PEAT BED FILTERS FOR ON-SITE TREATMENT OF SEPTIC TANK EFFLUENT

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Abstract

The addition of a bed of peat, approximately 600 mm deep, as a treatment mechanism for reducing the impact of septic tank effluent (STE) on the receiving environment (land or water) has been shown to be significant. By regular dosing of a Biogreen™ peat filter through a pressurised distribution system to maintain an aerobic environment, reductions in typical STE contaminants can be achieved.

At Tingha, on the Northern Tablelands of New South Wales, seven on-site systems have had biological filters installed, each comprising a blended peat product from Biogreen's peat resource in Colac, Victoria. Five of these on-site systems are being monitored to evaluate the treatment of STE through the peat filter. By sampling from both the septic tanks and the peat beds, direct comparisons for each system are being made.

To date, the monitoring program has shown the success of the peat filtering systems in providing beneficial treatment of the STE by removing much of the potentially contaminating components from the effluent, prior to its ultimate treatment in the soil. Results show that faecal coliforms (FC) have been reduced by 99.46%, total nitrogen (TN) by 44.2% and total phosphorus by 83.6%. Of similar significance is the oxidation of ammonia to nitrate and the beneficial loss of odour nuisance from the effluent.

The predictions, based upon the above results, are that there will be a likely improvement in nitrogen removal, ongoing reduction in FC and a gradual increase in phosphorus levels moving through the peat until it is life-expired in relation to peat. Overall the results confirm Biogreen™ peat's reduction in contamination of highly permeable soils in a system that is almost maintenance free and does not rely upon any change in the behaviour of residents.

Keywords

biogreen, disinfection, faecal coliforms, peat, phosphorus, total nitrogen,

1 Introduction

At Tingha in northern New South Wales, the failure of the traditional drainfields in the village where only small areas are available for effluent application, was the trigger for a review of domestic wastewater treatment and disposal options for existing and new houses to be built by the Mrangalli Aboriginal Corporation. The lot sizes for the proposed new rental homes were from 600 - 1400 m^2, with the potential cumulative effects a major consideration because of the highly permeable soil.

Leakages from current subsurface drainfields have lead to elevated soil phosphorus levels at distance from the drainfields and lateral flows through the soil appear to be driving the nutrients towards Copes Creek. The soils in the Tingha area are mainly coarse sands over a sandy light clay in places or deep coarse sands throughout. Large granite torrs are common, outcropping throughout the town and often limiting on-site effluent disposal. The soils have very low cation exchange capacity and the phosphorus sorption is less than 250 mg kg^{-1}.

The potential for tertiary effluent treatment in the soil profile is remote, as few soil properties offer additional treatment or removal mechanisms. Where the soil properties are at risk of failing (hydraulic failure or soil structural instability) under the application methods, amendments need to be made to the chemistry of the effluent so that the impact on the soil environment is minimised.

The treatment of domestic wastewater in a conventional septic tank provides only primary treatment with the septic tank effluent (STE) remaining at highly polluted levels with respect to faecal coliforms (FC), ammonia (NH_3) and total phosphorus (TP). Technologically advanced aerated wastewater treatment systems (AWTS) incorporate aeration and chlorination to the process after primary treatment and discharge an effluent low FC, ammonia oxidised to nitrate, however, phosphorus and total dissolved solids (TDS) remain unabated. The disposal of effluent may be by subsoil absorption or surface irrigation, maximising where possible the soil as the final filter and tertiary treatment. While the term disposal may be debated, in many cases the intent is to return the water to the hydrologic cycle through the quickest route irrespective of a beneficial use.

The site assessments and a review of the suitable systems were completed in May 1999 and a proposal for using large septic tanks and peat treatment of effluent prior to gravity-flow subsurface absorption was made to the architects for approval and funding. The proposed systems were not of a type addressed in either the Environment and Health Protection Guidelines (DLG, 1998) or the Australian Standard 1547-1994 (Standards Australia, 1994) but had previously been installed by Patterson (1994) and Patterson *et al.*, (1986) as part of a successful full-scale research project. Peat has been used for treatment of domestic wastewater in other parts of the world with great success (Brooks *et al.*, 1984).

