# Effective Treatment of Domestic Effluent with a Peat Biofilter – A Case Study at Tingha

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# EFFECTIVE TREATMENT OF DOMESTIC EFFLUENT WITH A PEAT BIOFILTER - A CASE STUDY AT TINGHA

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## ABSTRACT

The discharge of septic tank effluent onto highly permeable soils may lead to nutrients entering the groundwater or flowing laterally from the site to pollute local streams. Seven domestic dwellings in a small village in northern New South Wales (NSW) were refurbished with new septic tank systems, and individual on-site land application systems were constructed to reduce the high risks of contamination of the groundwater and other off-site effects in this village.

Peat biofilters were installed between the septic tank and the subsoil leach drains to reduce levels of phosphorus, nitrogen and faecal coliforms entering the soil. Wooden boxes, each 3 m x 3m x 0.9 m deep were built above ground, over prepared leach drains. Firstly, 100 mm of sand and 600 mm of a blend of humic and fibrous peat were placed into the box. Secondly, a pipe distribution system was placed on top of the peat and an additional 100 mm of peat covered the distribution system. Each 60 litres of effluent, pumped from a collection well into the distribution system, percolated through the biofilter before entering the leach drains underneath.

Six septics and five of the seven peat biofilters were monitored between April 2001 to March 2002 for a range of chemical and biological indicators. Faecal coliform removal averaged 99.7%, ammonia reduction was 96% although most of this was converted to nitrate (increase of 275%), while nitrogen and phosphorus removal averaged 54% and 75% respectively. The peat biofilter was an economic long-term solution, utilising a low energy, low maintenance system to improve the quality of the effluent, removing problem nutrients and allowing the effluent to be more safely applied to the sandy soils.

**KEYWORDS.** biofilter, biological filter, fecal (faecal) coliforms, peat, nitrogen reduction

## INTRODUCTION

In vast areas of rural and peri-urban Australia, where reticulated sewerage schemes are not available, individual dwellings must treat their domestic wastewater on-site and apply the effluent to land on the same lot in a sustainable manner. The collection of all domestic wastewater from toilets, kitchen, bathroom and laundry through conventional plumbing fixtures and drainage lines delivers highly contaminated water to a primary treatment vessel. The effluent from this septic tank typically drains by gravity to a subsoil drainfield (leach drain) for final treatment.

Where the concentrations of total nitrogen (TN), total phosphorus (TP) and faecal coliforms (FC) in the primary effluent are at levels that cannot be treated adequately in a sandy soil profile, additional pre-treatment is required. Systems such as single pass and recirculating sand filters or Wisconsin Mounds can provide such additional treatment, while amendments can be added to the soil to adsorb phosphorus, and chlorine can be used as a disinfecting agent.

Peat is a naturally occurring humic material with properties that enhance microbiological activity in denitrification, adsorb phosphorus and has a natural disinfecting capacity because of its low pH (pH < 3.5). The use of peat as a biofilter for pre-treating septic tank effluent (STE) has been used

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with significant success by Brooks *et al.*, (1984) and Patterson *et al.*, (1986 and 2001) and Patterson (2001). The effectiveness and relative economic advantage of peat as a low maintenance, long-term pre-treatment system lead to the proposal to install peat biofilters during the refurbishment of septic tanks and soil absorption systems for seven dwellings in Tingha.

This paper outlines the monitoring of five of the seven peat biofilters over 12 months to March 2002. At each monitoring, samples were taken from the septic tank and the peat biofilter treatment to compare the effluent quality and gauge the efficiency of the peat biofilter in renovating the effluent. One peat biofilter was consistently dry and no sample was available during this period.

### Tingha On-site Wastewater Disposal

Tingha, a small village (293 dwellings) in northern New South Wales, is without a reticulated sewerage scheme and totally reliant upon individual on-site wastewater systems for all domestic and commercial wastewater treatment. Subsurface soil absorption on the small lots (often less than 600 $m^2$) is the common method of treating the hydraulic and nutrient loads from septic tanks. The widespread failure of the traditional septic tanks and subsurface drainfields is of concern to the local community that does not have the resources to address the problem.

The results of a site assessment revealed that the soils in Tingha are mainly highly permeable coarse sands over light sandy clays that have a very low cation exchange capacity (CEC) and phosphorus sorption capacity less than 250 mg/kg. The potential for tertiary treatment of STE in the soil profile was poor, as few soil properties offer any nutrient treatment or removal.

