DESIGNING EVAPOTRANSPIRATION TRENCHES TO MINIMISE SEASONAL IMPACTS

Ben Kele
Plant Science Group, Central Queensland University (CQU)

On-site wastewater systems generally rely on biological methods for treatment and biological and physical processes for reuse and disposal. Septic tanks, aerated wastewater treatment systems, sand filters, and peat filters (biofilters) all use biological processes to treat wastewater. The treated effluent is either reused or disposed of through biological means, such as transpiration, or by physical means, like evaporation or dilution.

Legislation dealing with on-site wastewater has been updated with the new Queensland on-site wastewater code (2002) and the revised Australian and New Zealand code ANZECC 1547:2000. The codes reflect a change in philosophy in regards to on-site wastewater treatment, system performance and reuse and disposal conditions. Under the two codes both the blackwater and greywater produced by the household must be treated. Treatment systems must comply with a set of specific guidelines in regards to their performance. All treated effluent must be either reused or disposed of in a safe and environmentally sustainable manner within the setback distances of the property. To achieve these legislative requirements, old treatment system technologies like septic tanks have been increased in volume. Likewise reuse and disposal sites now require larger surface areas.

Evapotranspiration trenches reuse treated effluent through the biological process of plant transpiration and dispose of treated effluent through the physical method of evaporation. Legislation requires absolute minimal subsurface or surface runoff from evapotranspiration trenches. Many factors influence the amount of treated effluent that can be reused or disposed of from an evapotranspiration trench and/or trenches. These factors include plant species, canopy architecture, plant development, plant health, climate factors, daily weather factors, soil factors, method of irrigation, depth of irrigation, effluent characteristics, and specific site details.

These factors mean that there can be large fluctuations over time in regards to the amount of effluent that evapotranspiration trenches can reuse and dispose of safely. Treatment chambers can be designed to treat a certain volume of wastewater per hour. It is much more difficult to design an evapotranspiration trench to reuse and/or dispose of a set volume of effluent an hour. Doubling the size of an evapotranspiration trench does not mean that the capacity to reuse and/or dispose of a set volume of effluent has in itself been doubled.

Evaporation and transpiration are two distinct processes. Conditions that are ideal for evaporation may not be ideal for transpiration and vice versa. Transpiration and evaporation though distinct processes do operate simultaneously under most conditions. In an evapotranspiration trench effluent reuse and/or disposal per hour can be described as a ratio between transpiration and evaporation. This ratio between evaporation and transpiration effluent use is constantly varying as the multitude of factors that influence evapotranspiration change.

Evapotranspiration trenches need to be designed so that the processes of evaporation and transpiration can safely reuse and/or dispose of the expected daily flow of effluent from the site. The aim of this presentation is to highlight the factors that need to be considered when designing evapotranspiration trenches so that they are not overloaded. Case studies of the CQU recirculating evapotranspiration trench, site characteristics, plant species, and irrigation methods will be discussed.

Appendix A

Equations for the modeling of effluent water use figures from evapotranspiration trenches

A standard method of modeling evapotranspiration rates is the crop coefficient approach, i.e. relating actual evapotranspiration to a reference evaporation crop (Eastham and Rose 1988).

The equation is as follows:

$ET_c = K_c \, ET_0$

Where;
ET_c crop evapotranspiration (mm d^{-1})
Kc crop coefficient (dimensionless)
ET_0 reference crop evapotranspiration (mm d^{-1})

By multiplying the crop coefficient (K_c) by the reference crop (ET_0), crop evapotranspiration (ET_c) can be calculated (Allen et al. 1998; Whitehead and Kelliher 1991).

Calculation of ET_0
The ET_0 is determined by the Penman-Monteith equation (Allen et al. 1998). The Food and Agriculture Organisation of the United Nations (FAO) have developed an adapted form of the Penman-Monteith equation. The FAO Penman-Monteith requires meteorological data in the form of radiation, air temperature, air humidity, and wind speed, so that climatic ET0 data can be calculated (Allen et al. 1998).

