Suitability of Peat Filters for On-site Wastewater Treatment in the Gisborne Region

NIWA Client Report: HAM2006-172
December 2006

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Prepared for

Gisborne District Council

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1. Introduction

NIWA have been engaged by Gisborne District Council (GDC), under funding through the FRST Envirolink Small Advice Grant scheme (Advice Number: GSDC34), to provide advice on the suitability and potential application of peat filters as a secondary treatment device in on-site wastewater management systems.

Numerous residents within the GDC region live in unsewered areas and therefore rely on on-site systems and the in-situ soil to treat and dispose their wastewater. In a lot of cases, on-site systems are located on poor or shallow soils or on sections that are too small to enable sustainable infiltration of primary treated effluent. To overcome this, aerobic package treatment plants have been installed in some situations to provide secondary level treatment prior to land application via subsurface irrigation. However, poor performance or inadequate maintenance has caused the subsurface irrigation areas in many of these systems to become blocked with carried-over solids or organic biofilm build-up. As a result of these various problems, numerous on-site systems in the GDC region are suffering from failure in the form of overloaded land application areas and subsequent ponding/surfacing of poorly treated effluent within peoples backyards. This situation poses a serious hazard to public and environmental health. Thus, there is a strong need for an appropriate, robust, low-maintenance and cost-effective secondary treatment device that can be easily retro-fitted to existing, or included in new, on-site systems in the GDC area.

This report reviews the potential of peat filters as a secondary treatment device in on-site systems in the GDC region and provides advice on the design and application of a trial peat filter as part of an existing on-site system identified during a site visit on 01/09/06.

2. Peat Filters for On-site Wastewater Treatment

The percolation of wastewater under gravity through a filter medium is a common on-site wastewater treatment approach. Wastewater is typically loaded in intermittent small doses onto the upper surface of the filter in order to maintain unsaturated flow conditions and facilitate air movement through the filter between doses. Such a system is technically referred to as an “Intermittent Packed-Bed Reactor”. A range of filter materials have been successfully used in packed-bed reactors including organic materials such as soil, peat, compost, bark chips, wood chips and coconut fibre, and inorganic materials such as sand, crushed glass, plastic media, sponge cubes or synthetic fabrics. A peat filter is therefore a packed-bed reactor where the bulk of the filter media consists of peat, as depicted in Figure 1.

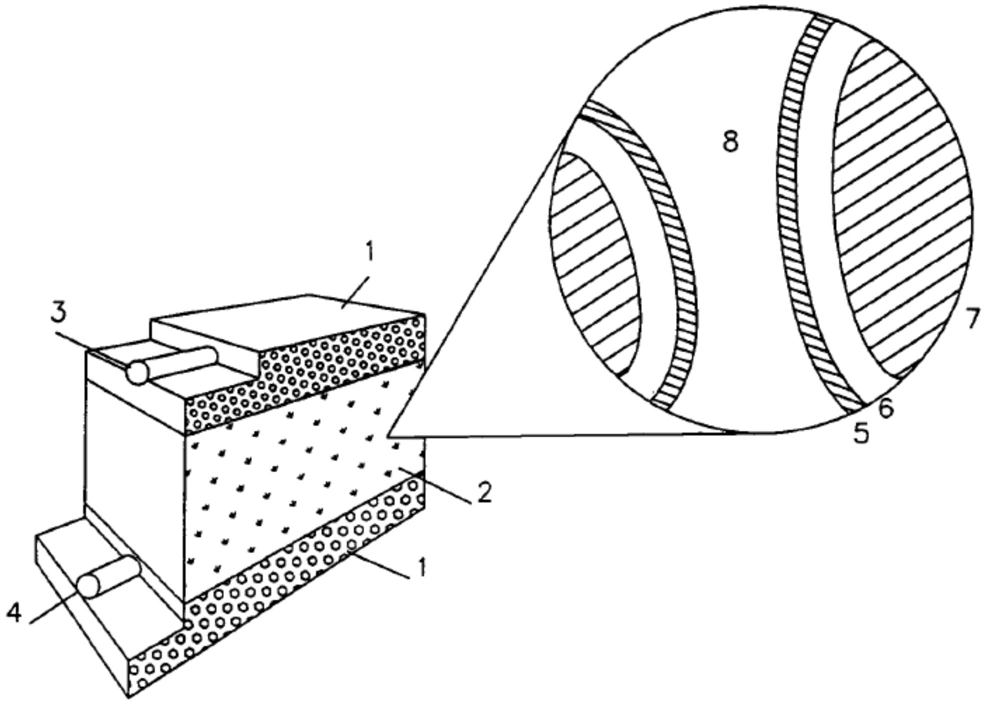

Fig. 1. Schematic representation of a percolator. 1, Gravel; 2, percolator material; 3, wastewater supply; 4, effluent drain; 5, wastewater; 6, biofilm; 7, percolator material; 8, void.