The proposal for using peat biofilters between larger septic tanks and subsurface soil absorption area was made after collaboration between the contractor and Biogreen Limited to source humic and fibrous peat from their peat resources in Colac, Victoria. The use of peat biofilters in Tingha complies with the principles of wastewater treatment for low energy, low maintenance systems that will treat and remove major contaminants prior to soil absorption.

## PEAT BIOFILTER TREATMENT SYSTEMS

### Wastewater Collection and Primary Treatment

Potable water is provided to each house by either a pressurised town water supply, or combined trickle-fed town water to supplement rainwater collection and storage. Projected wastewater generation of 300 litres per bedroom per day was later proved to be a severe under-estimation of potential daily water use as water conservation was not practised in these homes and the normal occupancy rates were well above expected.

For each of the four existing dwellings (H-1, H-2, H-3 & H-4), the wastewater treatment system was completely rebuilt to replace the old concrete septic tank while the drainfield was abandoned and a new subsurface leach field constructed. Three new houses (H-5, H-6 and H-7) required completely new systems of a similar configuration.

Each on-site wastewater management system had four major components as shown in Figure 1 that included the baffled septic tank fitted with a Zabel outlet filter, the collection well with submersible pump, the peat biofilter, and the subsoil drainfield to the designed area.

### Peat Biofilter

A wooden box of dimensions 3.0 x 3.0 x 0.9 m was constructed of treated pine and the inside sides of the box lined with an impermeable membrane. The bottom of the box was open so effluent could percolate into the subsoil drainfield below the peat biofilter. Figure 2 shows the peat biofilter indicating a layer of sand over the drainfield and 600 mm of peat blend above the sand.

A distribution system of 32 mm PVC pipes was placed over the peat biofilter material and an additional 100 mm of peat placed over the top of this pipe network. The 32 mm pipe was placed on and covered with geotextile to prevent fines from entering the holes in the distribution system.

During construction of the biofilter, a 100 mm trap was installed to facilitate monitoring of the biofiltrate leaving the bottom of the peat biofilter, prior to entry into the subsoil absorption system. This trap was not effective in H-1 and no sample was able to be collected.

A submersible pump in a collection well, triggered by a float switch, sends 60 L of primary treated effluent to the distribution system in the peat biofilter, taking less than two minutes to complete the task. The next dose depends upon the rate of flow of wastewater from the house. Thus, irregular intermittent dosing occurs during peak periods while overnight the system can rest.

