United States Environmental Protection Agency
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Decentralized Systems Technology Fact Sheet
Evapotranspiration

DESCRIPTION

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 disposes of wastewater into the atmosphere through evaporation from the soil surface and/or transpiration by plants, without discharging wastewater to the surface water or groundwater reservoir. ET can offer flexibility by combining seepage with evaporation when absolute protection of the groundwater or surface water is not required.

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

Process

Evapotranspiration is the net water loss caused by evaporation of moisture from the soil surface and transpiration by vegetation. Three conditions must be met for continuous evaporation. First, it requires latent heat of approximately 590 cal/g of water evaporated at 15 °C. Second, a vapor pressure gradient between the evaporative surface and the atmosphere must exist 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, ET can remove high volumes of effluent in the late spring, summer, and early fall, especially if large silhouette and good transpiring bushes are present.

There are three main types of evapotranspiration systems; ET, evapotranspiration/absorption (ETA), and mechanical.

The first type, an ET system, is the most common. The main components are a pretreatment unit (usually a septic tank or an aerobic unit) used 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 must 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 equipped with continuous impermeable liners and carefully selected sands. Capillary action in the 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 shows a cross-sectional view of a typical ET bed. Although this design may be acceptable in certain sites, local and state regulations should be checked to ensure approval.

The second type of evapotranspiration system is known as ETA. In addition to evaporation and transpiration, percolation also occurs through an unsealed bed. This design provides discharge to both the atmosphere and to the subsurface.

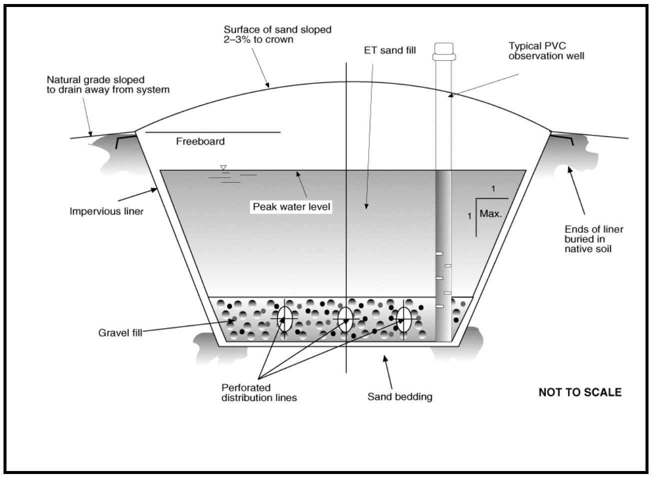

FIGURE 1 CROSS SECTIONAL VIEW OF A TYPICAL EVAPOTRANSPIRATION BED

The third type of evapotranspiration system, which involves the use of mechanical devices, is still under development. There are two types of mechanical evaporation systems, both of which require a septic tank for pretreatment and storage tank. The first type consists of a rotating disk unit, in which the disks rotate slowly, providing a large surface area for the wastewater to evaporate.

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

Mechanical systems use little electricity and require minimal maintenance, which makes them attractive options for individual home wastewater disposal in regions where evaporation exceeds precipitation.

APPLICABILITY

Onsite systems with ET disposal are appropriate in locations with a shallow soil mantle, high groundwater, relatively impermeable soils, absence of fractured bedrock, or other conditions that put the groundwater at risk. ET systems perform well in semi-arid and arid locations. In certain parts of the United States, ET systems are feasible for homes, outdoor recreation areas, and highway rest areas. It is important to note that assessment of the reliability of the system requires micro-climatic data.

Boyd County Demonstration Project

A demonstration site was set up about five miles from the Huntington Airport in Kentucky, in an area with low population density and rough topography. Approximately 60 families live in the sanitary district. The demonstration project serves 47 families, with 36 individual home aeration treatment plants and two multi-family aeration plants which serve 11 families. Six manufacturers provided 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.

