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ON-SITE WASTEWATER DISPOSAL IN CLAY SOILS - THE USE OF EVAPOTRANSPIRATION SYSTEMS AND CONVENTIONAL METHODS

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On-site disposal of wastewater in clay soils in Western Australia was investigated. Shire Councils in the Perth metropolitan area that had households on clay soil were approached and the methods used in overcoming site limitations investigated. Research into wastewater disposal using an evapotranspiration (ET) system developed by the Remote Area Developments Group (RADET system) was discussed. It was found that all shires were using a modified form of leach drain that was partially to fully inverted depending on the depth groundwater table. The role ET played in disposing of wastewater from these leach drains was not known. The RADET system differed from previous designs in that no piping was used to distribute wastewater in the trench and plants were grown adjacent to as well as on top of the system. A list of plants native to Western Australia for use in conjunction with the ET system is currently under development.

INTRODUCTION

The successful functioning of the conventional septic tank/leach drain employed in Western Australia for on-site wastewater disposal can largely depend upon the absorptive capacity of the soil in which it is situated. If the soil is highly permeable such as is the case with sand, percolation of effluent away from the disposal field will be very rapid, although the rate will decrease as a clogging mat develops. In impermeable soils such as those containing clay or bedrock, movement of water is restricted and effluent will move away from the disposal field very slowly. In these situations the leach drain will fail because the rate of percolation of effluent through the soil is less than the effluent generation rate. When this occurs, common practice has been to install reticulated sewerage with an oxidation or evaporation pond which can be very expensive ($300 000 - $500 000 for a community of around ten houses).

The effluent disposal problem that arises in clay soils can be overcome in a considerably less expensive fashion however, by the use of evapotranspiration (ET) systems. An ET system is comprised of a shallow trench or bed partially filled with gravel above which a sand layer is placed. A thin layer of top soil (5cm depth) is placed above this capillary layer. Wastewater flowing into the system is taken up by plants growing on the trench and by evaporation from the surface of the trench.

In this paper the methods used for on-site wastewater disposal in clay soils in the Perth metropolitan area and the evapotranspiration system developed by the Remote Area Developments Group (RADG) will be examined.

ON-SITE WASTEWATER DISPOSAL IN PERTH METROPOLITAN REGION

Shire councils that were known to have households situated on clay soils were approached in October 1989 and health surveyors in each region consulted about the shire's wastewater disposal policy. The shires that took part in the survey were Mundaring, Armadale, Swan, Serpentine and Kalamunda. In all the shires, wastewater disposal in difficult areas where there was clay and/or a high groundwater table, used a modified form of leach drain that was partially or fully inverted. The leach drain design used by all the shires was based upon work sponsored by the Kalamunda shire. The drains were usually 12.2m long surrounded by and shallowly covered by a pad made up of coarse, clean sand, giving a system area of 60-90m^2, depending upon the shire. The estimated cost ranged from $1000 to $3000.

There was some disparity in the use of gravel adjacent to the leach drains. Kalamunda, Mundaring and Swan shires used it and believed it increased system longevity. Armadale shire did not think it was necessary but would use it if the system required renovation. The leach drain method appeared to be working fairly well in all the shires but failures still occurred regularly, particularly in the winter months and when the systems had not been properly installed. Movement of effluent through rock fissures and by overland could still be a problem in some areas.

New regulations regarding leach drains were passed in March 1990 stating that any new systems installed would have to be dual leach drains. This system consisted of two 9m long leach drains covered and surrounded by a sand pad. A switch is installed to allow wastewater flow to be alternated from one leach drain to the other at regular intervals (usually changed over each winter). This theoretically allows the leaching field to rejuvenate and the clogging mat to decompose, hence increasing system longevity (A. Stephens, personal communication, 1989). Kalamunda Shire had already been using the dual system for over three years. Swan Shire was starting to implement these systems but Mundaring and Armadale had not.

How the leaching system worked was the subject of some conjecture. None of the people interviewed had any idea on the extent of effluent loss by evapotranspiration. The Kalamunda shire's design was solely for soil percolation although other shires believed that evaporation played a major role in effluent disposal. Studies by Brouwer and Bugeja (1983) on absorption trenches in Eastern Australia suggest that plant transpiration and soil evaporation contributes significantly to wastewater disposal.