Figure 1: Schematic representation of typical fixed-bed reactor. In the case of a peat filter, the “percolator material” (7) would consist of peat (source: Lens *et al*., 1993).

During the passage through the filter wastewater comes in contact with the media and attached microbial biofilms and becomes purified by physical (filtration, adsorption) and biological (microbial degradation) processes (Lens et al. 1993) under predominantly aerobic conditions.

Peat can be described as partially fossilised plant matter which accumulates in wet areas (wetlands) where there is a lack of oxygen and the accumulation of the plant material is more rapid than its decomposition (Couillard, 1994; Viraraghaven, 1993). Peat is a porous, complex material containing lignin and cellulose as major constituents. These constituents contain polar functional groups, such as alcohols, aldehydes, ketones, acids, phenolic hydroxides, and ethers than can be involved in chemical bonding (Viraraghaven, 1993). This polar nature gives peat a high specific adsorption capacity for suspended and dissolved solids, such as transition metals and polar organic molecules. The particulate and highly porous nature of peat also makes it an effective physical filter (Pérez et al. 2005). Studies have shown that partially decomposed peat has a relatively high porosity of approximately 95% and a specific surface area of 200 m^2 per gram.

Intermittently dosed peat filters have been used to remove a range of impurities from wastewater, such as suspended solids, organic matter, nutrients, and pathogen indicators and are considered to offer a relatively inexpensive, low-maintenance alternative for treating municipal wastewater in some parts of the world (Pérez et al. 2005). Peat filters have been successfully used for treatment of septic tank effluent in the USA since the first system was installed and monitored in 1978 (Brooks et al. 1984) and are now used in Canada, Australia, Spain and Ireland. Peat filters have been hailed as a suitable solution for failing on-site systems or constrained sites, such as where the soil is compacted, high in clay, shallow or with high water table (Viraraghaven, 1993; Brooks et al. 1984). Peat acts as a very effective filter for removing suspended solids from wastewater (Pérez et al. 2005) and should therefore prolong the operational life of downstream treatment, soil infiltration and/or irrigation components of on-site systems.

Patterson (1999) reported that a peat filter receiving septic tank effluent from a domestic household in Australia achieved > 90% removal of biochemical oxygen demand (BOD), > 66% removal of total nitrogen (TN) and effluent total suspended solids (TSS) concentrations < 15 mg L^{-1} over a 13 years period of operation (HLR ranged from 34–81 mm/day). Patterson (2004) and Patterson et al. (2001) monitored a number of on-site peat filters receiving septic tank effluent at hydraulic loading rates of 100–150 mm day^{-1} in an Australian Aboriginal village and reported TN removal efficiencies of 44–54%.

Corley et al. (2006) dosed peat columns with artificial sewage and found that TSS, BOD and ammonium (NH_4-N) removal exceeded 96%, 94% and 99% respectively, over a range of filter depths.

Lens et al. (1994) compared the treatment performance of columns of peat, bark and woodchip at a HLR of 100 mm day^{-1} and found that all media achieved TSS, BOD and TN reductions of greater than 70%, 90% and 40% respectively. However, the peat was more effective at removing faecal coliforms, achieving a 3–4 log reduction compared to less than one log reduction for bark and woodchip.

It seems to be a common occurrence that discoloured effluent with high chemical oxygen demand (COD) and low pH is flushed out of a peat filter initially as the water soluble components of the peat flush out. However, this is only a temporary phenomenon.

Field evaluations of peat filters used in on-site systems indicate that they are relatively robust under the typically variable loadings experienced in domestic situations (Patterson, 1999). They also represent a relatively low maintenance and passive treatment system, especially compared to package aerated wastewater treatment systems which generally require at least quarterly servicing by a trained technician. For example, Patterson (1999) reported that a domestic peat filter required only two hours of active maintenance in over 13 years of successful operation (1986–1999).

In summary, peat filters show good removal of BOD, TSS and TN, but offer only limited capacity for removal of phosphorus (P) in the long term (approx. 20%). Significant P reduction will typically occur subsequently when the treated effluent is discharged to the soil, particularly if the in-situ soil contains sufficient clay.

Due to their relatively robust and low-maintenance character, peat filters therefore offer great potential as a secondary treatment device in on-site systems within the GDC region, particularly on remote sites or those sites constrained by size or poor soil characteristics.

2.1 Peat Filter Design

As with other packed-bed filters, the key design parameters of concern relate to the appropriate hydraulic loading rate (mm of effluent applied per day) and the depth of the peat bed. Other issues that are also of importance are the characteristics of the peat, peat bulk density (or degree of compaction) and effluent loading requirements. A number of studies have examined performance of peat filters under various configurations of the above mentioned design parameters and reported varying degrees of success. This section of the report aims to present and summarise some of the key findings from this research.