The proposal for Tingha was made with the knowledge that peat is available from Biogreen Limited in Colac, Victoria and that the systems would adequately treat the effluent prior to soil absorption. The objectives of the peat bed treatment systems were to comply with the principles of wastewater treatment as required by legislation. These principles are:

- protection of public health
- protection of lands
- protection of surface waters
- protection of groundwaters
- conservation and reuse of resources
- protection of community amenity

That the systems were almost maintenance free and require no special behaviour in the household were operational requirements.

This paper outlines the systems that were constructed at seven sites in Tingha, five of which have been monitored since early 2001. There have been sufficient data collected to date to permit a review of the systems and predict the likely long-term benefits of these systems on highly permeable soils, on small lots under low management priorities.

2 Peat Bed Treatment Systems

2.1 Wastewater Collection and Primary Treatment

Clean water is provided to each of the houses by either a pressurised town water supply or a combination of trickle-fed town water to supplement rainwater collection and storage. As such, the houses have an unrestricted water supply to meet their daily requirements. Water conservation is not an active element is any of the houses while the numbers of residents in each dwelling can vary quite considerably from day to day. Existing septic tanks and drainfields were generally in poor condition, undersized for the number of household occupants and poorly equipped to handle the wastewater loading. In some systems effluent was seeping out of the soil and ponding in road table drains.

For each of four existing dwellings, the wastewater treatment systems were completely rebuilt to replace old concrete septic tanks while the drainfields were abandoned as they would not be required as part of the system. At three houses, new systems were installed. All seven systems were of the same configuration. A new primary septic tank, baffled and of 3000 litres capacity was installed at each house. A Zabel Model filter was installed on the outlet from this primary tank to remove a proportion of the suspended solids load. The effluent flowed through the filter into a 3000 L collecting tank of three compartments. Initially the water was held behind a trickle feed weir with the purpose of further reducing the sediment load and any scum sloth off the filter. The second chamber collected the feed from the first chamber and directed it to a pumped collection well. A 240 V electric submersible pump was installed in the sump and set to activate by a float switch.

Effluent from the collection chamber was pumped to a pressurised distribution network in the peat treatment filter bed. The peat bed filter is dosed in small volumes many times during the day, dependent upon the rate of effluent passing from the septic tank to the collection tank.

2.2 Peat Filter Bed

A box of dimensions 3.0 x 3.0 x 0.9 m was constructed of treated pine and bolted at the corners to four steel corner plates. The sides of the box were lined with an impermeable membrane and the top secured in place by an angle capping. The bottom of the box was open to allow effluent to percolate into the subsoil drainfields below the peat bed.

A layer of coarse sand was placed in the bottom of the box and 600 mm depth of peat placed above this. The peat used was a blended peat from Biogreen's resources. Over the peat filter material, a distribution system of 32 mm pipes was placed and an additional 100 mm of peat placed over the top of this network. The peat beds are protected by shade cloth and welded steel-mesh to keep children and animals from interfering with the system.

2.3 Drainfield

Each peat bed, servicing one dwelling, was located adjacent to or on top of a subsurface drainfield. In the conventional manner, slotted pipes carried the effluent away from the bottom of the peat bed to distribute the effluent over a number of shallow trenches according to the design-loading rate for the soil. Effluent percolates into the soil for final treatment and returns to the hydrologic cycle, mostly by evapotranspiration but also by soil absorption.

3 Monitoring Program

During construction of the peat bed a device was installed to facilitate monitoring of the water leaving the bottom of the peat bed and prior to entry into the subsoil absorption system. Monitoring from this point in each bed commenced in April 2001 and is continuing.

The purpose of the monthly monitoring is to evaluate the quality of the effluent leaving the peat filter for final treatment in the soil absorption system. The criteria against which the monitoring results are compared is to minimise the effluent's impact on the receiving environment in relation to FC, phosphorus, ammonia and nitrate.

There are no standards that apply to this type of wastewater treatment. Suffice that AS/NZS 1547:2000 (Standards Australia and Standards New Zealand, 2000) and the Environmental and Health Protection Guidelines (DLG, 1998) can be satisfied when the environmental load of nutrients on the environment is sustainable and the risk to public health is minimised. The application of general effluent criteria as applies to AWTS would be inappropriate, as the peat bed system is passive, without post chlorination and destined for subsurface soil absorption.