EVAPOTRANSPIRATION SYSTEMS

Evapotranspiration systems provide a means to designing a disposal system in which the ET contribution to wastewater disposal is incorporated into the design rather than being considered as insignificant as in conventional methods. Studies into the contribution of ET to water loss from a system have been completed. It was found that the presence of grass and trees increased water loss from a system and that water loss from systems planted with trees could exceed pan evaporation (McGrath et al., 1990).

Background

Bennett and Linstedt (1978) concluded from their research that ET systems should be employed in locations experiencing low annual rainfall (<700mm) and high evaporation. The system was comprised of three layers; a bottom layer of gravel for wastewater distribution, a middle capillary layer and a layer of top soil. The capillary layer was made up of fine sand (d_{50} of 0.1mm) to allow movement of water by capillarity from the bottom of the trench to the surface to be evaporated.

Evaporation from bare soil was shown to decrease appreciably with increasing depth to the water level in the bed (Bennett and Linstedt, 1978, Rugen et al., 1977) and hence ET systems should be shallow. Plants were not thought to play a significant role in removing water from the system by the above authors, although others such as Lomax and Lane (1979) believed plant transpiration could be significant. The system size was usually determined from the water balance equation. The evaporation component of the equation was derived from a number of sources, either being derived from an approved equation based on climatic data or solar energy studies or estimating ET from pan evaporation data (Rugen et al., 1977, Bennett and Linstedt, 1978).

In Australia ET system design has been based on the water balance equation using pan evaporation data (ET=0.75 pan evaporation). The Health Commission of Victoria (1979) design provided maximum storage for 10 consecutive days of rainfall without any evaporation occurring. The ET system design developed by Day (1982) provided maximum storage of effluent and rainfall for a year, assuming that what was not disposed of in winter would be disposed by ET in summer and spring. A list of plants suitable for growth on ET systems in Eastern Australia was developed by the Environment Protection Authority (1980).

There appears to be little information available on system longevity and on changes in Biochemical Oxygen Demand, Total Suspended Solids and coliform levels, although evidence would suggest that there is a reduction in these (Day, 1982, Lomax and Lane, 1979). It is thought that salt concentration would increase considerably in the system although this has not been monitored (Day, 1982).

RADET System

Studies on ET systems by RADG has been concentrated into two areas; the actual design or layout of the system and secondly, selection of plants for use with the system.

The ET system design developed by RADG is somewhat different to previous designs. As with other authors, ET system area was calculated from the water balance equation:

Storage = (Wastewater load + Rainfall) - (ET + Soil seepage)

Evapotranspiration from the trench is estimated from pan evaporation data (McGrath et al., 1990).

The features that distinguish the RADETS (Remote Area Developments Evapotranspiration System) can be seen in Figure 1. Some points in evaluating the design are as follows.

1. The RADET system consists of a trench no deeper than 1.0 m that is filled with graded gravel above which is placed a layer of sand. A layer of top soil is not used as it could decrease evaporation (Bennett and Linstedt , 1978). The fill used for the sand and gravel layers should be that which is available locally to keep costs down. If obtaining different gravel sizes is a problem, a length of hessian or shadecloth or a geotextile fabric such as Bidum 14 can be placed between the gravel and sand layers to prevent sand falling into the gravel voids.

2. Distribution of wastewater in the trench is by a soakwell located within the first few metres of trench. Wastewater entering the soakwell flows out and is distributed throughout the length of the system in the gravel layer. There is hence no need for distribution pipes which can become blocked.

3. Trees and bushes are planted adjacent to and small shrubs on top of the trench. The area of ET system is thus effectively increased by the planting of vegetation adjacent to the trench. It is envisaged that most of the effluent entering the system will eventually be taken up by the plants once they are well established. The vegetation can also act as a buffer for unexpected flows. As the plants grow, the quantity of water transpired will increase although this will be affected by other factors such as climate, leaf area, and plant species involved (Day, 1982). If more people use the system than what it was originally designed for, opportunistic species such as the river red gum (*Eucalyptus camaldulensis*) will take up the effluent.

4. Wastewater enters the soakwell from the septic tank or ablutions block via a 10cm diameter pipe. This should be no longer than 5 or 6 metres so that if a blockage occurs it would be relatively easy to clear.

The RADET system is currently being constructed at the Kawarra Community in the Bungle-Bungles National Park. The system will be required to dispose of greywater from an ablutions facility which will be used by approximately 15 people. Because of the reasonably high rainfall (682mm) in the region, a system area of $75m^2$ and a depth of 1m was needed for storage and disposal. Due to government policy on national parks, the vegetation planted on/adjacent to the trench have to be grown from seed taken from plants in the region. Several species of plant chosen as suitable for use on an ET system are being grown by the Conservation and Land Management nursery in Broome.