2.1.1 Type of Peat

A range of different types of peat have been used successfully around the world to date, including both reed-sedge and sphagnum peat. Reed-sedge peat is typically used in Australia due to its relative availability (e.g., Patterson, 1999). In general, however, it seems that sphagnum-derived peat is most suitable and long-lasting.

A preliminary investigation into the range of peat materials readily available within or close to the Gisborne area has indicated that the cheapest option is likely to be the use of 100 L compressed “peat moss” bales that are readily available from nurseries in Gisborne (approx. \$150 per m^3). One of the benefits of using this product is that it is milled, dried and compressed, therefore making handling relatively easy (hand loadable) and providing good consistency in product quality.

There are no major peat reserves within the Gisborne district for easy, bulk supply of peat. The nearest bulk supplier of peat is likely to be Daltons in Matamata, who have estimated that suitable peat would cost \$180–200 per m^3 (including transport to Gisborne). This would require deliveries of substantial quantities (25 m^3) at any one time, and would therefore require an intermediate holding/handling yard in Gisborne in order to supply the peat to on-site system installers. This is likely to add extra handling costs.

At a cost of \$150–200 per m^3, peat may prove to be too costly, especially when compared to other media alternatives such as sand which is available within Gisborne for approximately \$65 per m^3. However, it is unclear at this stage whether the sand available within Gisborne has the appropriate characteristics for use as a packed bed filter media (washed and with appropriate particle size). If the readily available sand is not suitable, then additional processing (sorting and washing) may be required, which may increase the cost considerably above \$65 per m^3. The use of sand also requires light machinery (such as small excavator, back-hoe or bob-cat) to load the sand into the filter, whereas the use of compressed peat bales can be done manually, thereby reducing installation costs. All of these factors need to be taken into account when considering the economic merits of using peat over sand or other media.

The environmental impacts of peat mining and extraction should be taken into consideration when assessing the potential use of peat filters. Although much larger quantities of peat are currently used by the horticultural industry than are likely to ever be consumed in on-site wastewater systems, there is a growing public perception that peat extraction is an unsustainable and decreasingly acceptable practice. Alternative filter media from potentially more sustainable sources that have been used elsewhere with success include:

- coconut fibre (coco-peat, coir) or husk chips;
- fine woodchips (approx. 5 mm);
- coarse sand;
- crushed recycled glass; and
- fine gravel (5 – 10 mm);

With the exceptions of pathogen and metal removal, filter systems using any of the above media are likely to achieve largely similar treatment performance to a peat filter and could be designed in much the same way. With regard to pathogen removal, the majority of pathogen attenuation in on-site systems (without active disinfection) typically occurs within the soil infiltration / land application system during passage through the unsaturated soil (assuming the land application area is appropriately designed and loaded).

2.1.2 Peat Bulk Density

Bulk density of peat in situ ranges from 20 to 40 kg m^{-3} at the surface to about 100 kg m^{-3} at depths of 10 to 30 cm. Rock et al. (1984) recommend that peat be lightly packed into a peat filter to obtain a bulk density of 100–120 kg m^{-3}. Although peat filters have been used at bulk densities up to 230 kg m^{-3} with success (Patterson, 1999), Rock et al. (1984) found that columns compacted to bulk densities of greater than 150 kg m^{-3} clogged when loaded with septic tank effluent. At the other extreme, unconsolidated peat may lead to flow channelling, poor effluent distribution and sub-optimal treatment performance.

In practice, it seems that the desired compaction can be achieved by placing the peat into the filter container in 10–15 cm layers, raking it and then standing on it to lightly tramp it down.

2.1.3 Peat Filter Depth

A range of peat filter depths have been examined in laboratory and field scale applications. For instance, Rock et al. (1984) compared peat columns of different depths (100–900 mm) and found that 0.2 – 0.3 m depth of peat gave excellent removal of BOD (< 30mg L^{-1}), COD and TSS and achieved virtually complete nitrification. They recommended a minimum peat depth of 0.3 m.

Corley et al. (2006) dosed peat columns of different depths (300, 600, 900 and 1200 mm) with artificial sewage at a hydraulic loading rate (HLR) of 180 mm day^{-1} for one year without any clogging or decline in hydraulic performance and reported that TSS, BOD and NH_4-N removal exceeded 96%, 94% and 99% respectively, regardless of filter depth. Although performance did improve slightly with increased peat depth, at least up to 1.2m (HLR = 180 mm day^{-1}), they found that the majority of COD, BOD, NH_4-N, phosphate (PO_4-P) and TSS removal occurred in the top 30 cm of peat.

