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AFFORDABLE WATER SUPPLY AND SANITATION

Macrophyte trenches for septic tank effluent

P.R. Thomas, La Trobe University and T. Kalaroopan, Rural City of Wodonga, Australia.

IN LOW- AND MIDDLE-INCOME areas of developing countries and in rural areas of developed countries, it is usual to provide septic tanks and associated drainfields or soakage pits as excreta disposal systems for individual households as well as for small communities up to about 300 people. Although such treatment systems are efficient and economical, septic tanks often have a bad reputation because of either inadequacy in the design of the unit or more often because of the failure of the drainfield which follows it. Many situations exist where the odorous septic tank effluent either ponds on the ground or seeps into the nearby stormwater drain due to poor performance of the drainfield causing health risks to people. This can be attributed to one of the following:

- inappropriate soil condition;
- excessive organic / hydraulic loading; or
- faulty design.

To avoid pollution problems the design and construction of the effluent disposal system is as important as the main part of the septic tank system. Proper functioning of the drainfield depends on percolation of the effluent into the soil profile and adequate aeration of the bed. Several alternatives to the standard drainfield system have been developed because of the pollution problems encountered with the standard drainfields (AWRC, 1988) and one such alternative is the use of macrophyte trenches or constructed wetlands. It has been shown that constructed wetlands have the potential to provide a relatively low cost, technologically simple method of wastewater treatment (Finlayson, 1983; Scholes et al., 1986; Davies, 1988).

Macrophyte trenches

A "macrophyte trench" can be defined as a wetland specifically constructed for the purpose of pollution control and waste management, at a location other than existing natural wetlands. There are two basic types of constructed wetlands, the free water surface wetland and the subsurface flow wetland, the latter being considered to have some advantages over the other. In the subsurface flow wetland the flow is maintained below the media surface and there is little risk of odours, insect vectors or public health problems. A subsurface flow wetland system can be a discharge type or a non-discharge type, however, for an average household septic tank a non-discharge type can be reliably designed and constructed because of the low effluent flows. For higher flows, a discharge system can be used with potential for effluent reuse.

Aquatic plant species for use in macrophyte trenches treating wastewater should generally be selected using the following criteria (Mitchell, 1978):

- rapid and relatively constant growth rate;
- ease of propagation;
- capacity for absorption of pollutants;
- tolerance of hyper-eutrophic conditions; and
- ease of harvesting and potential usefulness of harvested material.

Also, it is preferable to select from native plant species which grow locally in the area. Examples of aquatic macrophytes that have been used in the artificial wetland systems are:

Floating plants:

- *Eichhornia crassipes* (Water Hyacinth)
- *Spirodela* (Duckweed)
- *Salvinia molesta* (Salvinia)

Emergent plants:

- *Schoenoplectus validus* (Great Bulrush)
- *Juncus ingens* (Giant Rush)
- *Phragmites* (Common Reed)
- *Typha* spp. (Cumbungi or Cattail).

These plants are able to transfer oxygen into the bed, creating aerobic microzones around the plant roots and anaerobic zones away from them. As a result, aerobic and anaerobic bacteria will both carry out the breakdown of the organic matter and removal of nitrogen through nitrification and denitrification processes. Wetlands can significantly reduce biochemical oxygen demand (BOD_5), suspended solids (SS), nitrogen, pathogens and metals through their complex chemical / biological processes as well as some uptake by the vegetation. Phosphorus removal in many constructed wetland systems is not effective because the gravel media offer limited contact opportunities between the wastewater and the soil, and due to the short hydraulic retention times. Removal of BOD_5 in the wetlands can be approximated by the first-order plug flow kinetics but they do not have a strong relationship with the hydraulic retention times as well as with aspect ratio (length:width) (Reed and Brown, 1992).

Home septic tank systems

For individual houses, macrophyte trenches to treat septic tank effluent can be designed and constructed to satisfy owner's landscape requirements in regard to position, and decorative plants such a lilies, cannas or ferns which grow well in wet conditions can be used to create an aesthetic value. *Typha* and *Phragmites* spp. are not recommended for domestic installations because of the massive seasonal release of wind-blown seeds (Mitchell et al., 1990). To dispose 1 m^3/d of septic tank effluent, conventional drainfields require a surface area of 50-100 m^2 whereas macrophyte trenches need 24-50 m^2 of surface area with virtually no pollution problems.