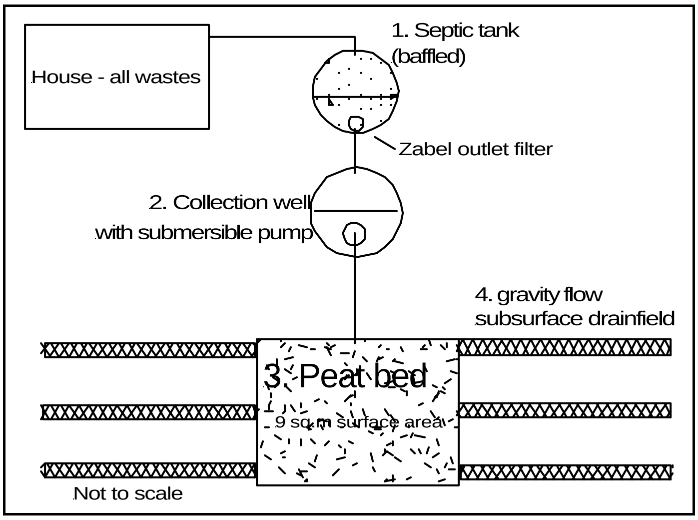

**Figure 1. Plan view of four components of Tingha on-site systems.**

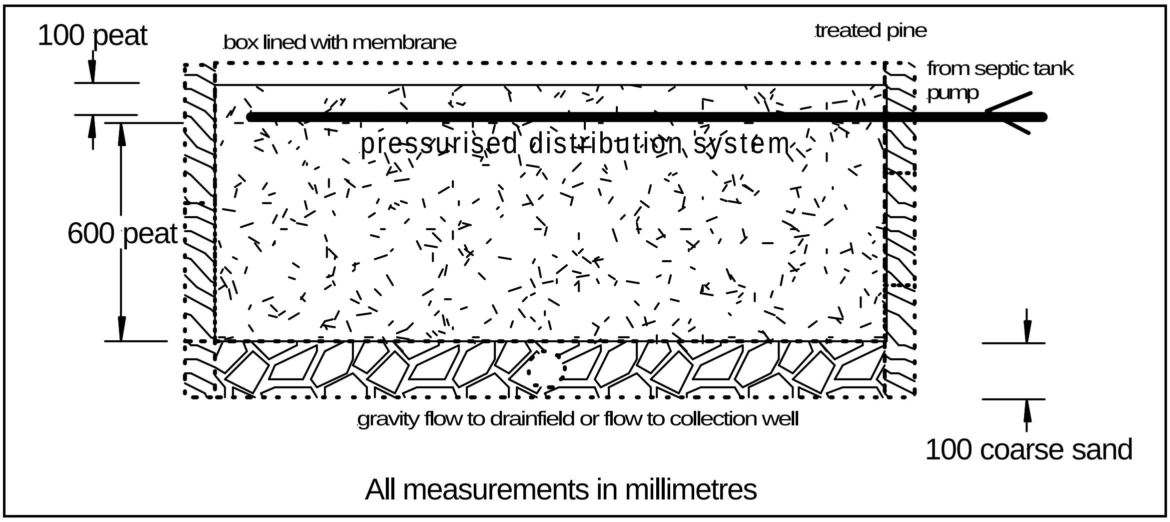

**Figure 2. Cross-section of peat biofilter sitting on drainfield at natural soil level.**

Effluent Monitoring

The purpose of the monitoring program was to compare the STE quality with the peat biofiltrate and evaluate the changes to the chemical and microbial properties of the effluent. The sampling program commenced in April 2001 and finished in March 2002. The residents were not forewarned of the day of sampling, so that each event was random within the normal activities of the house, although some sampling events followed very large washing activities.

For each of seven sampling events, STE samples were taken from the pump chamber in the screened pump vault and at the same visit, a sample from each of the peat biofilters was taken from the special sampling well set-up in the peat biofilter during initial construction. A small 12 V electric submersible pump was used to collect a sample of the biofiltrate.

The effluent analyses were conducted using "Standard Methods 19th Edition" (APHA, 1995). Cations were analysed using flame atomic absorption spectroscopy (AAS) for the first three events and then by Inductively Coupled Plasma (ICP) for the last four events following the commissioning of an ICP by Lanfax Laboratories in August 2002.

Corel's QuattroPro™ was used to determine analysis of variance (ANOVA) and other statistics.

## THE MONITORING RESULTS

### Sampling Events

Samples were taken from the septic tank and the peat biofilter at each of the seven sampling events over 12 months to March 2002. At house H-1 there was insufficient effluent to collect a sample in the biofilter except for the first sampling. An additional house (H-4) was added to the program (at third sampling), while the septic tank at H-1 continued to be monitored. The seven sampling events for six dwellings resulted in 40 STE samples (two samples missed during changeover) and 33 biofiltrate samples (five biofilters, two dry biofilters at sampling). The wide range of results for all parameters in both the STE and the biofiltrate are summarised in Tables 1 and 2 respectively. Except where specifically stated, the results in the text refer to the median value of each parameter.

### Septic Tank Effluent

The range of values for pH and EC are within expected limits for STE. The total suspended solids (TSS) levels are lower than from typical septic tanks, because of the Zabel filter fitted to the septic tank, and the screened pump vault are not usually part of a traditional septic tank system.

Sodium adsorption ratio (SAR), which is used to indicate the potential influence of sodium in soil absorption areas, is higher in the Tingha STE than published by Patterson (1994). The source is most likely the high sodium (median 145 mg Na $L^{-1}$) from chemical use within the house. House H-1 averaged very high sodium levels of 232 mg Na $L^{-1}$ while only house H-5 was below 100 mg Na $L^{-1}$. The high SAR also results from low calcium (mean 23 mg Ca $L^{-1}$) and low magnesium (mean 10 mg Mg $L^{-1}$) in domestic waste as reflected by systems dominated by rainwater inputs.