A Canadian study compared the performance of columns with different depths of sphagnum peat (200, 250, 300, 350, and 500 mm) under different HLRs (64, 89, 115, and 140 mm day^{-1}) (Viraraghavan, 1993). In summary, effective TSS removal was achieved by all depths (effluent TSS < 30 mg L^{-1}), while the shallowest peat depths generally performed poorly in terms of BOD and TKN removal, particularly at the higher loading rates. When moderately loaded (89 mm day^{-1}) a peat depth of 0.5 m was required to achieve good TKN removal (87%). The shallower columns achieved < 35% TKN removal. Consequently, Viraraghavan (1993) recommended a peat depth of at least 0.5 m.

In summary, providing that the peat filter is not overloaded (HLR discussed in Section 2.1.4), it seems that the majority of TSS and BOD removal occurs within the upper 0.2–0.3 m of peat, whilst at least 0.4–0.5 m depth of peat is required for effective TKN removal. Thus, a peat depth of 0.5 m is likely to be sufficient in the majority of cases.

2.1.4 Hydraulic Loading Rate (HLR)

In general, there is a trend of better treatment performance and reduced clogging potential at lower HLRs.

Rock et al. (1984) found that clogging of peat occurred at HLR of 210 and 630 mm day^{-1}, although BOD removal was still high (influent BOD = 250 mg L^{-1}). BOD removal at 81 mm day^{-1} (20.2 kg BOD per 1000 m^2 per day) was excellent for the entire 420 day column experiment without clogging. However, those authors took a conservative stance and recommended that a lower application rate of 41 mm day^{-1} be used in practice.

As described above in Section 2.1.3 ("Peat Filter Depth"), Corley et al. (2006) observed TSS, BOD and NH_4-N removals exceeding 96%, 94% and 99% respectively for peat columns loaded at 180 mm day^{-1} (for peat depths between 0.3 and 1.2 m).

In the study of Viraraghavan (1993), effective TSS removal (effluent concentrations < 30 mg L^{-1}) were achieved at all HLRs investigated (64–140 mm day^{-1}) regardless of peat depth (200–500 mm). At HLRs of 89 mm day^{-1} or less, with the exception of the shallowest depth (200 mm), greater than 87% removal of BOD and effluent concentrations less than 30 mg L-1 were achieved under all peat depths studied. A TKN reduction of 84% was achieved at a HLR of 89 mm day^{-1}, but required a peat depth of at least 0.5 m. Nitrogen removal declined rapidly at HLRs of 115 mm day^{-1} and above. Viraraghavan (1993) recommended a HLR of 90 mm day^{-1} (with a peat depth of 0.5 m) for effective removal of TSS, BOD and TKN.

Patterson (2004) and Patterson et al. (2001) monitored a number of on-site peat filters receiving septic tank effluent at hydraulic loading rates of 100-150 mm day^{-1} (with short term peaks of up to 300 mm day^{-1}) in an Australian Aboriginal village and reported the following removal efficiencies: 94–96% NH_4-N, 77–79% TKN, 44–54% TN and 2–3 log reduction in faecal coliforms. Removal of TSS was apparently variable due to the flushing out of particulates from the peat on some sampling occasions.

In summary, there is substantial variation in the reported treatment efficiencies of peat filters operated under different HLRs and a range of recommended HLRs given by different authors. This variability can be at least partially explained by the fact that a range of peat depths have been studied (depth being an important factor effecting treatment) and that reported studies range from laboratory-based column experiments to field scale operational trials. Nevertheless, it seems that the following generalisations can be made:

- clogging of the peat surface is likely to occur at HLRs > 200 mm day^{-1};
- effective TSS and BOD removal can be achieved even at high HLRs (not withstanding the above point);
- at least 80% reduction in NH_4-N can be achieved at HLRs of 80 – 150 mm day^{-1};
- lightly loaded systems should generally achieve better and more sustainable/stable treatment performance than more heavily loaded peat filter.

2.1.5 Design Recommendations

In summary, it seems that the majority of treatment occurs within the top 30 cm of peat and that peat filters as shallow as 0.2 m are capable of achieving reasonably good removal of BOD and TSS at low to moderate HLRs (20 – 100 mm/day). However, greater depths of peat are required (at least 0.5 m) to ensure high level nitrification (removal of NH_4-N), reasonable pathogen indicator removal and stable long-term performance. At higher HLRs (> 100 mm day^{-1}) a greater depth of peat (0.5–1.0 m) is likely to be required to maintain effective long-term performance. At HLRs above about 200 mm per day, peat filters receiving septic tank effluent are likely to eventually become clogged and fail, regardless of depth.

It is therefore recommended that the peat filter design criteria presented in Table 1 be used by GDC for initial trialling of peat filters in their region.

Table 1: Key design criteria recommendations for on-site peat filters.