For an average household a single cell macrophyte trench 0.6 m deep is adequate to treat the septic tank effluent. The bottom of the trench should be lined with an impervious layer to prevent seepage if there is no clay layer. The inlet zone with a buried perforated pipe should have 25-50 mm washed gravel for a length of about 1 m, and for the full depth of the bed. Similar size gravel can be used for the outlet zone as well. The gravel in the treatment zone should be clean with sizes up to 15 mm in diameter. Since a low aspect ratio of the macrophyte trench is a very important factor in the hydraulic design of the system, a value of 3:1 or less is recommended (Reed and Brown, 1992). The cost of a home septic tank macrophyte trench system can vary above or below that of the standard drainfields and will depend on conditions such as topography, soil type, and the cost of gravel media (which represents over 50% of the cost of subsurface flow macrophyte trenches). The longitudinal section of a single cell subsurface flow macrophyte trench is shown in Figure 1.

Treatment of secondary effluent - pilot studies

The pilot size subsurface flow macrophyte trenches at Wodonga Sewage Treatment Facility in Australia consist of four cells each 27.0 m long x 3.6 m wide x 0.6 m deep containing emergent vegetation growing in 0.5 m deep gravel media. Part of the secondary treated sewage from the treatment facility is used as the inflow to each of the four trenches, three of them planted with either *Schoenoplectus validus*, *Juncus ingens* or both species of plants and the fourth serving as an unvegetated control trench. The trenches with *Schoenoplectus validus* and *Juncus ingens* contain 10 mm and 14 mm size gravel respectively as bed media while 20 mm size gravel is used for the other two trenches. Monitoring began in December 1993 and mean concentrations of BOD_5, suspended solids, nitrate (NO_3), total phosphorus (Total-P), chemical oxygen demand (COD) and ammonia (NH_3) obtained to date from the inflow and outflow are presented in Table 1. During this period, flow to the trenches was varied to give different hydraulic retention times with 1 day being the lowest value.

The quality of the secondary treated wastewater from the sewage treatment facility has been inferior because of the unusual acceptance of effluents from a meat works and from a pet food industry to the treatment facility during the monitoring period. This affected the performance of the macrophyte trenches which were less than six months old and in the developing stage.

In the vegetated trenches BOD_5 removal efficiencies averaged between 56-63% whereas in the unvegetated control trench BOD_5 removal averaged 79%. In general the trench with both plant species, *Schoenoplectus validus* and *Juncus ingens* offered better BOD_5 and COD removal than the trench with either *Schoenoplectus validus* or *Juncus ingens*. Since BOD_5 removal is enhanced under aerobic conditions, it is reasonable to assume that the superior efficiency obtained in the control trench was due to the presence of oxygen in the higher voids component of the 20 mm gravel media. The macrophyte trench (20 mm gravel media) with the mixture of two plant species had slightly elevated effluent BOD_5 levels contributed by some of the decaying vegetation.

Figure 1. Longitudinal section of a Macrophyte trench.

Table 1. Performance of macrophyte trenches at Wodonga.

Sampling period: December 1993 to April 1994	BOD mg/L	SS mg/L	COD mg/L	NH3 mg/L	NO3 mg/L	Total-P ms/L
Influent	57	50	221	29	26	8
Effluent from:						
Schoenoplectus validus (10mm gravel)	25	10	80	24	12	7
Juncus ingens (14mm gravel)	23	6	80	25	5	7
Mixed species (20mm gravel)	21	10	72	22	9	7
Unvegetated Control (20mm gravel)	12	5	54	18	8	6

Suspended solids removal averaged 88% with *Juncus ingens* and 80% with both *Schoenoplectus validus*, and the combination of the two species whereas the control trench showed a reduction of 90%. For suspended solids and BOD_5, results to date show that removal rates were not improved with long hydraulic retention times.

Reduction in ammonia was poor, 14-24% for macrophyte trenches and 38% for the control trench, whereas for nitrate removal, the overall performance was better with *Juncus ingens* offering the highest reduction of 81%. Although it is expected to have a significant ammonia removal through nitrification-denitrification mechanisms from the macrophyte trenches, it is believed that the oxygen in the gravel media was insufficient to convert the ammonia to nitrate. Generally all of the trenches have been performing satisfactorily in regard to denitrification, with effluent nitrate levels dropping to as low as 3.5 mg / L in the trench with *Juncus ingens*. Phosphorus removal was low in all of the macrophyte trenches showing a removal efficiency of about 13%. During this initial period of monitoring. surface flows were observed at the inlet end of the macrophyte trenches from time to time. This may be either due to excessive organic loading or due to the aspect ratio of 7.5:1 for each of the trenches.

Conclusions

Macrophyte trenches have the potential to provide an economically feasible and simple method of polishing pre-treated wastewater where a consistent high quality effluent is not always required. They can be integrated into septic tank systems for single houses as well as into the wastewater treatment systems for small communities, particularly in rural areas. Since the effluent from a septic tank normally has a BOD_5 of about 150 mg / L, either a two-cell septic tank or a septic tank effluent sand filter built in the system may be useful to reduce the loading on the macrophyte trenches to prevent any potential clogging problems.

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