Ammonia levels ( $NH_3$-N) are typically high in septic effluent where anaerobic conditions dominate, while nitrate levels are generally very low because of the lack of oxygen to oxidise the ammonia. Median $NH_3$-N levels of 62.1 mg N $L^{-1}$ and $NO_3$-N of 5.6 mg N $L^{-1}$ reflect the typical anaerobic conditions in the septic tanks. The high total Kjeldahl nitrogen (TKN) levels reflect the combined $NH_3$-N and the organic-N levels.

**Table 1. Septic tank effluent quality from six houses over seven sample collections.**

| Parameter | Units | Minimum | Median | Mean | Maximum | 95th Confidence Level |
|---|---|---|---|---|---|---|
| pH | | 6.55 | 7.48 | 7.48 | 8.43 | ± 0.13 |
| EC | dS $m^{-1}$ | 0.610 | 1.213 | 1.207 | 2.100 | ± 0.107 |
| TSS | mg $L^{-1}$ | 20 | 70 | 78 | 220 | ± 14 |
| SAR | | 2.5 | 6.9 | 7.2 | 10.3 | ± 1.1 |
| Alkalinity | mg $L^{-1}$ $CaCO_3$ | 432 | 960 | 946 | 1760 | ± 91 |
| Ammonia -N | mg $L^{-1}$ | 0.1 | 62.1 | 57.7 | 105.1 | ± 7.5 |
| Nitrate-N | mg $L^{-1}$ | 0.1 | 5.6 | 10.3 | 41.7 | ± 3.6 |
| TKN | mg $L^{-1}$ | 4.5 | 76.2 | 75.0 | 146.3 | ± 9.0 |
| TN | mg $L^{-1}$ | 39.0 | 87.0 | 85.8 | 182.7 | ± 9.7 |
| TP | mg $L^{-1}$ | 8.3 | 10.4 | 10.3 | 26.1 | ± 1.7 |
| Faecal coliforms | cfu/100 mL | 11,000 | 142,500 | 189,150 | 510,000 | ± 46,600 |

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

TN levels are generally higher than reported from other similar domestic sources. Houses H-2 and H-3 averaged 105 mg $L^{-1}$ and 112 mg $L^{-1}$ respectively, while house H-5 was the lowest average at

54 mg $L^{-1}$. The source of the high TN was not investigated, but generally derived from the human diet (faeces and urine) and poor waste separation in the kitchen.

TP of the Tingha STE was lower than documented by Patterson (1994). However, very high levels up to 26 mg P $L^{-1}$ were measured in house H-1. The variation in TP between houses was not investigated, but is likely related to cheaper brands of laundry detergents.

Sulphur levels averaged 273 mg S $L^{-1}$ although average concentrations in house H-1 were 912 mg S $L^{-1}$, elevating the mean above the median (148 mg S $L^{-1}$). High levels of sulphur lead production of hydrogen sulphide under reducing conditions, and corrosion of structures such as septic tanks.

The thermotolerant coliforms (faecal coliforms) were typical of wastewater receiving human sewage, in the range of 1 x $10^4$ to 5 x $10^5$. The FC pass through the anaerobic treatment process.

Peat Biofiltrate

The STE is intermittently dosed from the screened pump vault when the float valve is triggered, delivering about 60 L of effluent to the peat biofilter. The distribution system at the top of the peat biofilter spreads the effluent evenly over the top of the biofilter. From this entry point the STE percolates through the peat biofilter under gravity and by capillary forces. During passage through the peat the effluent undergoes filtration, adsorption of chemicals onto the cation exchange sites, oxidation in the aerated zone and denitrification in the anaerobic zones by microbial processes. These processes occur simultaneously and continually even though dosing is intermittent.

Table 2 lists the same parameters as Table 1, showing values for the biofiltrate, giving minima, maxima, median and mean values for the 33 samples collected over the 12 months.

Across all STE and biofiltrate readings, typically median pH levels of the biofiltrate (6.36) were 15% lower than STE values (7.47). Individually the differences between the pH of the STE and biofiltrate were statistically significant at the 5% level ($P<0.05$) for H-3 and H-5, highly significant at the 1% level for H-4 and H-6 and not statistically different for H-2.

The median salinity value of the biofiltrate, as measured by electrical conductivity (EC), was 38% lower than the STE. The differences were highly significant ($P<0.01$) for H-3, H-4 and H-6 but not for H-2 or H-5. Over all, the differences were highly significant ($P<0.01$). The lower EC was brought about by the 82% decrease in median total alkalinity (bicarbonate and carbonate derived).