Design Parameter	Recommendation
Peat Depth	0.5 m
Hydraulic Loading Rate (HLR)	100 mm per day

3. System Design for a Trial Peat Filter at a Domestic Dwelling in Lysnar Street, Wainui

As a next step in verifying the suitability of peat filters for on-site wastewater treatment in the Gisborne area, GDC want to conduct a field trial of an operational system by retro-fitting a peat filter into a failing system. During a site visit on the 1st of September 2006, a suitable site was identified within the coastal settlement of Wainui. The property identified currently has a failing on-site system which is in need of rectification.

3.1 Relevant Site Information

- Bedrooms: 3.
- Water Supply: Rainwater.
- Wastewater generation (as estimated by GDC): 140 L per person per day x 6 persons = 840 L day^{-1}.
- Existing System: Septic tank → pump well with disc filter on the outlet (blocked) → subsurface irrigation (surfacing).

3.2 Problems Identified with Existing System

The subsurface irrigation area is displaying obvious signs of ponding and surcharging, which poses a significant public and environmental health risk and is creating problems with odour and aesthetics. The subsurface irrigation system appears to be clogged with solids carried over from the failing septic tanks. The irrigation area is also located in a somewhat sheltered and damp position that is likely to receive seepage and run-on from an adjacent hill.

The treatment system consists of two septic tanks in series. The second tank acts as a pump well, from which the irrigation area is loaded. Although there is a filter on the outlet line from the pump well, this appears not to have been maintained and is blocked. The disc-type filter being used is considered too fine for the quality of effluent expected out of a septic tank and would require routine (probably weekly) cleaning in order to operate properly. The pump was operating continuously during our site visit, indicating that the filter and irrigation lines were blocked. This is likely to lead to on-going failure (burn-out) of the pump used to load the irrigation area.

Generally, the application of primary treated effluent to subsurface dripper irrigation is considered inappropriate due to the typically high organic (BOD) and suspended solids load in the effluent. Subsurface irrigation with drip emitters should only occur after at least secondary level treatment, where the BOD is less than 20 mg L^{-1} and TSS less than 30 mg L^{-1}.

It is recommended that a secondary treatment system be incorporated after the septic tanks in order to reduce the organic and particulate load being discharged to the subsurface irrigation area. Suitable low-maintenance secondary treatment systems include:

- sand filter;
- subsurface-flow wetland;
- peat filter (the focus of this report).

It is also recommended that the irrigation system be replaced as it is blocked and failing. Drainage should also be installed to divert run-off and seepage from the adjacent hill-side away from the irrigation area.

The depth of sludge and scum in the septic tank should be inspected in order to identify whether the tank needs de-sludging (pumping out). If the septic tank is in need of de-sludging, this should be done prior to the upgrading/replacement of any other components of the system (such as installation of peat filter or irrigation system) so as to prevent blockage of downstream infrastructure

3.3 Proposed Peat Filter System Design for the Wainui Site

It is proposed that the system be upgraded to include a peat filter following the septic tanks to provide secondary treatment of the effluent before it is loaded to a new subsurface irrigation system. A general layout of an upgraded system including a trial peat filter is depicted in Figure 2.

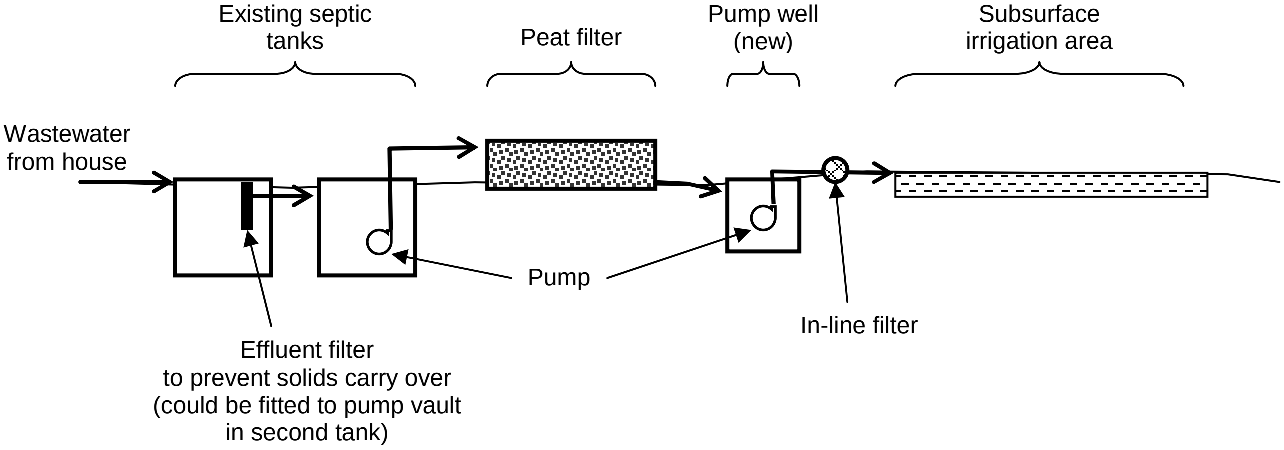

Figure 2: Lateral schematic of proposed on-site system upgraded to include secondary treatment by a peat filter.

