flow rates must be calculated as part of the design process to prevent overloading problems associated with undersizing or the excessive cost associated with oversizing a system. The design flow rate should include a safety factor to account for peak flows or future increased site use.

Like other disposal methods that require area-intensive construction, the use of ET systems can be constrained by limited land availability and site topography. For year-round, single-family homes, ET systems generally require about 4,000 to 6,000 square feet of available land. However, the use of water conservation plumbing devices could reduce the bed area requirements.

The maximum slope that an ET system can be used on has not yet been determined, although a slope greater than 15% could be used if terracing, serial distribution, and other necessary design features are incorporated.

By far the most important performance consideration of any ET system is the rate of evaporation. This is largely affected by climatic conditions such as precipitation, wind speed, humidity, solar radiation, and temperature. Since these factors continually change from time to time, evaporation rates will also vary significantly, which must be considered in the design.

Although most of the precipitation will be absorbed into the ET bed, hydraulic overloading could occur if more water enters the system than is evaporated. Provisions for long-term storage of excess water can be expensive. Thus for ET systems, the evaporation rate must exceed the precipitation rate, which makes an ET system suitable for areas of relatively low rainfall, such as the western and southwestern parts of the U.S. For ETA systems, the climate requirements are not as well defined, although the soils must be able to accept all of the influent wastewater if net evaporation is zero for any long period of time.

In addition to the climate, there are other factors that determine the performance of an ET system, which are discussed below.

Hydraulic Loading

If the hydraulic loading is too high, wastewater could seep out from the system. However, too low a loading rate results in a lower gravity (standing) water level in the bed and insufficient evaporation. This situation can be solved by sectional construction in level areas to maximize the water level in a particular section of the bed.

Sand Capillary Rise Characteristics

The sand must be fine enough to draw up the water from the saturated zone to the surface by capillary action. The potential for capillary rising must be slightly more than the depth of the bed. However, the sand should not be too fine or the bed can be clogged by solids from the wastewater.

Cover Soil and Vegetation

The vegetation that is used in an ET system must be able to handle the varying depths of free water surface in the bed. Grasses, alfalfa, broad-leaf trees, and evergreens are some of the vegetation used in ET beds that have been known to increase the average annual evaporation rate from an ET bed to a rate higher than that for bare soil. However, grasses and alfalfa also result in nearly identical or reduced evaporation rates as compared to bare soil in the winter and the spring when evaporation rates are normally at a minimum. Similarly, topsoil has been shown to reduce evaporation rates. Some evergreen shrubs have resulted in slightly higher evaporation rates than bare soil throughout the year. Water seekers with hair roots, such as berries, are not recommended because the distribution pipes could become clogged.

Construction Techniques

Although ET system performance is generally affected less by construction techniques than most subsurface disposal methods, some aspects of ET construction can affect performance. For ET systems, some construction considerations are ensuring that the impermeable liner is watertight without any puncture and that the sand has sufficient potential for capillary rise.

Salt Accumulation (for ET only)

As wastewater is evaporated, salt and other elements build up at the surface of the ET bed during dry weather. During precipitation, the salt is distributed throughout the bed. For non-vegetated ET systems, this salt accumulation is generally not a problem. However, salt accumulation in systems with vegetation may have negative effects after extended periods of use.

Soil Permeability (for ETA only)

Soil permeability affects the performance of ETA beds that involve seepage into the soil in addition to evaporation. A portion of pretreated wastewater is absorbed and treated by the soil. As a general rule, the wastewater must travel through 2 to 4 feet of unsaturated soil for adequate treatment before reaching the groundwater.

Application

Onsite systems with ET disposal are mostly applicable in locations with a very shallow soil mantle, high groundwater, relatively impermeable soils, or fractured bedrock. Observations of ET systems have shown that adequate performance can be achieved in semi-arid and arid locations. In certain parts of the U.S., ET systems are feasible for summer homes, permanent homes, outdoor recreation areas, and highway rest stops. Reliability of the system requires micro-climatic data that is often not known.