Biochemical oxygen demand (BOD) was not measured on any samples, since the BOD_5 test is easily distorted by high levels of ammonia and nitrate, each present in the water samples.

Any reduction from the primary treated effluent is a reduction on the environmental load and the soil is capable of consuming large BOD_5 loads, well beyond the BOD_5 of the STE.

Phosphorus reduction in the effluent is critical in the Tingha environment where little protection is given to phosphorus leaching through the soil profile from the natural soil P-sorption. For practical purposes the P-sorption capacity has been taken to be zero.

The reduction in FC is paramount to the treatment of the primary treated effluent through the peat bed, as such reductions will minimise public health risks. Since FC are only indicator species, it is expected that die-off of FC reflects a similar die-off of other pathogens.

Samples of effluent were taken from the sampling point using either a hand bailer or 12V electric sampling pump and collecting in a sterile 1 L high density polyethylene (HDPE) container. Excess effluent was pumped from the collecting sump in order to removed sediment from the bottom of that device. The samples were placed in an esky with freezer blocks and returned to the laboratory for analysis. The author and staff performed the tests in accordance with Standard Methods (APHA, 1995) in Lanfax Laboratories.

4 Results

Three sampling events have been conducted on the houses, collecting samples from the septic tank and from within the peat bed. Because of the nature of the soil (coarse sands) it has not been practical to collect water samples from the disposal fields. The three sampling dates were 5th April, 28th May and 16th June. The 16th June sampling event was observed to coincide with washing day at each of the residences, with full rotary clotheslines indicating that large volumes of water had passed through the septic tanks.

The results of the chemical analysis of the septic effluent and the peat treated effluent are given in Tables 1 and 2 respectively. Other parameters also measured but not reported here include total solids, total dissolved solids, cations (sodium, calcium, potassium, magnesium) and calculations for hardness and total dissolved solids.

Effluent samples could not be obtained from one of the peat beds for reasons not yet clear. The statistics in Table 2 have been compiled from the results of only four peat bed filters.
Using the values of the average STE from Table 1 and the average from the peat beds, the percentage change in the quality as a result of the treatment in the peat bed filter has been calculated and reported in Table 2. In every case, except for nitrate-N, the peat bed has decreased the concentration of contaminants in the effluent. For nitrate-N there was a 740% increase which results from the oxidation of ammonia to nitrate. By comparing the average combined ammonia-N and nitrate-N in each of the tables, 59.9 mg L^{-1} for the septic effluent and 28.0 mg L^{-1} for the peat bed, the latter reduces the combined value by 53% through denitrification within the peat bed prior to expected denitrification in the soil.

Total suspended solids (TSS) were also monitored as part of the program but the results indicate that the suspended solids in the peat treated effluent varied considerably, for some system there was a decrease in TSS during treatment while in others there was an increase in TSS with peat treatment. The differences in TSS were attributed to the flushing of peat fragments into the collection well as the peat bed settled during the first months of operation.

Colour is pronounced in the peat treated effluent, compared with the STE. The latter is a straw yellow to grey colour, contaminated by the organics from both the toilet and kitchen wastes while that from the peat treatment is pale brown to orange brown, stained by the tannins from the peat. It is the author's experience that these tannin colours will continue to leach from the peat for many years but are not detrimental to the receiving environment.

Table 1. Septic Tank Effluent Quality from Five Houses over Four Collections

PARAMETER	UNITS	MINIMUM	MEAN	MAXIMUM
pH		6.96	7.51	8.04
EC	dS m^{-1}	0.719	1.084	1.355
SAR		3.9	6.4	8.4
Alkalinity	mg L^{-1} $CaCO_3$	535	828	997
Ammonia-N	mg L^{-1}	36.1	57.1	84.1
Nitrate-N	mg L^{-1}	1.2	2.8	5.1
TKN	mg L^{-1}	44.2	67.1	103.5
TN	mg L^{-1}	46.3	69.9	108.2
TP	mg L^{-1}	3.4	6.7	9.8
Faecal coliforms	cfu/100 mL	1.1×10^5	2×10^5	2.8×10^5

EC = electrical conductivity, SAR=sodium adsorption ratio, TKN = total Kjeldahl nitrogen, TN total nitrogen, TP = total phosphorus, cfu/100 mL is colony forming units per 100 mL

Table 2. Quality of Effluent from Four Peat Beds over Three Collections.

