The Treatment of On-Site Wastewater using Willow Bed Evapotranspiration Systems in Ireland

S. Curneen and L. Gill

Department of Civil, Structural and Environmental Engineering, Trinity College Dublin, Dublin 2, Ireland
(Email: curneens@tcd.ie ; gilll@tcd.ie)

Abstract

Willow bed treatment systems can treat on-site wastewater effluent with the advantage that, if sized correctly, they produce no discharge either to ground or to surface water. Water is removed through evapotranspiration, whilst the organics and nutrients are taken up by the tree biomass. The treatment system takes the form of a sealed basin, into which the wastewater is fed from either a septic tank or a secondary treatment facility. Willow beds are a viable alternative to conventional treatment methods, when for example, in situ soil is of too low a permeability to allow for treatment / disposal via percolation or when a discharge of treated/untreated effluent to a watercourse is not permitted. This project has investigated the evapotranspiration rate of four different willow varieties against reference evapotranspiration while also monitoring the effects of the application of three different effluent types onto each variety. The willow varieties being used are Tordis, Sven, Inger and Torhild, which are all subspecies of *Salix viminalis*. The effluents applied were primary (septic tank) effluent, secondary treated effluent and rain water (control). The preliminary results obtained from this research have been used to identify the willow variety with the optimum evapotranspiration for use on full-scale systems and indicate that the application of both primary and secondary effluent increase the evapotranspiration rates for all the varieties of willow. The effect of the different strength effluents on the evapotranspiration rate has been used to accurately design the required area for eight large scale on-site treatment systems which have been constructed and are in their first year of operation.

Keywords

On-site wastewater, Willow Beds, Zero Discharge, Evapotranspiration, Crop Factor

INTRODUCTION

Over 40% of Ireland's population live outside of urban areas making the country one of the most ruralised in Europe (CSO, 2006). As a result, most of these dwellings are not connected to a public sewer system, and hence require some form of on-site wastewater treatment before disposal to surface water or (more usually) to groundwater. On-site treatment usually consists of a septic tank, which provides limited anaerobic treatment (Metcalf and Eddy, 1991) or a secondary aerobic treatment package plant, which then discharge effluent to the subsoil via a percolation area. However, in some regions of Ireland the subsoil is of very low permeability (for example, heavy clay soils) which would not be able to percolate the typical on-site hydraulic loads, so an alternative form of treatment is required. In addition, a new Code of Practice for on-site wastewater treatment in Ireland (EPA, 2009) has introduced a minimum subsoil hydraulic conductivity, below which the discharge of on-site effluent to ground is not permitted.

County Wexford, which is located in the south east of Ireland, is one such region which has considerable deposits of clay subsoils. In the last decade, during the construction boom, the local authority in Co. Wexford granted hundreds of planning permissions for single houses, for which on-site treatment consisted of a septic tank followed by a discharge of the effluent to a nearby stream. Since this, the council has been receiving complaints about the poor water quality in streams and rivers throughout the county with on-site effluent considered to be the major contributor to this problem. To address this problem the council has implemented a series of full-scale trials using zero discharge willow bed systems to treat the effluent.

The three year project is being carried out on eight different single house sites throughout the county.The design of the zero-discharge willow systems was carried out by the development of a mathematical model which predicts the water balance in such systems according to realistic hydraulic loading rates and local weather conditions. The willow beds were then constructed similar to the systems outlined by Gregersen and Brix (2001) which have proved successful in Denmark, consisting of a rubber or high density polyethylene-lined basin refilled with soil and then planted with willow cuttings. The effluent to the willow bed is either gravity fed from the septic tank or secondary treatment plant or pumped from a sump. The primary objective of the project is to determine the optimum size required to treat a known volume of effluent and corresponding volume of rainfall at any given location. Other parameters being compared between sites includethe aspect ratio of the system, effect of different influent types (septic tank or secondary treated) and different varieties of willow tree.Whilst the full-scale systems are in their first couple of years of growth, the latter two parameters have been looked at in more detail in a more controlled mesocosm experiments that compare four different varieties of willow receiving three different strengths of wastewater.

METHODS

Twelve cylindrical containers of height 1000mm and diameter 540mm were placed at an open site, and filled with layers of gravel (76mm), sand (440 mm) and topsoil (460mm). A 30mm inspection plastic inspection pipe was also inserted into each container to allow for measurement of the water level. Each pipe had small holes drilled at the bottom to allow for the ingress of water from the gravel layer (see Figure 1). Before planting the willow trees, each barrel was calibrated in order to show the quantity of water in the barrel being represented by a water depth. Four willow varieties were then planted, *Tordis*, *Sven*, *Inger* and *Torhild*, which are all subspecies of *Salix viminalis*. A plant from each variety was then given an application of primary (septic tank) effluent, secondary treated effluent and rain water (as a control). The dosage was 2.2 litres per week which equated to the approximate amount that one willow tree would have to treat in a large scale willow bed. A weather station was set up in close proximity to the 12 barrels in order to calculate accurately the reference potential evapotranspiration (ET_0) at the site using the modified Penman-Monteith equation.