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

The Kentucky test provided valuable data on how the system handles variations in loading rates. Although the ET beds were designed for a family of four, seven people lived at the site which increased water usage, yet the ET system continued to perform well with only one small modification to the distribution box. Before installation of the ET beds, raw sewage pooled in the yard of this house from a nonfunctioning septic tank and soil absorption field. Despite high rainfall, the ET system continues to perform satisfactorily.

Leigh Marine Laboratory, University of Auckland, New Zealand

Leigh Marine Laboratory, a research institution on the New Zealand coastline about 62 miles north of Auckland, has an ETA system which was installed in 1982. It has a design load to support 35 persons (including residents and day visitors) at 4,565 L/d (1,180 gallons per day) total flow. Three septic tanks feed a sump pump that discharges through 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. This system includes extensive groundwater and surface water drainage controls. The total bed area is 450 m^2 divided into 20 beds, each 15 m by 1.5 m, arranged in four groups of five beds, with each group dose loaded for one week and rested for three.

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

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 onsite systems.
- ET systems can be used to supplement soil absorption for sites with slowly permeable shallow soils with high water tables.
- ET systems can 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 United States.
- Landscaping enhances the aesthetics of an ET system as well as beautifies the area.

Disadvantages

- ET systems are governed by climatic conditions such as precipitation, wind speed, humidity, solar radiation, and temperature.
- ET systems are not suitable in areas where the land is limited or where the surface is irregular.
- ET systems have a limited storage capacity and thus cannot 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.

DESIGN CRITERIA

There are several variables that determine the size requirement of an 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 associated with undersizing or the excessive cost of oversizing a system. The design flow rate should also include a safety factor to account for peak flows or increased site use in the future.

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 percent could be used if terracing, serial distribution, and other necessary design features are incorporated.

PERFORMANCE

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 are variables, evaporation rates can vary significantly, a factor which must be considered in the design of an ET system.

Although most 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, the evaporation rate must exceed the precipitation rate. This makes an ET system suitable for areas with relatively low rainfall, such as the western and southwestern parts of the United States. Climate requirements are not as well defined for ETA systems, although the soils must be able to accept all of the influent wastewater if net evaporation is zero for a long period of time.

In addition to the climate, other factors influence the performance of an ET system. These are discussed below.

Hydraulic Loading

If the hydraulic loading is too high, wastewater could seep out from the system. However, if a loading rate is too low, it can result 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 the water up 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, if the sand is too fine, the bed can be clogged by solids from the wastewater.

Cover Soil and Vegetation

The vegetation 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 types of vegetation used in ET beds. They 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 during winter and 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 they may clog the distribution pipes.

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, main considerations are to ensure that the impermeable liner is watertight and that the sand has sufficient potential for capillary rise.

Salt Accumulation (for ET only)

As wastewater is evaporated during dry weather, salt and other elements build up at the surface of the ET bed. Precipitation distributes the salt throughout the bed. For nonvegetated ET systems, salt accumulation is generally not a problem, but systems with vegetation may experience negative effects over time.

Soil Permeability (for ETA only)

Soil permeability affects the performance of ETA beds that use 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 two to four feet of unsaturated soil for adequate treatment before reaching the groundwater.

OPERATION AND MAINTENANCE

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

- Ensuring that all stormwater drainage paths/pipes are not blocked and that stormwater drains away from the system.
- Using high transpiration plants suitable for the wetness at ground level.
- If there is more than one bed, alternating the bed loading as necessary.
- Installing additional beds as required.

If an ET or ETA system is properly installed on a suitable site, maintenance is rarely needed.

COSTS

The cost of an ET system depends on the type of system, site, and wastewater characteristics. 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 located in suitable areas, the loading rate ranges from approximately 1.0 mm per day to 3.0 mm per day.) Other cost considerations include the availability of suitable sand, the type and thickness of the liner, use of a retaining wall (if needed), and vegetation (usually native to the area).

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

REFERENCES

Other Related Fact Sheets

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owmitnet/mtbfact.htm

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