PARAMETER	UNITS	MINIMUM	MEAN	MAXIMUM	CHANGE %
pH		5.44	6.17	6.47	- 19.42
EC	dS m^{-1}	0.642	0.712	0.783	- 36.4
SAR		2.8	3.4	4.2	- 49.2
Alkalinity	mg L^{-1} $CaCO_3$	61	161	293	- 80.5
Ammonia-N	mg L^{-1}	0.50	3.16	9.02	- 94.5
Nitrate-N	mg L^{-1}	12.7	23.8	41.2	740
TKN	mg L^{-1}	11.0	15.3	17.9	- 77.2
TN	mg L^{-1}	30.8	39.0	57.0	- 44.2
TP	mg L^{-1}	0.59	1.09	2.13	- 83.6
Faecal coliforms	cfu/100 mL	167	1084	2973	- 99.5

5 Discussion

Each of the parameters measured in both the STE and the peat treated effluent (PTE), prior to soil absorption, indicates a decrease in the concentration of the constituent in the PTE. In most cases this decrease is to the benefit of the receiving soil and wider environment, immobilising nutrients in the organic fabric of the peat bed, providing food resources for the microbial populations in the peat as well as leading to the denitrification of part of the nitrogen load.

The changes in the effluent pH from the STE quality to that of the PTE discharge are mainly related to the organic acid components flushed from the peat resource, as well as the loss of alkalinity (HCO_3^-) during the denitrification process. The lower pH of the peat effluent (pH

6.05) is less than the ideal for denitrification. The system that is assumed as having the highest wastewater throughput has the lowest pH of all the peat beds.

Electrical conductivity (EC) of the STE is often high, but is reduced by about 34% during its transit through the peat bed. It is clear that loss of alkalinity (80%) plays a major role in this reduction while the movement of cations is only minor. As a conversion to salinity, the average reduction in total salt content is about 240 mg L^{-1} from the STE to the PTE.

Sodium adsorption ratio (SAR) is the numerical ratio of the concentration of sodium to that of calcium and magnesium combined and is used as a measure of the potential for sodium to induce soil instability in susceptible soils and plant physiological problems. The reduction in SAR by 47% to a level around 3.4 presents less of a problem than levels around 6.4 (Table 1).

An additional advantage of the peat bed filter is that as the SAR increases over time with the displacement of calcium and magnesium salts by the high sodium concentrations in STE, gypsum (calcium sulphate) or dolomite (calcium/magnesium carbonate) can be safely added to the peat bed. Such additions will provide amelioration to the effluent without detriment to the operational efficiency of the system.

Alkalinity is a measure of the buffering capacity of the effluent. High alkalinity requires large volumes of a weak acid to reduce the pH to 4.5. While some alkalinity is required to prevent sewerage infrastructure (concrete tanks, pipe and pumps) from dissolving in the effluent. Alkalinity is also required to drive denitrification.Much of the alkalinity in STE is derived from laundry detergents. The reduction in alkalinity from levels of 828 mg L^{-1} $CaCO_3$ to 161 mg L^{-1} $CaCO_3$ is significant (reduction of 81%). At this level, the effluent has returned to more normal background levels in natural waters.

Ammonia (NH_3) is the initial nitrogen product derived from the decomposition of proteins. As a cation (NH_4^+) it is immediately available for plant uptake and adsorption to the cation exchange sites. However, as cation exchange capacity (CEC) of the Tingha soils is very low, the potential loss of ammonium ions to the groundwater is high.

In the groundwaters, the ammonia will consume oxygen in the next step towards oxidation (a natural process in aerobic zones). High ammonia levels in STE are expected as the septic tank is an anaerobic (without oxygen) zone. Typical levels in the Tingha systems are 57 mg L^{-1}. In the peat bed filter, the ammonia is oxidised by the high levels of atmospheric oxygen permeating through the medium, resulting in low ammonia and high nitrate (NO_3^-). The overall mass of nitrogen would remain the same except that in the peat bed filter there are anaerobic zones which favour denitrification. Denitrification is the reduction of nitrates to gaseous nitrogen and loss to the atmosphere. Overall, there is a loss of 53% of this source of nitrogen as the STE passes through the peat bed filter.