There was an unexpected decrease in sodicity, with the median value of sodium falling from 145 mg Na $L^{-1}$ in the STE to 100 mg Na $L^{-1}$ in the biofiltrate. The sodium adsorption ratio fell by 40% from median of 6.9 to 4.1 in the STE and biofiltrate respectively. There was no statistical difference ($P>0.05$) in the SAR between the STE and the biofiltrate.

The hardness of the biofiltrate (a function of calcium and magnesium) in comparison between the STE and biofiltrate increased due to the higher calcium (10%) and magnesium (160%) median values. Both these salts can be leached from the biofilter when influenced by high concentrations of sodium ions. The mean sodium levels in the STE (145 Na mg $L^{-1}$) would be sufficiently high to cause that leaching as well as potential swelling and dispersion problems in susceptible soils.

The ratio of the nitrogen species in the STE is 10:1:14 (ammonia:nitrate:TKN) compared with a ratio of 1:8:6 in the biofiltrate. The ratios are different because of the aerobic treatment the effluent receives during its transit through the peat biofilter. NH3-N is oxidised to $NO_3$-N, reflected by the low NH3-N (median 2.6 mg N $L^{-1}$) and the elevated NO3-N (median 21 mg N $L^{-1}$) of the biofiltrate compared to the STE. The TKN values will be lower since TKN measures both organic-N and ammonia, that latter being lower due to oxidation effects. Median TKN levels of 15.7 mg N $L^{-1}$ in the biofiltrate are less than the median value of 76 mg N $L^{-1}$ in the STE and this reduction is statistically highly significant at the 1% level across all samples.

Overall, it is the reduction in TN of 45.5% that is highly significant ($P<0.01$) from the STE to the biofiltrate when comparing mean values and a reduction of 53.9% when using median values. House H-2 only measured an average reduction of 23% (range -4.1% to -49%) and the difference was not significant ($P> 0.05$) and H-4 had a TN reduction of 23.1% (range +25% to -50.7%), not significant ($P> 0.05$). The variability was high for all systems including for H-6, the best performer, with a reduction range of 23.5% to 67.4%. Across all samples the changes were highly significant ($P<0.01$).

Changes to TP were highly variable from one sampling to another and from system to system, although the overall average reduction was 71.3% (median 74.6%). There was a noticeable increase in the P in the biofiltrate over time, although these increases were not constant. House H-2 performed the worst ($P> 0.05$) but this was likely due to the high concentration in the STE and the reported high residency rate (high total load). At House H-4, the TP levels in the biofiltrate did not exceed 3.5 mg $L^{-1}$ (average 2.7 mg P $L^{-1}$). The changes from STE to the biofiltrate for TP were significant ($P<0.05$) for H-5 and H-6 and highly significant ($P<0.01$) for H-3 and H-6.

The most significant benefit ($P<0.01$) was the disinfection of the effluent passing through the biofilter. A die-off rate of 99.7% (median) and 99.2% (average) to FC with a passive treatment system is very efficient. While the monitoring did not extend to parasites and protozoans, the filtering capacity of the peat is likely to be as efficient as most manufactured filtration systems, at least as good as a sand filter.

The last column in Table 2 indicates the calculated changes for the median values of the STE compared to the biofiltrate. As expected the only positive change is to $NO_3$-N which is the result of the oxidation of the $NH_3$-N because of the continuous aerated state of the peat biofilter.

**Table 2. Quality of effluent from 33 peat biofilters samples.**

| Parameter | Units | Minimum | Median | Mean | Maximum | 95% Confidence level | Change % to median |
|---|---|---|---|---|---|---|---|
| pH | | 5.00 | 6.36 | 6.40 | 7.72 | ± 0.2 | -14.9 |
| EC | dS $m^{-1}$ | 0.100 | 0.750 | 0.766 | 1.390 | ± 0.085 | -38.1 |
| TSS | mg $L^{-1}$ | <1 | 40 | 193 | 2000 | ± 158 | -42.9 |
| SAR | | 2.3 | 4.1 | 4.4 | 8.2 | ± 0.5 | -40.6 |
| Alkalinity | mg $L^{-1}$ $CaCO_3$ | 20 | 178 | 304 | 1060 | ± 100 | -81.5 |
| Ammonia-N | mg $L^{-1}$ | <0.05 | 2.5 | 7.0 | 66.4 | ± 5.7 | -96.0 |
| Nitrate-N | mg $L^{-1}$ | <0.05 | 21.0 | 24.5 | 66.3 | ± 5.8 | +275 |
| TKN | mg $L^{-1}$ | 5.3 | 15.7 | 21.2 | 84.3 | ± 6.7 | -79.4 |
| TN | mg $L^{-1}$ | 17.9 | 40.1 | 46.8 | 94.2 | ± 7.9 | -53.9 |
| TP | mg $L^{-1}$ | <0.05 | 2.6 | 3.0 | 9.8 | ± 0.9 | -74.6 |
| Faecal coliforms | cfu/100 mL | <10 | 460 | 1566 | 12000 | ± 966 | -99.7 |