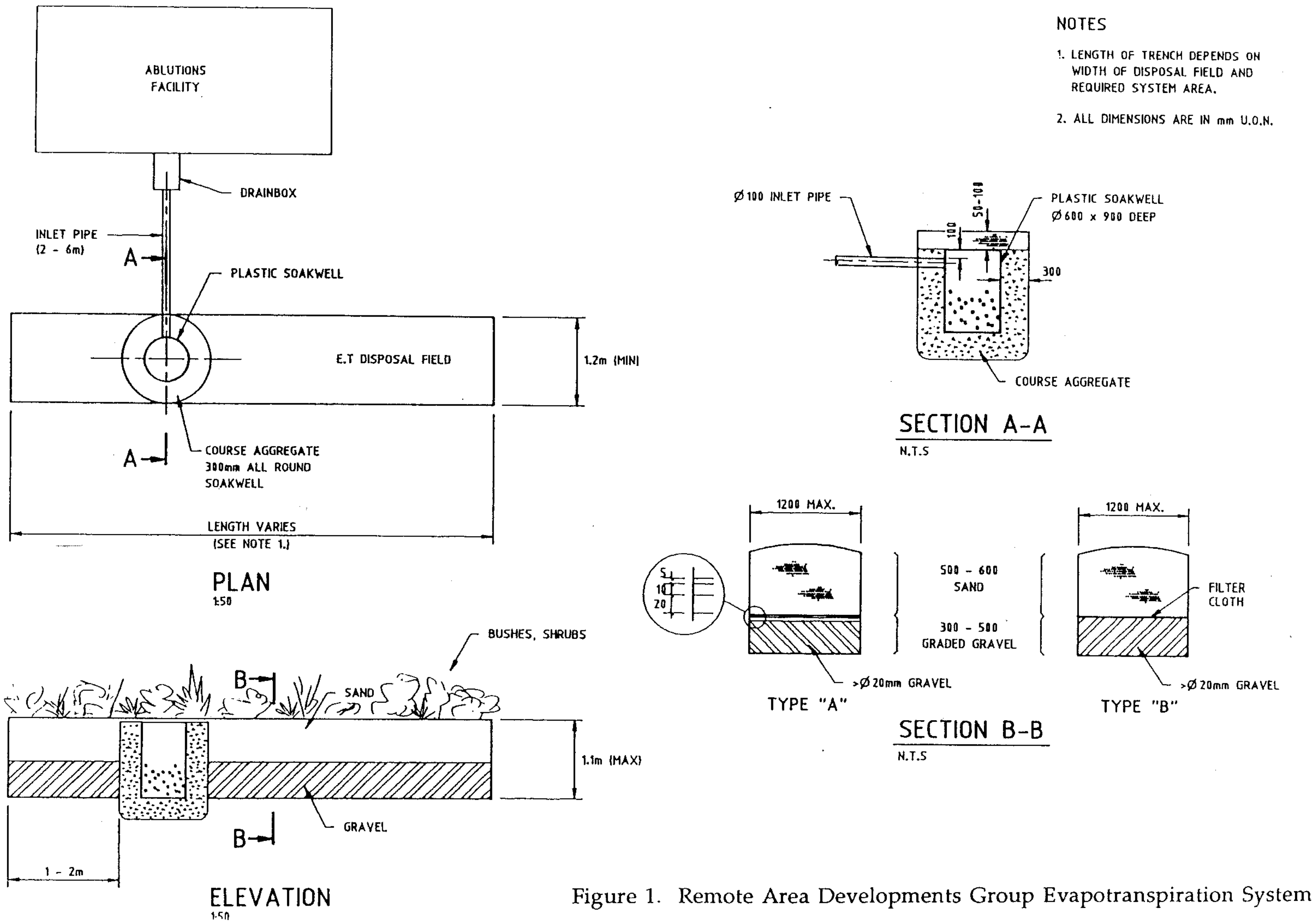

Figure 1. Remote Area Developments Group Evapotranspiration System

Plant Selection

Plants suitable for use on or next to ET systems were selected according to the following criteria: i. waterlogging tolerance, ii. salt tolerance, iii. good nutrient users/unaffected by high levels of nutrients, iv. high water users/fast growers, v. important to Aboriginals for uses such as food, medicine, shelter, shade, utensils etc.

