Economics of Using Local Peat for Biofiltration of Domestic Wastewater in New Zealand

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ABSTRACT
Primary treatment of domestic effluent fails to remove sufficient nutrients and organics to allow discharge of effluent onto poor soil absorption areas. A passive secondary treatment process, in the form of a peat biofilter, increases the opportunity for on-site discharge into marginal areas.

New Zealand's native peat resources provide ample opportunity for developing low-energy, passive, secondary treatment modules. Peat, mined in Hauraki Basin and in Southland, is exported for horticultural purposes but has excellent biofiltration properties and deserves use within New Zealand for on-site wastewater treatment.

Samples of New Zealand peat have been analysed for their potential as a biofiltration medium, particularly with respect to phosphorus sorption and nitrogen removal. Such a system compares more than favourably with other secondary treatment processes, such as aerated systems or sand filters.

The paper compares a typical peat biofiltration system for a single household with other secondary treatment systems to show that the consumer and environmental benefits of using local peat outstrip those of other systems.

INTRODUCTION

Whether domestic wastewater requires primary or secondary treatment for public health and/or environmental protection depends upon the sensitivity of the receiving environment to the quality of effluent discharged. In cases where the receiving environment is at risk of damage from poorly treated domestic effluent, higher levels of treatment before discharge are critical to long term effective operation of the whole system, since failure within any part may result in failure of the whole. Where aerated wastewater treatment systems (AWTS) are required to provide secondary treatment prior to land application, a failure in electricity supply to the treatment device and pumped irrigation system may be sufficient to render the process unsatisfactory for discharge, yet there are no safeguards to prevent discharge of the poor quality effluent. Replacement of the secondary treatment process with a passive, biofiltration mechanism reduces risks associated with incorrectly treated effluent, reduces on-going resource use for the generation of electricity as well as regular operational costs characteristic of aeration device of an AWTS. For example, the peat biofilter has an ability to adsorb phosphorus in the short term and denitrify by up to 60% through-out its life (Patterson, 2004). As shown in the instance of the Hawkesbury River [NSW] the financial costs associated with environmental remediation resulting from excess phosphorus entering the surrounding landscape was millions of dollars.

Gravity-fed single-pass sand filters, constructed wetlands and reed beds are some secondary treatment devices that can replace the aeration and clarification chambers in an AWTS while siphons can be used to replace pumps. Peat, in the form of either reed-sedge or sphagnum moss, has been used for decades as a passive secondary treatment medium for domestic effluent. Patterson (1994, 2004) reported the effective use of peat biofiltration for domestic wastewater and previously Brooks *et al.,* (1984) had installed many systems in United States households. Fortunately, New Zealand has significant peat resources that could be economically utilised for domestic wastewater treatment as a passive biofiltration mode on single household, community systems or commercial premises. Those NZ peat resources exist in both the north island (Hauraki peat) and in the South Island (Southland and Westland) and are extensively mined for export as horticultural media.

Currently these peat resources are mined from naturally occurring deposits, treated by physical processes and dried to a low moisture content (around 40%). Peat in its saturated state may hold up to 300% of water by weight, which makes handling difficult and transport expensive.

DESIGN OF PEAT BEDS

The purpose of the peat in the biofilter unit after primary treatment is to provide a substrate on which fungi and bacteria can thrive; to provide an acidic environment in which human pathogens cannot survive; to filter solids from the percolating effluent; as well as total nitrogen reduction through firstly nitrification (ammonia oxidised to nitrate) and then through denitrification (nitrate reduced to nitrogen oxides); and phosphorus sorption by the media.

Patterson (2004) showed that 3 m x 3 m boxes filled with peat to a depth of 700 mm were capable of being dosed with primary treated domestic effluent at 100-150 mm per day (100 -150 L m^{-2}.d) while rates up to 300 mm per day were sustainable for short periods.

A typical design of the peat biofilter is shown in Figure 1 where the effluent is pressure distributed through a manifold over the top of the biofilter and the effluent is collected in an under-drain and piped to a collection well from where it can be pressure irrigated to landscape areas for greater benefit. An alternative system is one where the percolating effluent is drained by gravity into the soil directly below the biofilter.

Whether the box is located at the original soil surface, partly or fully sunken into the ground will relate to the site specific conditions and proposed fate of the biofiltered effluent.

It is also noted in Figure 1 that the construction products are low resource demanding and are readily recycled at the conclusion of the capital asset's production period. Further, the consumptive components are also reusable in a manner acceptable to the general environment, thereby the waste product is not making significant intergenerational demands.