## DISCUSSION

The peat biofilters, constructed by the contractor (Natural Waste Water Systems) on each of the lots at Tingha, were monitored by Lanfax Laboratories over a period of 12 months, from April 2001 to March 2002. At each visit a sample was taken from the septic tank and one from the biofilter. The sampling and analysis were done independently of the contractor, or the landlord.

The peat biofilter has three specific operating mechanisms:

**Physical properties - filtration** - the small particulate matter (usually high in $BOD_5$) that passes through the septic tank treatment is captured within the interstices of the peat fibre, and does not percolate through the peat with the drainage water. Thus, the loading of $BOD_5$ and TSS at the top of the peat can be significantly higher than the quality from average septic tanks. House H-2 operated for several months with a known residency rate several times more than its maximum design loading at which the hydraulic and nutrient loading rates would have been many times higher than the design. The higher levels of TSS measured in the biofiltrate are likely to be the fines from the biofilter matrix, rather than the solids from the STE. This is partly confirmed by the lower organic-N in the biofiltrate even though there had been a rise in TSS.

**Biological properties - microbial decomposition** – the peat fibres support a significant population of microbes which consume organic matter in the incoming primary treated effluent in much the same way as the zoogleal in a trickling filter consume the organic loading in a conventional sewage treatment works. In the peat system, the actual surface area of the peat fibres is many thousand times that of the trickling filter. This fact is borne out by the very high CEC of the peat that is a direct relationship with surface area. The 99.2% removal of FC without any external disinfecting agent indicates the efficacy of the peat as a disinfecting medium. The naturally high acidic properties of the peat also play a role in the disinfection process.

**Biological properties - aerobic environment** - similar to an aerated wastewater treatment system, a highly developed population of aerobic bacteria is maintained within this environment. Laboratory results show that the peat can hold up to 300% of its own weight in water and maintain an air-filled capacity of more than 30% (about that of a soil at field capacity). This high aeration is confirmed by the ability of the peat to oxidise up to 96% of the ammonia-N in the STE.

**Chemical properties** - the high CEC of the peat and its mineral content resulted in the changes to the cation ratios from the start of the trial to the end, reflected in the reduction in sodium adsorption ratio of the effluent in its transit through the peat. The loss of 74.6% of TP by adsorption is a highly significant reduction without further chemical additions. The reduction in salinity by 38% and the loss of 81.5% of alkalinity are further chemical changes induced by the peat environment. These losses are statistically significant.

Biochemical oxygen demand was not measured on any samples since the $BOD_5$ test is easily distorted by high levels of ammonia and nitrate, each of which is present in the effluent samples. The $BOD_5$ test is expensive and inconclusive where the effluent is to be disposed of in the soil. The soil is capable of consuming large $BOD_5$ loads, well beyond the $BOD_5$ of even the poorest quality STE. The installation of the Zabel septic tank filter, and the screened pump well before the peat biofilter, provided above average filtration and sedimentation of the STE. The low TSS levels (as low as 20 mg $L^{-1}$) reflected these additional steps of filtration and sedimentation. The author's experience with other peat biofilters is that this level of pre-treatment is unnecessary, provided the distribution system remains clear.