Organic-N exists in the STE and the PTE as resistant organic fragments and colloids, and dissolved components. Nitrogen in this form may not be easily oxidised into more available forms in the short term and accounting for organic-N as part of the overall nitrogen budget may be flawed. In the peat beds, however, there was a 77% reduction in organic-N as measured by total Kjeldahl nitrogen (TKN). Much of this, it is suspected, is due to the physical filtering in the peat bed and the ready population of bacteria consuming tough organic molecules.

The total nitrogen content of the effluent is the sum of the organic-N (ammonia and TKN) and nitrate nitrogen (NO_3-N). A reduction of 44% has been effected through the peat treatment. As this component may overestimate the amount of nitrogen available for leaching or plant uptake, there has been a significant loss of nitrogen and a reduction in potential impact upon the receiving environment from the treatment in the peat filter.

Total phosphorus is a measure of both the soluble (labile inorganic) and insoluble (organic) phosphorus in the effluent. About half the normal household phosphorus budget is from laundry detergents and the other half from the human diet. The peat bed filter is highly efficient at removing phosphorus through its strong P-sorption capacity. Losses of 83% from the effluent during peat treatment are significant, particular where the soils of Tingha have almost no ability of preventing the leaching of phosphorus directly to groundwater or surface water systems. Over time the P-sorption will diminish and the peat can be replaced. It is expect that the systems will take about seven years to reach this stage. It is the author's experience that once the threshold for phosphorus removal has been exceeded, other removal processes continue unabated.

Faecal coliforms that originate from human faeces are at high levels in STE, often more than 1×10^5 colony forming units per 100 mL (cfu/100 mL). These organisms are indicators of contamination from sewage, by themselves may not present a problem, but when they exist in high levels in effluent it is possible that pathogenic organisms may also be present.

The destruction of FC is, therefore, seen as indicative of destruction of the pathogens. The peat treatment of STE in every case above has shown at least 98.9% reduction in FC with a mean reduction of 99.5%. These reductions relate to average FC levels of 1084 cfu/100 mL.

One area that requires additional monitoring is the actual water use within the houses to better calculate the actual loads entering the peat bed filters and calculation of the potential life of the peat under varying domestic conditions. It is obvious from inspections of the systems during monitoring that some of the houses are generating significant quantities of water. Water meters are being read in the on-going monitoring process.

6 Conclusions

The purpose of the Tingha trials was to provide practical real-time solutions to a localised environmental problem where STE from poorly management on-site wastewater systems. STE was possibly entering the groundwater and local streams, and certainly causing problems of elevated bacterial and nutrient levels around the systems.

With funding for new systems and a collaborative program for the monitoring of the systems, seven Biogreen™ peat bed filters were installed, three on new houses and four as replacement of failed systems. Monitoring of five of the septic tank and peat bed systems commenced in early 2001 and is continuing.

The addition of a bed of peat, approximately 600 mm deep, as a treatment mechanism for reducing the impact of STE on the receiving environment (land or water) has been shown to be significant. By regular dosing of a peat filter through a pressurised distribution system to maintain an aerobic environment reductions in typical STE contaminants can be achieved.

By sampling from both the septic tanks and the peat beds, direct comparisons for each system can be made. The results presented above are for the massed data and averages have been compared to overcome aberrations in the quality of effluent from the individual systems. The results indicate the beneficial treatment of the STE as it passes through the peat beds.

In the five monitored systems at Tingha where a blended product of Biogreen Limited's resource from Colac, Victoria has been used to provide a biological filter, FC have been reduced by 99.46%, total nitrogen by 44.2% and total phosphorus by 83.6%. Of similar significance are the oxidation of ammonia to nitrate and the loss of odour nuisance from the effluent.

The review to date has demonstrated the success of the systems to provide beneficial treatment of the STE and removing much of the potentially contaminating components from the effluent prior to its ultimate treatment in the soil. The predictions, based upon the above results, are that there will be a likely improvement in nitrogen removal, a maintenance of the reduction in FC and a gradual increase in the level of phosphorus moving through the peat until it is life-expired in relation to peat.

Overall the results confirm Biogreen™ peat's reduction in contamination of highly permeable soils in a system that is almost maintenance free and does not rely upon any change in the behaviour of residents.

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