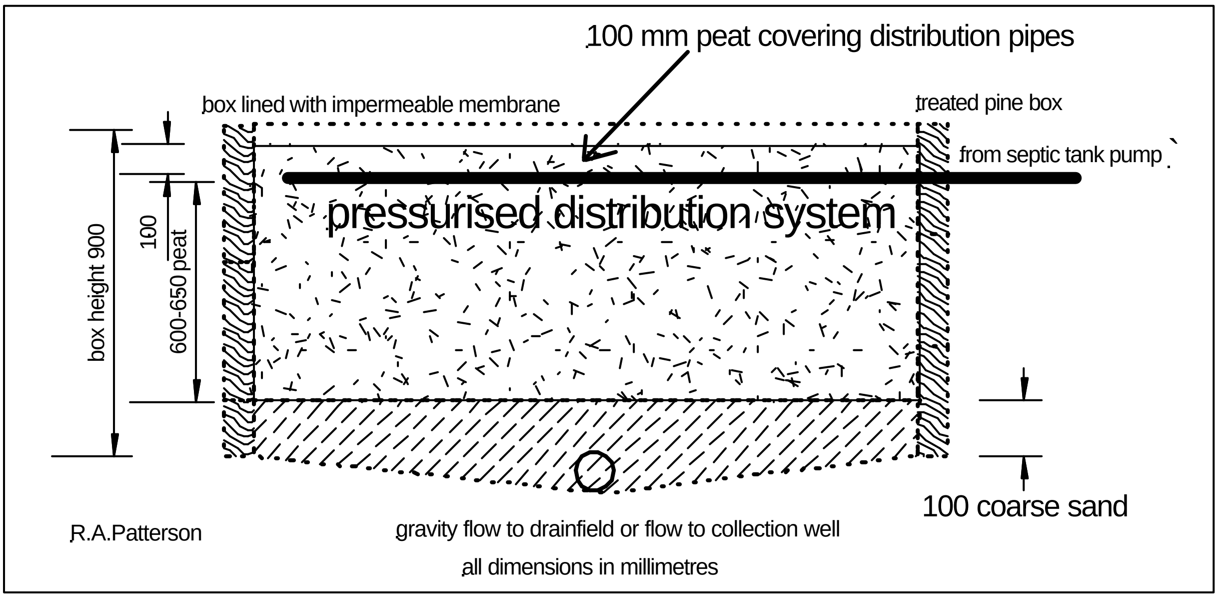

Figure 1 Cross-section of typical peat biofilter (source: Patterson, 2004)

NEW ZEALAND PEATS

Four NZ peat products were sourced from commercial importers and resellers in Australia as set out in Table 1. Other sources may be available locally and some simple testing of the products for suitability in on-site biofiltration can be carried out by local laboratories. Other brands that can be found in an internet search and through email contacts with various suppliers include "Kiwipeat", "Global Peat" and "Hauraki Peat". The Yates peat processing business in Southland was purchased by NZ Peat in 2002 and continues to be sold under the Yates label. NZ Peat began processing peat from the Hauraki Peat bog in 1998. Other brands are sold as mill peat (undried and unprocessed) for the local NZ markets and are not exported. These mill peat products are generally cheaper than dried and processed products.

Table 1. Four brands of NZ peat sourced from importers in Australia

Commercial brand	Moisture content as packed (% w/w)	Type of peat	Colour	Size of package
Ultragrow compressed peat blocks	6%	Sphagnum leaf only	Compressed biscuits, pale yellow	10 kg box of 60 blocks
NZ Peat	70%	Sphagnum peat moss	Brown/black, fibrous	105 L compressed
Yates Sphagnum Peat	85%	Sphagnum peat	Brown/black, fibrous	100 L compressed
Searles Organic Peat Moss	44%	Sphagnum cristalum	Brown/black, fibrous	25 L compressed

The moisture analysis reported in Table 1 was conducted on the samples as purchased in Australia. The chemical analysis of these products was not completed in time for inclusion with this paper and will be presented at the conference.

ECONOMICAL ANALYSIS

The purpose of this paper is to compare the economics of using peat as a secondary filter in domestic wastewater treatment against a fully engineered AWTS. It is to be noted that this household-based analysis does not necessarily extrapolate to larger installations. Further, it is assumed that the systems are on level ground and pumping to the final soil disposal field is required through a similar network of pipes and those costs are excluded from the comparison.

Current NZ market conditions contain three main cost factors: [a] economies of scale of extraction; [b] extent of processing; and [c] transportation. Benefit Cost Analysis [BCA] is sensitive to producer processing, indicating that the cheaper ‘mill peat’ may have a higher unit marginal cost than products of lower moisture content and higher packaging compression. A typical peat biofilter, as shown in Figure 1, contains about 6.3 m^3 of peat, or 32 bales of “Yates” compressed peat. Table 1 shows different packaging rates for the various products.