The 15% reduction in pH from the STE to the biofiltrate is mainly related to the increase in organic acids flushed from the peat, as well as the loss of alkalinity ($HCO_3^-$) in the passage of effluent through the biofilter. The pH of the biofiltrate (median pH 6.36) is higher than ideal for denitrification, although the high carbon source in the peat may improve denitrification. The lower alkalinity (median reduction of 81.5%) reduces the potential for further denitrification. 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. Much of the alkalinity in STE is derived from laundry detergents. Some alkalinity is required to prevent sewerage infrastructure (concrete tanks, pipes and pumps) from dissolving in the effluent. Alkalinity is also required to drive denitrification. The reduction in alkalinity from median levels around 960 mg $L^{-1}$ $CaCO_3$ to 178 mg $L^{-1}$ $CaCO_3$ is significant (reduction of 81.5%). At this level, the effluent is closer to normal background levels found in natural waters.

The EC of the STE is often high (median 1.213 dS $m^{-1}$), but is reduced by 38.1% during its transit through the peat biofilter. It is clear that loss of alkalinity (81.5%) plays a major role in this reduction while the movement of cations is only minor. The average reduction in total salt content is about 310 mg $L^{-1}$ from the STE to the PTE, equivalent to about 113 kg salt per year prevented from reaching the disposal field. This amount is not insignificant when there is no extra cost of achieving this reduction. A further reduction could be gained by modifying the use of chemicals within the house that then enter the wastewater stream (Patterson, 1994).

Sodium adsorption ratio 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. Levels of SAR greater than SAR 5 are generally considered detrimental to Australian soils (Patterson, 1994). The reduction in median SAR by 40.6% to a level around SAR 4.1 represents a reduction in the risk of either sodium toxicity or dispersion potential in the soil application area.

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 on the cation exchange sites. However, as CEC of the Tingha soil 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 median levels of ammonia in the Tingha systems are 62 mg N $L^{-1}$. In the peat biofilter, 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 resultant median ammonia levels in the biofiltrate were 2.5 mg N $L^{-1}$, a reduction of 96%.

Organic-N exists in the STE and the biofiltrate as resistant organic fragments and colloids, and dissolved components. Nitrogen in this form is not easily oxidised into more available forms in the short term and accounting for organic-N as part of the overall TN budget may be flawed. In the peat biofilters, however, there was a 6.4% reduction in organic-N as measured by total Kjeldahl nitrogen (TKN) minus ammonia. This low reduction rate is likely to result from the organic fractions that originate from the peat filtrate, the source of colour in the peat. It is not expected that after filtration any of the organics in the STE would percolate through the biofilter.

The TN content of the effluent is the sum of the organic-N (ammonia and TKN) and NO3-N. The overall mass of TN is reduced from the STE to the biofiltrate because of the anaerobic zones in the peat biofilter which favour denitrification. While the peat has a high permeability, its capacity to absorb over 300% moisture (120% at air-dry) supports many saturated cells within the mass. These saturated cells become anaerobic as oxygen is consumed by micro-organism and chemical processes and the process of denitrification is enhanced. Denitrification is the reduction of nitrates to gaseous nitrogen and nitric oxide and their subsequent loss to the atmosphere. Overall, there is a loss of 53.9% of this source of nitrogen as the STE passes through the peat biofilter and influenced by these anaerobic cells. A further reduction would be expected in the soil environment, when adequate carbon was available, and vegetation would assimilate a large portion in its normal nutrient requirement. No plants were growing on the peat beds in this period.

Total phosphorus is a measure of both the soluble (inorganic) and 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 biofilter is highly efficient at removing phosphorus through its strong P-sorption capacity. Median losses of 74.6% from the effluent during peat treatment are significant, particular where the soils of Tingha have a low ability of preventing the leaching of phosphorus directly to groundwater or laterally to the surface water systems. Over time, the P-sorption will diminish and the peat can be replaced or lime can be added to the surface of the biofilter each year. It is expected that the systems will take about seven years to saturate with phosphorus. It is the author’s experience that once the threshold for phosphorus removal has been met, other removal processes continue unabated, but to a lesser degree.

Sulphur in the wastewater originates from laundry detergent powders and other soaps and from the human diet. Higher levels of sulphur are more likely related to the former. The loss of 90.3% of sulphur from the STE to the biofiltrate is caused by similar microbial and chemical reductions as occurs with nitrogen. Sulphur can also be co-precipitated with calcium carbonate and may also be driven with the loss of alkalinity. The importance is that the loss of sulphur reduces the potential incidence of hydrogen sulphide under anaerobic conditions. It is the hydrogen sulphide (rotten egg gas) that makes STE noticeable and its reduction is important where systems are close to homes.