3.3.1 Wainui Peat Filter Design Criteria

Peat filter size

It is recommended that the peat filter be sized to operate with a hydraulic loading rate of 100 mm/day. At a daily wastewater load of 0.84 m^3 day^{-1} (6 people at 140 L p^{-1}.d), this equates to a peat filter surface area of 8.4 m^2.

Filter media

The overall depth of the peat filter is to be 0.6 m (Figure 3). Progressing vertically up from the bottom, the filter media will consist of a 50 mm deep layer of 10 mm gravel encapsulating the drainage collection pipes (Figures 3 and 5), overlain by a 50 mm depth of 5 mm pea gravel which is overlain by a 0.5 m depth of peat. The inlet distribution pipes will sit on top of this peat (Figures 3 and 4) and be covered with a 100 mm layer of peat or bark chips.

The peat should be placed progressively in 100 mm layers that are evenly spread out with a rake and compressed slightly by standing on it.

Based on the above dimensions, the following quantities of media will be required:

- Peat: 5 m^3 (approximately 30 x 100 L bales of Yates "Hauraki Gold" peat or similar).

- 10 mm gravel: 0.5 m^3.

- 5 mm gravel: 0.5 m^3.

Inlet dosing and distribution system

Effluent from the septic tank pump well is to be intermittently loaded onto the surface of the peat filter using a submersible pump operated by float switch. The float switch should be set to deliver relatively small doses (ideally 40 – 80 L per dose) so as to avoid hydraulic overloading or saturation of the peat filter with each dose.

The inlet distribution system is critical for ensuring uniform distribution of the effluent over the full surface of the peat filter and therefore maintaining optimal treatment and sustainable operation. Achieving uniform distribution through such a closed-pipe-with-orifice system is affected by the pump characteristics (pressure and flow rate), pipe length, diameter and number, and the diameter, spacing and number of orifices in the distribution laterals. Non-uniform distribution of the influent will lead to poor treatment performance and promote clogging and failure of the peat filter system.

The inlet distribution specifications shown in Figure 4, notably the number, diameter and spacing of pipes and orifices, have been specifically designed for a peat filter measuring 2.1 m wide by 4.0 m in length and loaded with a Lowara DOMO 7VX submersible pump. There are a wide range of potentially suitable submersible pump brands and models available on the market. The Lowara DOMO 7VX pump has been used here as an example only and to enable a design of the inlet distribution system to be provided (a pump pressure vs flow rate curve is necessary for this task).

IMPORTANT NOTE: Should a bed of different dimensions, or different pipe size, or orifice size, or pump be used from that depicted in Figure 3, the distribution system MUST be redesigned to ensure uniform flow distribution! Please consult the author in this event.

Sampling and Monitoring

Consideration should be given to the inclusion of sampling ports/valves to facilitate collection of wastewater samples before and after the peat filter in order to monitor and assess its performance. To facilitate sample collection, sampling valves could be included in the pipe running from the dosing pump to the peat filter inlet, and from the pipe draining from the peat filter outlet into the disposal pump well. This would be the best way to ensure that samples are representative of actual wastewater flowing into and out of the peat filter. Alternatively, samples could be collected from within the pump wells before and after the peat filter. However, it should be noted that it may be difficult to obtain a sample representative of the influent to the peat filter from within the preceding pump well due to the configuration of effluent filters and the pump.

It is suggested that samples be collected on a monthly basis and analysed for pH, conductivity, TSS, BOD, TN, NH_4-N, oxidised N (NO_x-N), TP and e-coli (or faecal coliforms). Ideally, monitoring should be conducted for 12 months, as performance may vary with season and during the initial months of operation as the peat filter adapts to the operating conditions.