Table 2. Comparative analysis for aerated system with peat biofilter components

Component	AWTS	Septic + peat biofilter
Primary treatment vessel	Concrete tank	Concrete tank
Discharge from primary to secondary component	Gravity flow to aeration chamber	Pressure pump preferred for distribution over peat
Collection well	Part of combined tank	300 L in-ground tank
Secondary treatment tank	Aeration chamber, part of combined tank	3 m x 3 m box, plastic lined, under-drained
Secondary treatment device	Aeration tank, aeration pump delivering air at 100 L/min.	None required
Secondary treatment media	Fixed media, part of combined tank	6.3 m^3 peat
Clarification tank	Clarification chamber, part of combined tank	None required
Sludge return	Pump from clarification chamber to sludge tank, or primary chamber	None required
Irrigation chamber	Pump from clarification tank to irrigation chamber	300 L in-ground tank, collection by gravity
Chlorination device	Chlorine tablets	None required
Irrigation pump	Small irrigation pump	Small irrigation pump

The layout of components within the peat system is not critical to the performance of the biofilter since each components can be located to take advantage of gravity flows. However, while dosing of the biofilter by gravity flows is permitted, a more even distribution, hence heavier application rate is achieve when the effluent is pumped through a distribution system.

In Australia ,the capital cost of an AWTS is about $8000 excluding the cost of the irrigation fields. By comparison a peat biofilter system has a capital cost of less than $6000, including the septic tank. As noted previously, operating costs and risk reduction favour peat biofilters.

Table 3. Economic analysis of AWTS versus peat biofilter for energy and maintenance.

Event	Aerated treatment system	Peat biofilter after septic
Energy for flows from primary to secondary tank	Gravity flows, no energy requirements	Small low-head pump, energy to pump daily volume to distribution system in biofilter
Secondary aeration device	Approximately 880 kW/year	None required
Pumping sludge return from clarification to primary tank	Regular sludge return and desludging	None required
Pumping from clarification chamber to irrigation tank	Small low-head pump, energy to pump daily volume	Gravity flow from peat biofilter to irrigation chamber
Inspections and reporting	Quarterly service call (approx $320 annually)	No servicing required
Breakdowns	As required	As required
Electrical item replacements	Aeration pumps generally have life of 3-5 years (cost $500)	No aeration device, pump life in excess of 15 years no uncommon.

It is clear from Table 3 that there are significant savings operating costs and annual inspection and reporting fees when the passive operation of the peat biofilter is compared with the AWTS. The primary author has operated a peat biofilter, utilising gravity flow from septic tank to peat biofilter and gravity under-drain to irrigation well, producing consistent high quality effluent since 1985. Total maintenance has been less than one-hour since then. The submersible pump has not been replaced since the system was commissioned.

DISCUSSION

There are significant local resources of sphagnum peat moss in both the north and south islands of New Zealand which would have a positive environmental benefit in the treatment of domestic wastewater while reducing the energy requirements associated with AWTS. Either as processed peat in compressed bales for economic transport or as “mill peat” in an “as-mined” condition of higher moisture and less even texture (lumpy), a volume of 6.3 m^3 can provide a suitable long-term biofilter. As market conditions change it will be necessary to review the BCA of which peat product is the most economically efficient.

A significant environmental benefit of the peat biofilter over the AWTS is that shock loads are well accommodated in the biofilter. This is because fluctuations in the loading rate are of little consequence, as the peat can provide an energy source to the microbial populations and moisture within the peat is never critical to its effective operation. In the AWTS, intermittent loadings, high fluctuations in loads and loss of power will contribute to significant loss of effluent quality. The peat biofilter has additional economic benefit in that it has an ability to adsorb phosphorus, reduce ammonia immediately and denitrify by up to 60% through-out its life (Patterson, 2004). The Hawkesbury River example illustrates the importance reducing both phosphorus and nitrogen in effluent discharges.

In both economic and environmental values, the peat biofilter offers the resident microbial population a choice of energy-substrate. When organics in the effluent are in short supply, the microbes in the peat biofilter simply substitute the carbon of the peat as their energy source and continue at population equilibrium. The process of denitrification which is also related to the carbon:nitrogen ratio is never limited in the peat biofilter, hence loss of nitrogen from the effluent will always be achieved. These advantages are not found in sand filters.

Both macro and micro economics play an important role in the overall operational management of the peat biofilter domestic wastewater treatment system. Unlike the engineered AWTS, either in a single tank or dual tank configuration, the peat biofilter can operate with minimum maintenance and is highly accommodating of fluctuating loads and significant excess loading rates. At the end of any "useful" life, the peat can be re-used as a horticultural product with new peat replacing the old expired peat, for the cost of the peat.

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This table of properties was presented at the conference but not included in the paper

New Zealand Peats - Feb 06								New Zealand Peats - Feb 06			
Exc.Al+H	**Ca**	**K**	**Mg**	**Na**	**ESP**	**ECEC**	**Ca/Mg**	**Site Location**	**pHw**	**pHca**	**EC**
meq/100g	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**%**	**me/100g**	**ratio**	**Sample ID**			**dS/m**
2.00	2138	140	1466	284	4.7	26.3	0.9	**Searles Peat**	3.84		0.700
1.60	2544	238	1677	391	5.6	30.4	0.9	**NZ Peat**	3.89		1.050
2.00	1711	193	1593	464	7.7	26.2	0.6	**Yates Peat**	3.79		1.000