Plants that are high water users may not necessarily be as good when subjected to the stress of waterlogging and/or high salinities. Similarly, plants that are both waterlogging and salt tolerant may still die when subjected to both these stresses simultaneously. It has been shown that tolerance to waterlogging was a better indication of a plant's tolerance to combined stresses than a plant's tolerance to salinity alone. Provenance variation is quite significant in a salt tolerance and plants should be chosen by their provenance rather than their species (Scholfield et al., 1989).

It has been suggested that fast growers show a poorer adaptation to the environment than slow growing plants which appear to be suitable for use in situations where the soil profile is shallow or less permeable (Pate & McComb, 1981). As far as growth on an ET system is concerned, it may be wise to have a few slow growing species present along with the faster growing plants to ensure the presence of vegetation on the system for a long time.

There does not seem to be much information available on water use by native plants in north-west Western Australia and studies for the south-west are somewhat limited as well (P. van der Moezel, personal communication, 1989, Scholfield et al., 1989). This component will continue to be investigated. From the studies available however, it would appear that there are differences in transpiration between tree species. This transpiration though, depends on factors such as: 1) site conditions- climatic variables, 2) landscape position, 3) soil type , 4) soil water salinity, 5) groundwater salinity, 6) depth to groundwater

Present data is insufficient to distinguish actual transpiration from background "noise" arising from site characteristics. Studies on transpiration need to have the species being compared; 1) of the same age, 2) exposed to the same site conditions, 3) sampled on the same days, 4) measurements carried out for at least a year using an accurate method (Scholfield et al., 1989).

Most native plants have a low requirement for nutrients and some plants can die when provided with only moderate levels of nutrients (Pate & McComb, 1981). It is hence important to choose plants that are tolerant of varying nutrient levels and/or can use the nutrients in the wastewater in growth processes.

Table 1. Plants of Western Australia Suitable for Growth On/Adjacent to ET System

Acacia ampliceps	*Brachychiton diversifolius*	*Melaleuca acacioides*
Acacia coriacea	*Carissa lanceolata*	*Melaleuca bracteata*
Acacia eriopoda	*Citrullus lanatus*	*Melaleuca leucodendra*
Acacia hemignosta	*Cucumis melo*	*Melaleuca nervosa*
Acacia hemsleyi	*Cyperis bulbosus*	*Nauclea orientalis*
Acacia holosericea	*Erythrina vespertilio*	*Panicum cymbiforme*
Acacia ligulata	*Eucalyptus camaldulensis*	*Phragmites sp*
Acacia maconochiena	*Eucalyptus microtheca*	*Sesbania formosa*
Acacia pellita	*Eucalyptus papuana*	*Terminalia bursarina*
Acacia salicina	*Eucalyptus ptychocarpa*	*Terminalia platyphylla*
Acacia sclerosperma	*Ficus racemosa*	*Terminalia volucris*
Acacia victoriae	*Laminatia aristrata*	*Ventilago viminalis*
Atalaya hemiglauca	*Lophostemon grandiflorus*	*Vigna lanceolata*
Atriplex nummularia	*Lysiphyllum cunninghami*	

After discussion with several people (Arpad Kalotas, WA Museum; Fiona Walsh, University of WA; Paul van der Moezel,University of WA; Peter White, CALM; personal communication, 1990) a list of plants native to WA (Table 1) was developed. This list is by no means extensive and has looked mainly at plants suitable for use on clays, particularly cracking clays in the Kimberley and specifically, the Bungle-Bungle region. Many of these plants are also found in the Pilbara region but this aspect requires further research.

Of the plants chosen, some are suitable for use on the ET system while others should only be planted adjacent to the trench as they grow to a greater height. If these species were grown on the bed, the roots would not extend into the soil outside of the ET system resulting in the plant becoming rootbound and likely to topple over in high winds (A. McComb personal communication, 1989). It is thus important that only small to medium bushes, trees and shrubs (< 6m) are planted on the ET system.

CONCLUSIONS

Wastewater disposal by the conventional septic tank/leaching field does not work in areas of heavy clay soils or bedrock. If leach drains are used they must be modified to increase the soil absorption area. Evapotranspiration must play some role in effluent disposal from these modified systems although the extent to which it does may vary according to the circumstances and has not been fully investigated. Evapotranspiration systems offer an attractive alternative to leach drains which not only have the potential to effectively dispose of wastewater in problem soils, but also to encourage plant growth in what can be often a denuded landscape in remote communities. The RADET system has the added advantage in that failure due to blockages or clogging is much less likely to occur than in a leach drain system.

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