Boyd County Demonstration Project

A demonstration site is located about 5 miles from the Huntington Airport in Kentucky, an area with low population density and rough topography. Approximately 60 families are living within the boundaries of the sanitary district. The demonstration project serves 47 of those families and uses 36 individual home aeration treatment plants, and two multi-family aeration plants serving 11 families. Six manufacturers were represented with 16 stream discharge units, two spray irrigation units, one ET unit, and 19 subsurface field discharge units. Four recycle units serving five homes produced clear, odorless water. For the purpose of this fact sheet, the discussion will be centered around the performance of the ET system.

The ET unit was 2,000 square feet (two 1,000 square foot beds) designed for disposing effluent from a Cromaglass model C-5 aeration plant. The beds were sealed with plastic to keep the high groundwater at the site from flooding the beds, which had 8 inches of gravel and 18 inches of sand and were crowned to shed rainwater. The beds were covered with topsoil and planted with grass and junipers.

One of the values of an in-the-field test of such equipment is to observe how the system handles any variations in loading rates. Although the ET beds were originally designed for a family of four, eventually seven people were living at the site. Consequently water usage increased, but the ET system continued to perform very well with only one small modification to the distribution box. Before the ET beds were installed, raw sewage used to pond in the yard of this house from a nonfunctioning septic tank and soil absorption field. High rainfall made people unsure that the ET concept would be successful in that area. However, the ET system continues to perform satisfactorily.

Leigh Marine Laboratory, University of Auckland, New Zealand

Leigh Marine Laboratory, a research institution on the coastline about 62 miles north of Auckland, New Zealand, has an ETA system, installed in 1982, with a design load of 35 persons (including residents and day visitors) at 4,565 L/d (1,180 gallons per day) total flow. Three septic tanks feed a pump sump and a 400 m rising force main to an ETA bed system on an exposed grass ridge 70 m above the laboratory complex.

There is a loading factor of 1.0, an ETA loading rate of

10 mm per day for beds, and an areal rate (including spaces between beds) of 3.75 mm per day. Extensive groundwater and surface water drainage controls were installed. The total bed area is 450 m^2 divided into 20 beds each, 15 m by 1.5 m and arranged in four groups of five beds, with each group dose loaded for 1 week and then rested for 3 weeks.

Since commissioning, the ETA beds have performed as predicted by theory; in the summer, capillary action in the sand draws effluent to support vigorous grass growth, and in the winter, the effluent gradually accumulates for storage and disposal during drier weather. Currently, the system is loaded between 80% and 90% of its capacity and is performing successfully.

Operation and Maintenance

Regular operation and maintenance (O&M) for ET and ETA systems is usually minimal, mostly involving typical yard up-keep such as trimming the vegetation. If a septic tank is used for pretreatment, it should be checked for sludge and scum buildup and pumped as needed to avoid carryover of solids into the bed. Other recommended operational practices for a homeowner include:

- ensuring all stormwater drainage paths/pipes are not blocked and that stormwater drains away from the system,
- using high transpiration plants that are suitable for the wetness at ground level,
- alternating the bed loading as necessary if there is more than one bed,
- installing additional beds as required by any operating difficulties or system failures, and
- performing other site-specific O&M.

If an ET or ETA system is properly installed on a suitable site, scheduled maintenance should rarely be needed except in cases of poor operating practices such as irregular septic tank pumping.

Cost

The cost of an ET system is dependent on the type of system, the site, and the characteristics of the wastewater. The construction cost of an ET bed is determined by its surface area, which is a function of the design loading rate. (For non-discharging, permanent home ET units that are located in suitable areas, the loading rate ranges from approximately 1.0 mm per day to 3.0 mm per day.) Other cost considerations are the availability of suitable sand, the type and thickness of the liner that is used, a retaining wall (if needed), and the type of vegetation (usually native to the area).

Typical costs for a three-bedroom residence with a septic tank and ET system is approximately $10,000 (minimum) and may be higher depending on site conditions.

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