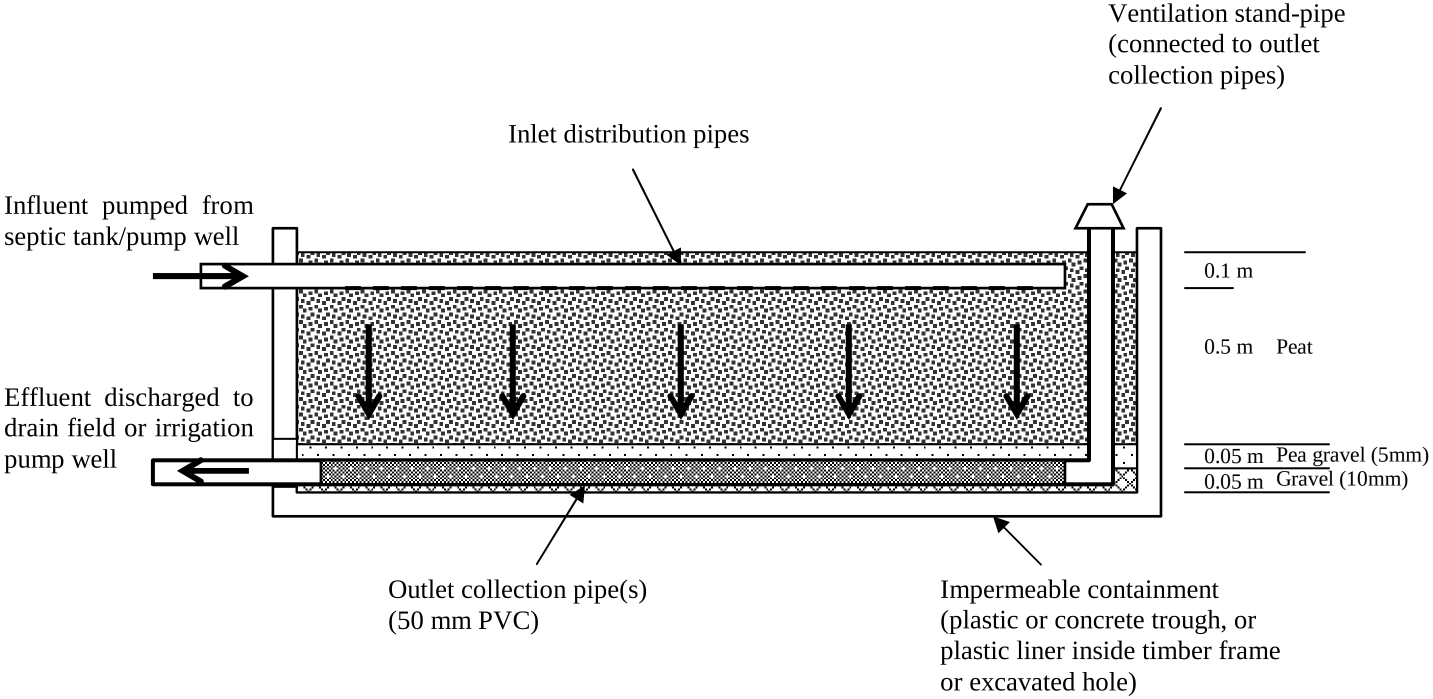

Figure 3: Lateral cross-sectional profile of typical peat filter system.