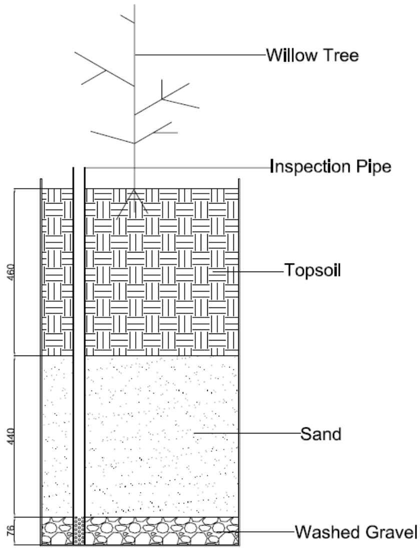

Figure 1 Cross sectional detail of mesocosm experiment

The water level in the barrels was measured at regular time intervals over an 18 month period, from which the volume was obtained. The actual evapotranspiration from each barrel for any particular time interval was then calculated using a water balance equation, taking into account the additional volume of rainfall onto each surface area. The values obtained for actual evapotranspiration were then compared with the potential evapotranspiration to calculate a crop factor. The values for each variety and treatment were also compared in order to determine the most efficient variety and the best treatment type.

RESULTS AND DISCUSSION

An example of the net evapotranspiration across the year from one of the willows (*Tordis*) receiving septic tank effluent is shown in Figure 2. The difference between the reference potential evapotranspiration and measured evapotranspiration is the crop factor and for this particular species can be seen to vary between 2.5 to 4 during the summer months.

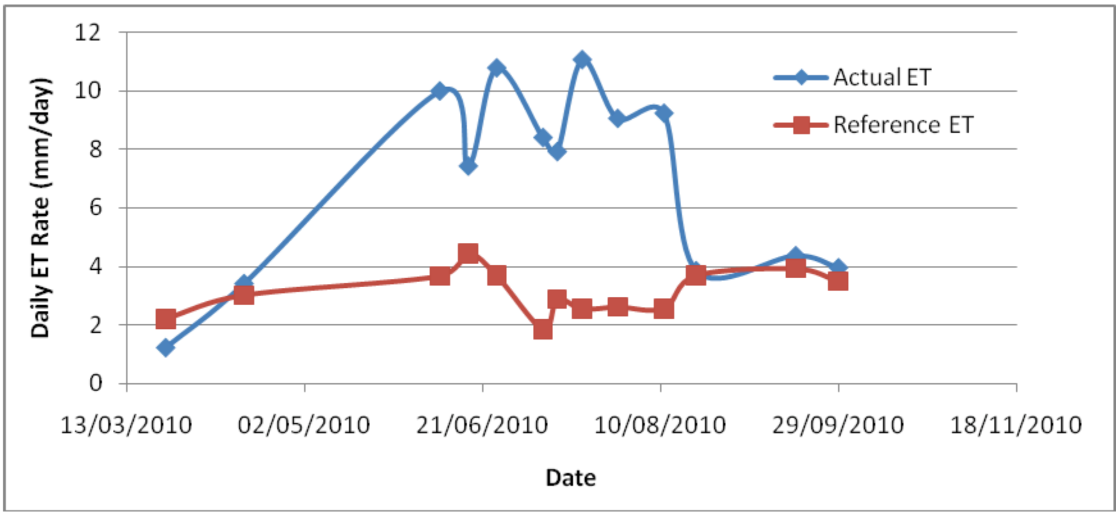

Figure 2 Potential ET and measured ET over a growing season for *Tordis*.

Preliminary results show that the addition of both primary and secondary treated effluent induces a marked increase in evapotranspiration, compared to the varieties dosed with rain water. The increase varied from 20% to over 100% in a growing season, presumably due to the faster growth rate of the trees under the application of organics and nutrients. Equally, the willows receiving septic tank effluent also showed a slightly higher evapotranspiration rate than those receiving secondary treated effluent. These results correlate closely with the findings of Guidi *et al.* (2007) which compares the evapotranspiration rates of a fertilised willow and a non-fertilised willow of the same variety. The change in evapotranspiration between varieties however, was much smaller. Apart from the clone *Inger*, which performed very well under the application of primary effluent, no significant difference could be discerned in ET between the four clones.

CONCLUSIONS

These results from 12 pilot scale experiments have enabled realistic crop factors to be ascertained for 4 different willow varieties in Irish climatic conditions. This information has been used to design and construct 8 full-scale evapotranspiration systems to treat the wastewater effluent from single houses which can not discharge their effluent to groundwater due to the very low permeability subsoils on the sites. If successful, these trials will provide confidence in the use of evapotranspiration systems as a sustainable solution to the problems of on-site wastewater treatment and disposal in such areas of heavy clay subsoils.

REFERENCES

CSO (2006). Census 2006. Central Statistics Office, Dublin Ireland.

EPA (2009).Code of Practice: Wastewater Treatment and Disposal Systems Serving Single Houses, Environmental Protection Agency, Ireland.

Metcalf and Eddy (1991).Wastewater Engineering: Treatment, Disposal, Reuse. Metcalf and Eddy, Inc., 3rd ed., McGraw-Hill Inc., pp. 1024-1098.

Guidi, W., Piccioni, E. and Bonari, E. (2007).Evapotranspiration and crop coefficient of poplar and willow short-rotation coppice used as vegetation filter. Biores.Tech. 99, 4832-4840.

Gregersen, P and Brix, H.(2001).Zero-discharge of nutrients and water in a willow dominated constructed wetland.Wat. Sci. Tech.,44, 407–412