Faecal coliforms that originate from human faeces are at high levels in STE, often more than 1 x $10^5$ cfu/100 mL (Table 1). These organisms are indicators of contamination from sewage and by themselves may not present a problem, but when they exist at high levels in effluent it more probable that pathogenic organisms may be present in high numbers. The destruction of FC is, therefore, seen as indicative of destruction of the pathogens, but not their absence. The peat treatment of STE results in a median reduction of 99.7% in FC with a mean reduction of 99.2%. These reductions result in a median FC level in the biofiltrate of 460 cfu/100 mL (average 1566 cfu/100 mL). At these levels, the water meets the Australian and New Zealand Guidelines for Fresh and Marine Waters (2000) for irrigation water used on pasture, fodder for grazing animals, and for raw human crops by subsurface irrigation. This is a significant improvement from the use of STE and allows alternatives methods of reuse, rather than disposal in leachfields.

The levels of statistical significance of the changes as effluent passes through the biofilter can be summarised in Table 3 which shows the results of the ANOVA computations for each of the five systems (H-1 did not have effluent in the biofilter sampling well during this period).

Table 3. Summary of results of significance of variations from STE to biofiltrate.

| Parameter | House identification number and probability* | | | | |
|---|---|---|---|---|---|
| | H-2 | H-3 | H-4 | H-5 | H-6 |
| pH | n.s. | < 5% | < 1% | < 5% | <1% |
| EC | n.s. | < 1% | <1% | n.s. | < 1% |
| SAR | n.s. | n.s. | n.s. | n.s. | n.s. |
| $NH_3$-N | < 1% | < 1% | <1% | < 1% | < 1% |
| TN | n.s. | < 1% | n.s. | < 1% | <1% |
| TP | n.s. | < 1% | <1% | < 2% | < 2% |
| FC | < 1% | < 1% | <1% | < 5% | < 1% |

* values <5% are significant and < 1% are highly significant, n.s. is not significant at 5% level

It can be seen from Table 3 that other than for house H-2, the changes brought about to the parameters in column 1 by the treatment of STE through the peat biofilter are highly significant, mostly at the 1% level. These changes have not occurred by chance and the treatment processes of the biofilter have been beneficial.

## CONCLUSIONS

The purpose of the Tingha monitoring program was to collect evidence of the efficacy of treating STE by filtration through a peat biofilter. A positive solution would solve a localised environmental problem where STE from poorly managed on-site wastewater systems was possibly entering the groundwater and local streams, certainly causing problems of elevated bacterial and nutrient levels around the systems.

The collaborative program, between Lanfax Laboratories and Biogreen Limited, for the monitoring of six peat biofilters was an opportunity to test the systems under real-time domestic situations. The contractor installed seven peat biofilters, three on new houses and four as replacement of failed systems. Monitoring of the septic tank and peat biofilter systems commenced in April 2001 and ceased in March 2002, independent of the contractor or landlord. H-7 was not sampled and the H-1 biofilter failed to produce sufficient effluent for testing.

The addition of a peat biofilter, approximately 3 m x 3 m x 700 mm deep, as a treatment mechanism for reducing the impact of STE on the receiving environment (land or water) has been shown to be beneficial under a variety of uncontrolled domestic situations. Reductions in typical STE contaminants were achieved by regular intermittent dosing of the STE to a peat biofilter through a pressurised distribution system, thereby maintaining an aerobic environment.

By sampling from both the septic tanks and the peat biofilters at the same time, direct comparisons for each system were possible. The results presented 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 biofilters.

In the five monitored systems at Tingha where a blended product from Biogreen Limited’s peat resource has been used to provide a biological filter, FC have been reduced by 99.7%, TN by 53.9% and TP by 74.6%. Of similar significance are the oxidation of ammonia to nitrate and the beneficial loss of odour nuisance from the effluent.

The overall assessment is that the biofilters are providing statistically highly significant beneficial treatment of the STE, and removing potentially contaminating components from the effluent, prior to its ultimate treatment in the soil.

The systems have low energy inputs (one small submersible pump operating every 60 L effluent collected), low maintenance requirements (nil during the 12 months trial) and have demonstrated their ability to improve the quality of STE under highly variable hydraulic and nutrient loadings. These biofilters can be retro-fitted to existing systems and play a significant role in removing potential contaminants from the effluent prior to its land application. It is expected that these systems will have a life in excess of ten years before the peat requires replacement.

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