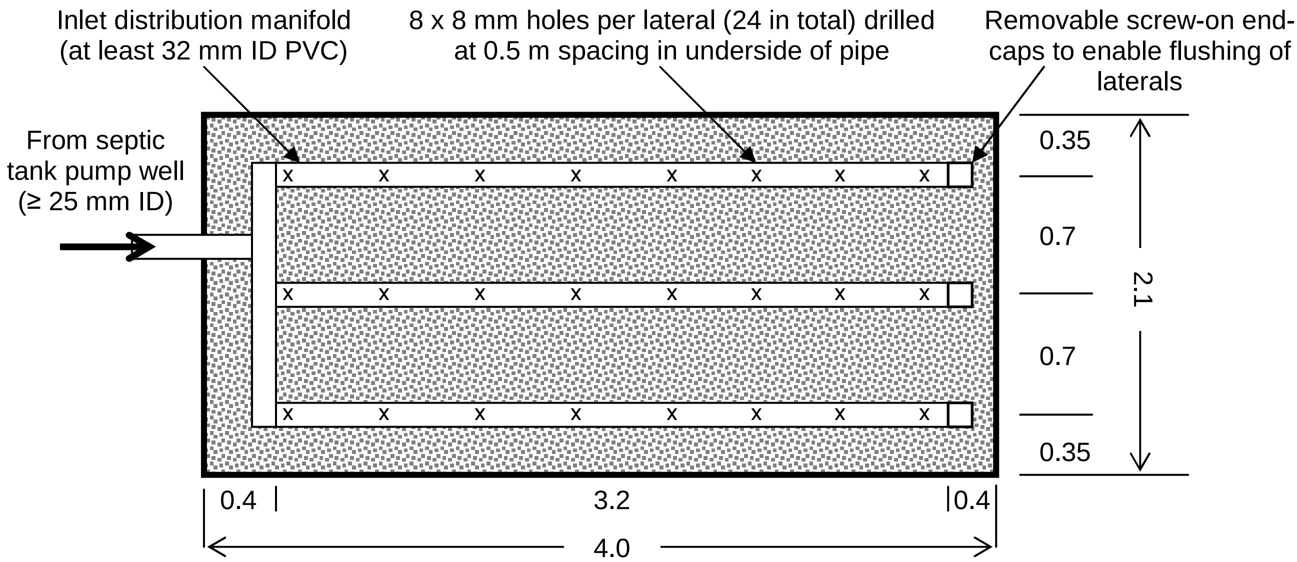

Figure 4: Plan view of inlet distribution system design for a 4.0 m x 2.1 m peat filter (all units are in metres unless otherwise stated). Pipes are located on top of filter bed. Pipe and orifice size, spacing and numbers are specific to the peat filter dimensions given here and assume the use of Lowara DOMO 7VX submersible pump. (Note: other suitable pump can be used; however diameter and number of inlet pipes and orifices must be designed on a case by case basis according to pump characteristics and peat filter dimensions!)

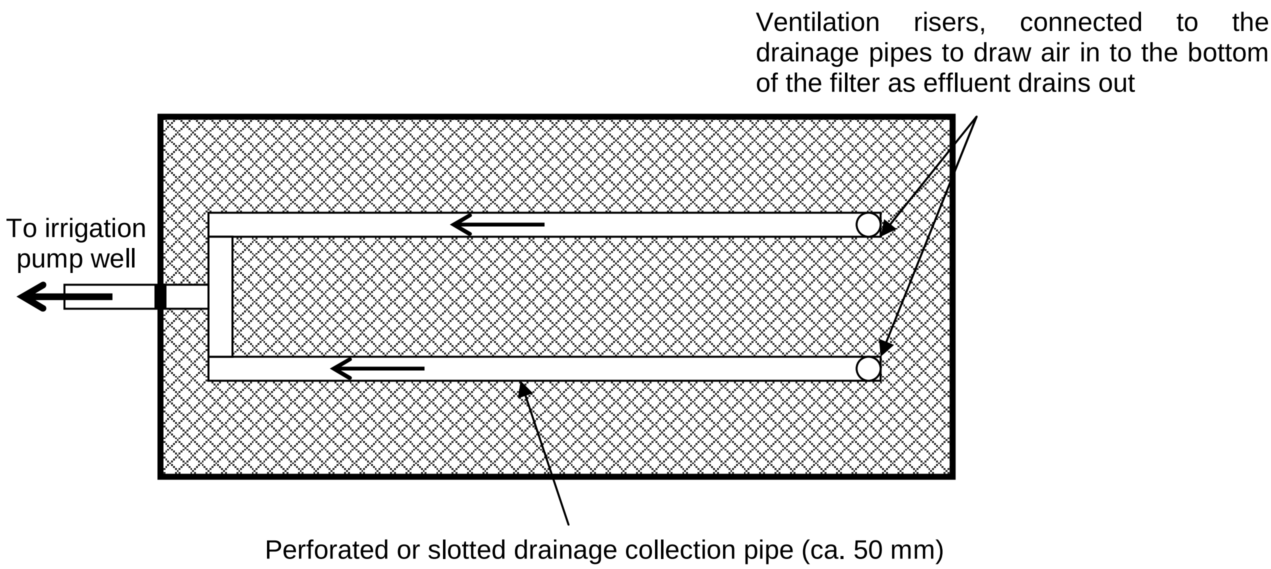

Figure 5: Plan view of effluent collection and passive ventilation system for peat filter. Pipes positioned on bottom of filter bed.

4. Conclusion

Peat filters offer significant potential as a relatively passive, low-maintenance and robust secondary treatment device for on-site systems in the Gisborne region. Experience with peat filters internationally indicates that they are highly effective at removing TSS and BOD, and are more effective at removing pathogen indicators than similar fixed-bed filters using other media, such as sand or gravel. Peat filters have also been shown to be highly effective at nitrifying domestic wastewater, and in many cases are capable of removing 30–50% of the total nitrogen load.

As there are no major peat deposits within the Gisborne area, the cost of importing peat may be the single biggest factor that limits the application of peat filters. Nevertheless, a range of other media (such as coarse sand or coconut fibre) could be used in place of peat to achieve similar performance within systems designed in much the same way. Another option worth considering is the use of subsurface flow wetlands, which will provide a low-maintenance and completely passive (no pump required) secondary treatment system also capable of removing approximately 40% of the total nitrogen load.

Some general peat filter design guidelines have been provided in this report, along with design specifications for the installation of a trial peat filter system on a failing septic system in Wainui. It is recommended that this site be used for a field trial to test the performance and assess the practical issues of implementing peat filters within the GDC region. This could involve collection of wastewater samples before and after the peat filter on a monthly basis and analysis for pH, conductivity, TSS, BOD, TN, NH_4-N, oxidised N (NO_x-N), TP and e-coli (or faecal coliforms).

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