The ET_0 of the equation is only directly influenced by climate, and by not species or canopy architecture. The reference crop evapotranspiration rate (ET_0) is a hypothetical crop of grass, 0.12 m high, a fixed surface resistance of 70sm-1, and an albedo of 0.23 (Allen et al. 1998).

The FAO Penman-Monteith equation can be made more sensitive to climate by including what is termed the hourly time step. This step allows hourly weather changes, such as wind speed, dew-point, and cloudiness to be factored into the equation (Allen et al. 1998).

The hourly time step FAO Penman-Monteith equation is:

$$\mathbf{ET_0} = \frac{0.48\Delta(R_n - G) + \gamma \frac{37}{T_{hr} + 273} u_2 [e^0(T_{hr}) - e_a]}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:
ET_0 reference evapotranspiration [mm $hour^{-1}$]
R_n net radiation at the grass surface [MJ m^{-2} $hour^{-1}$]
G soil heat flux density [MJ m^{-2} $hour^{-1}$]
T_{hr} mean hourly air temperature [^{0}C]
Δ saturation slope vapour pressure curve at T_{hr} [kPa$^0C^{-1}$]
γ psychrometric constant [kPa 0C-1]
$e^0(T_{hr})$ saturation vapour pressure at air temperature T_{hr} [kPa]
e_a average hourly actual vapour pressure [kPa]
u_2 average hourly wind speed [m s^{-1}]

The hourly time step FAO Penman-Monteith equation requires the following four factors to be measured thus (Allen et al. 1998):

1. Air temperature: mean hourly temperature (T_{hr})
2. Air humidity: mean hourly relative humidity
3. Wind speed: average hourly wind speed data measured at 2 m height (u_2)
4. Radiation: total hourly solar or net radiation (R_n)

By using this form of the FAO Penman-Monteith equation the greatest amount of climatic sensitivity can be given to the ET_0 value. Note that the calculation of some of these terms requires other equations not listed here.

Calculation of K_c Factors

Using the crop coefficient approach means that most of the climatic demand is dealt with in the ET_0 part of the equation. The K_c value varies mainly due to crop specific characteristics, and is only marginally impacted by climate factors (Allen et al. 1998). It is through the formulation of K_c that species, canopy architecture, and reduced soil evaporation can be given values (Whitehead and Kelliher 1991).

The four principle characteristics are (Allen et al. 1998):
1. Crop height – influences aerodynamic resistance.
2. Albedo (reflectance) – crop-soil surface interaction.
3. Canopy resistance – the resistance of the crop to vapour transfer, involves leaf area, number of stomata, leaf age, leaf condition, and degree of stomatal control.
4. Soil evaporation.

The crop height, albedo, and canopy resistance are all interrelated with plant species and canopy architecture. The soil evaporation is also affected by plant species and canopy architecture but the addition of a plastic mulch means that additional calculations are required.

To help simplify the determination of transpiration rates separate to evaporation a dual crop coefficient model will be used.

This model uses two coefficients, the basal crop coefficient (K_{cb}) to describe plant transpiration, and the soil water evaporation coefficient (K_e) to describe evaporation from the soil surface (Allen et al. 1998).

Thus:
$K_c = K_{cb} + K_e$

Reference materials and local calibration are needed to determine a final value for the effect of the plastic mulch on Kcb (Allen et al. 1998).

$K_e = K_r (K_{c\ max} - K_{cb}) \leq f_{ew} K_{c\ max}$

Where:

K_e soil evaporation coefficient

K_{cb} basal crop coefficient

$K_{c\ max}$ maximum value of Kc following rain or irrigation

K_r dimensionless evaporation reduction coefficient dependent on the cumulative depth of water depleted (evaporated) from the topsoil

f_{ew} fraction of the soil that is both exposed and wetted, that is, the fraction of soil surface from which most evaporation occurs

Thus the final step is $K_c = K_{cb} + K_e$

References

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